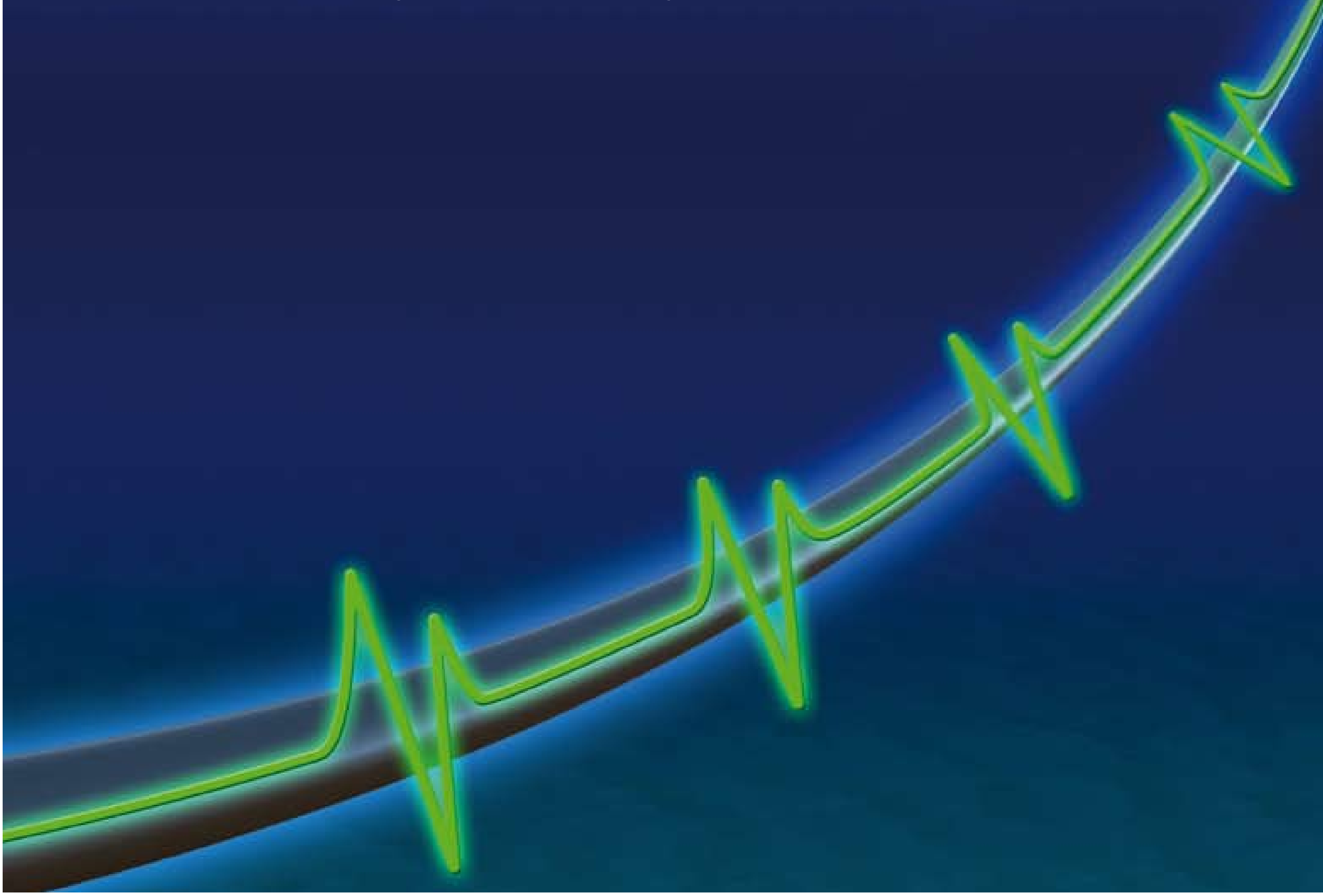
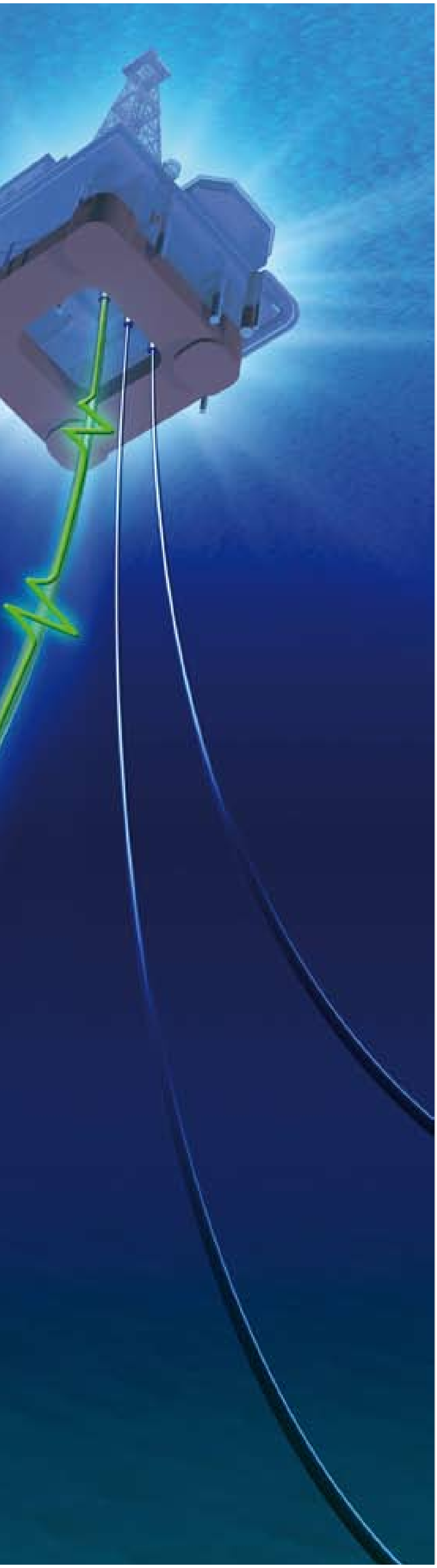
# Monitoring in depth

In challenging deepwater environments like the Gulf of Mexico, BP's new monitoring systems are helping to ensure that drilling and production risers remain up to the job of safely delivering oil. *Alex Markland* reports on BP's initiatives in riser monitoring that are now benefiting the wider industry





Safety and environmental problems with risers – the long pipes that run from an offshore drilling or production platform and connect with a wellhead on the seabed – are rare. And, says Howard Cook, BP's technical authority for risers, this is how BP is determined it should remain.

But as the percentage of BP's hydrocarbon production coming from platforms located in more difficult deepwater environments continues to grow, the safety, environmental and technology challenges associated with risers are becoming greater. Although BP has nearly 30 years' experience designing and operating shallow water platforms and risers, the company's pioneering moves into deeper water areas in the Gulf of Mexico and elsewhere from the late 1990s onwards has meant that a whole new range of environmental influences have come into play, factors with direct bearing on the design and operation of offshore facilities.

'This led to some very big technology stretches in some aspects of our offshore systems in the Gulf of Mexico,' recalls Cook, whose responsibility within BP's exploration and production business also covers underwater flowlines and the complex riser turrets often found on floating production platforms.

Risers play many important roles in hydrocarbon production. During drilling of a well they encase the drillstring and bit and serve as a conduit so that drilling muds can travel down into the well to flush drill cuttings up to the rig at the surface. For offshore production platforms, risers connect the platform with the wells on the seabed, and the platform to the field's pipeline system to allow hydrocarbons to be exported from the field. Risers can also be used to carry water or gas from the surface facilities for injection into the field's reservoir to enhance hydrocarbon recovery.

Because risers are the component that spans the entire water column from seabed to surface – a distance that can reach thousands of metres – BP recognised that the development of riser technology would present a major challenge as production moved into deeper water. 'This highlighted a number of important issues,' notes Cook. 'No matter what function a riser serves, it will always be a critical system. The failure of a riser could have serious implications.'

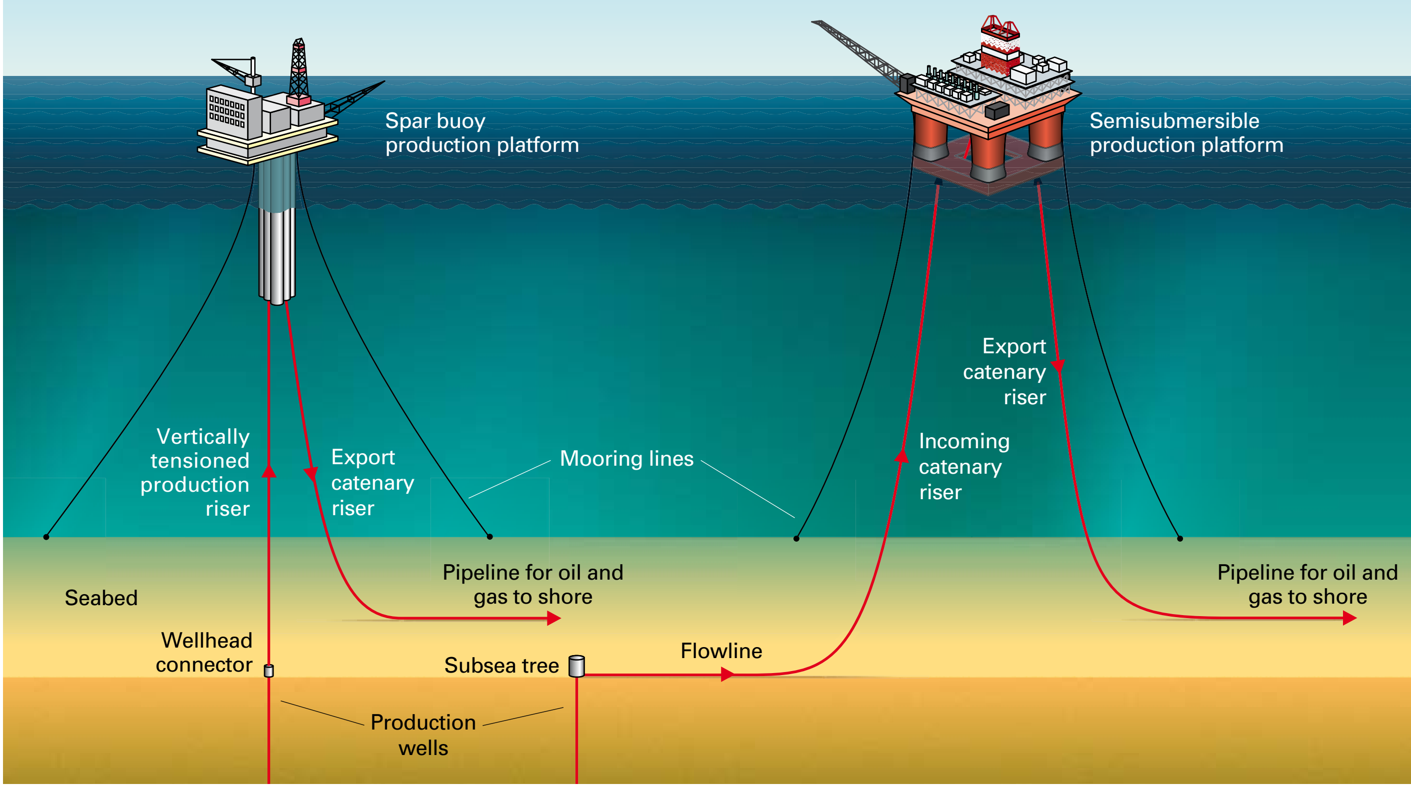
An offshore field can have a life of 25 years or more, and risers must be designed to last and be maintainable for the duration. The forces that exert themselves on risers are many and varied – and can all act at the same time. They can be subjected to high internal pressures and temperatures from the hydrocarbons they convey, high external hydrostatic pressure from the deep water column, very low external water temperatures, and are continuously in motion caused by waves at the surface and currents down below, as well as the shifting of the floating platform that they hang from – some platforms, although all are moored securely to the seabed, are designed to offset around their central position by many tens of metres. And risers – sometimes there are dozens of them supported from a single platform – do not always hang straight down towards the seabed, but fan out below the platform, held in S-shaped and other configurations by submerged buoyancy devices and tethers anchored to the seabed. Riser design challenges are clearly complex and the outcome has a significant impact on the design of the offshore platform too.

'The move into deeper water environments really made us focus our attention on making sure that we designed, operated and managed the integrity of our riser systems in the best way possible,' adds Cook. 'The challenges associated with designing risers for use in the Gulf of Mexico deepwater developments provided a real spur to developing a riser monitoring system.'

Early on, BP's project teams on the BP-operated Holstein, Mad Dog, Thunder Horse and Atlantis deepwater fields in the Gulf of Mexico – located in varying water depths up ›

## DEEPWATER RISERS ON FLOATING PRODUCTION PLATFORMS

**Semisubmersible and spar platforms are two of several types of floating production platforms deployed in deep waters such as the Gulf of Mexico. The examples here show a semisubmersible platform (below right) supporting steel catenary risers, while the spar platform (below left) uses vertically tensioned risers. There are many other riser configurations used throughout the industry.**




to 1870m – recognised the need to install instrumentation to accurately measure the stresses and strains on risers. As a result, BP established its riser monitoring programme in 2002. 'It's proving to be a very valuable tool in more ways than one,' Cook observes. 'As well as helping us to monitor how the risers are responding to the environmental conditions, the riser monitoring programme is also providing information that will help to improve our theoretical models, and ultimately, future riser design.'

### Ensuring integrity

The riser monitoring programme is playing a key role when it comes to the integrity monitoring carried out by BP in the Gulf of Mexico to maintain the safe operation of its deepwater floating production facilities. These have to be able to withstand extreme hazards, ranging from hurricanes to 'hundred year storms' and 'eddy loop currents' – very strong, deep currents that can affect a location for a few months at a time. A riser is constructed using stiff, strong, thick-walled sections of steel pipe – for deepwater developments like BP's Thunder Horse, individual risers can weigh up to 700 tonnes and have up to 40mm wall thickness. However, when a riser is suspended from a platform in the Gulf of Mexico in water depths approaching 2000m, and is buffeted by waves at the surface and underwater currents of up to two metres per second that vary along its length, the riser can bend like a long flexible cable. Potential damage due to fatigue loading and corrosion are important to assess, hence integrity monitoring is essential.

> The deepwater challenges of the Gulf of Mexico provided a real spur to developing a riser monitoring system

'Part of our role is to monitor the condition of a riser and to maintain it to ensure its safe operation throughout its lifecycle,' explains Sandeep Jesudasen, a riser systems engineer in BP's deepwater Gulf of Mexico business unit, and a member of the marine team that looks after integrity issues on the offshore facilities. 'During the course of a riser's lifecycle we have to know its condition, what threats it faces and what consequences they might have on the riser's performance. Using risk assessment we then determine how best to monitor the riser's condition and performance.'

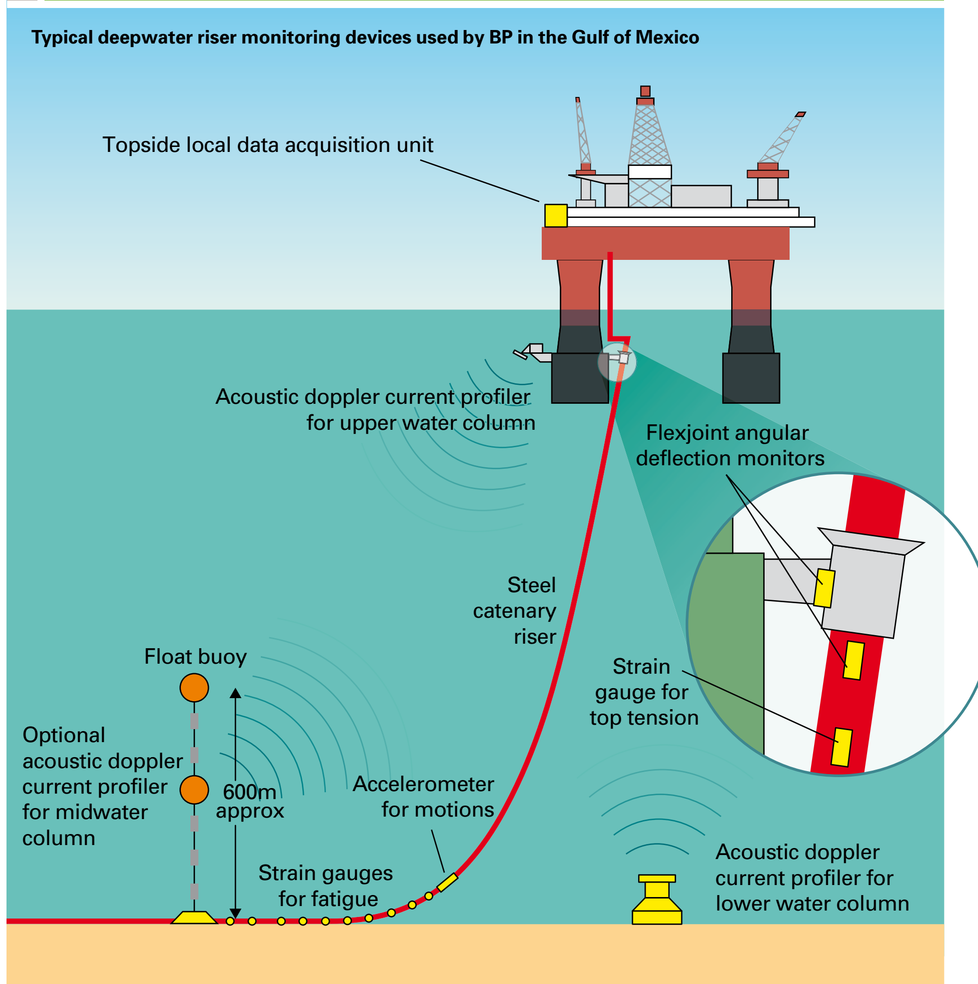
Because the riser is attached to the platform floating at the surface, riser monitoring involves both the platform motions and the behaviour of the risers themselves – there are a number of different platform types and riser designs operating in the Gulf of Mexico (see diagram on page 36). However, for practical reasons, it is not possible to monitor each riser – there can be dozens of risers hanging from a single platform. Instead, Jesudasen and his colleagues install monitoring equipment on a representative sample of risers, then use the information gathered to gain an idea about the conditions of similar risers.

This is the strategy the team adopted when the BP-operated Mardi Gras deepwater pipeline transportation system was being installed in up to 2200m of water, beginning in 2003. Export risers from BP's deepwater Gulf of Mexico platforms are connected to Mardi Gras, which is designed to bring crude oil and natural gas to shore, and is the highest capacity deepwater pipeline system ever built. After studying the situation the team decided that installing riser monitoring systems on the oil export risers in the Thunder Horse field in 1840m of water and Holstein field in 1310m of water would provide enough data to allow the team to infer the condition of the other risers on the other platforms – and, reports Jesudasen, they are more than satisfied with this decision.

In fact, he notes, the riser monitoring programme has already proved to be a very useful troubleshooting tool. In 2003, monitoring data from the production riser on one platform suggested a situation that could lead to a serious shortening of the riser lifetime. 'Fortunately,' says Jesudasen, 'we were able to go in and apply a successful fix. But without the riser monitoring programme, we might not have spotted this problem.'

Data from the riser monitoring programme is also being used to help the team determine when inspections or changes in operating conditions are required to ensure the continuing integrity of various components on risers, such as the 'flex joints' that allow relative motion between the platform and some types of riser.

## BP'S RISER MONITORING SYSTEMS




### Good sense

BP's riser monitoring programme gathers information generated by a number of different sensor systems, placed at key positions along the length of a riser. The devices include optical fibre-based strain gauges, accelerometers, inclinometers, curvature sensors, and angle rate sensors that monitor the rate of change of riser angles – knowing precisely where to locate each type of sensor requires in-depth analysis in its own right. Some of the sensors are wired-in and remain permanently attached to the risers underwater, while others are stand-alone battery-operated devices equipped with internal memory and must be retrieved to the surface to collect the data.

The data collected by all the sensors are fed into a central monitoring system on the platform, then sent to shore for analysis to reveal information about the long and short term integrity of the riser system. Although careful analysis will always take time, the data transfer operation will be speeded up once BP's *Field of the Future* optical fibre communications ring main is up and running in the Gulf of Mexico (*Frontiers*, December 2006).

Many of the sensors are being deployed in the Gulf of Mexico for the first time.

'It's been a real learning exercise working to develop the sensors we need to monitor risers,' reports Cook. 'One of BP's strengths is its ability to spot a good technology and to ›

**Joints of pipe used to construct a deepwater riser. In this case the pipes are 160mm internal diameter, with wall thickness of 40mm**


**Above: Deploying riser monitoring systems**

**Top row: Curvature sensors (developed by Insensys) using optical fibres are attached to a riser to determine the shape and bending stresses along its length**

**Bottom row: Accelerometer bottles (from 2H Offshore Engineering) are deployed for riser data logging on several BP platforms in the Gulf of Mexico, and on drilling risers (circled in white)**

encourage suppliers to adapt and develop it further. We form a close and good working relationship with a supplier and give them the opportunity to develop the technology and deploy it more widely on a selective basis in BP assets. This strategy is one reason behind our reputation for being at the forefront in the development and deployment of innovative riser monitoring technology.'

Sourcing and developing the instrumentation involves working with specialist suppliers to build sensors and develop new techniques. For both BP and the suppliers, this is proving to be a mutually beneficial situation.

In some cases BP has played a key role in encouraging suppliers to improve their products. For example, BP worked closely with 2H Offshore Engineering in the UK, a leading riser design and instrumentation company, which has among its riser monitoring products 'accelerometer bottles' deployed on drilling platforms and drilling risers to measure and record their motions. 2H Offshore Engineering adapted its devices for use on BP's deepwater platforms in the Gulf of Mexico, developing new, more compact accelerometer bottles with increased data gathering speeds, longer battery life and greater reliability. These are now installed on four of the seven BP Gulf of Mexico deepwater platforms to provide insight into the response of the risers in the severe and deep environment, and are also in use by other oil companies, benefiting the wider industry.

In other instances, BP provided a supplier with the incentive to develop a product from scratch. A case in point is an optical fibre-based curvature sensor, a new technology developed by the UK-based company Insensys to determine the shape and bending stresses along a riser using a multi-point direct strain measurement system. When Insensys proposed the idea, BP was quick to see the advantages and provided Insensys with their first order and first opportunity to test the device on a riser in the Gulf of Mexico. The device is now commercially available and BP is using the technology in four other applications in the Gulf of Mexico as well as in BP-operated assets in the Caspian Sea and offshore Angola.

## Reality checks

Information collected as part of BP's riser monitoring programme is also leading to a better understanding of potential longer term effects, such as material fatigue. 'An important cause of fatigue is related to the complicated interaction between the structure of the riser and the fluid flow of the current,' explains Mike Tognarelli, a floating systems engineer in the exploration and production technology group, based in Houston. 'This results in a phenomenon known as vortex induced vibration.'

Although software tools are available to predict the vibration, Tognarelli and his colleagues were not satisfied that the estimates of fatigue produced by these tools were sufficiently accurate. By deciding to collect actual data from its facilities in the Gulf of Mexico and elsewhere, BP, he says, 'became an industry leader in the attempt to understand the gap between reality and what the software and the theory predict.'

The group is now taking advantage of the monitoring data to improve the way they use existing analysis models. And the additional insights revealed by the monitoring data are also helping them to develop new models.

'The more monitoring data we can collect, the more we will know about the condition of the risers,' adds Tognarelli. 'It's all about confidence and assurance of operability. The monitoring reveals important information to help us identify a safe envelope of operation, to define safe operating limits and assess the success of various vibration mitigation devices – for example, aerofoil sections to reduce drag, or helical strakes attached to the risers – so we can decide which should be used. As well as providing assurance that we are operating safely at present, the monitoring data are also helping us to improve our theoretical predictions to ensure that we operate safely and even more efficiently in the future.'

Looking to that future, Cook concludes: 'Now that BP has demonstrated how useful riser monitoring is proving to be, the big question is how the industry will respond. For example, will suppliers now think it worthwhile to develop new cheaper, smaller, faster wireless instrumentation for oil companies to use?

'What is certain is that everyone benefits from working in this way. In BP we get access to the technology we need, the supplier has a new product to sell, and the industry as a whole is able to take advantage of the new development. There is an interesting future lying ahead.' ■