Sub-sea challenge

Oil and gas flow measurement on the sea bed

Harry Lawrence

The deeper the sea, the more unsuitable traditional techniques for the extraction of oil and gas become. To be able to economically exploit such sources, a different approach is adopted. Instead of a fixed platform on which all vital equipment is positioned, much of this equipment is moved to the sea bed and the oil is raised to the surface by flexible pipes leading to a ship-like surface station, the FPSO (Floating Production, Storage and Offloading).

But the approach is not as simple as it may sound. For equipment to function on the sea bed it must be designed for a minimum of human intervention. It must be sufficiently rugged to withstand the hostile environments of both deep-sea and oil and gas extraction. And when someone does intervene, it will be a diver wearing a heavy protective suit and gloves, or a remotely operated vehicle – so little chance of gentle handling. ABB develops and manufactures flow meters for exactly such environments.

Instrumentation

ABB's Workington plant in the North of England is a center for the manufacture of a comprehensive range of flowmeters, including differential pressure (DP) flow meters which find widespread application within the oil, gas and power generation sectors, as well as across many other industries. The basic principle of operation is based upon the fact that, when a fluid is passed through a restriction, the pressure is reduced as the velocity increases.

The law of conservation of energy tells us that energy cannot be created or destroyed and that a gain in one form of energy in a system must be at the expense of another. Here, a reduction in the pressure energy balances the gain in kinetic energy that results from the increased velocity through the restriction. This is the same phenomenon as that which applies to an airplane wing (or aerofoil), where the air flowing over the top of the wing is forced to travel further than that below the wing, but in the same time. This creates a faster moving air stream over the top of the wing, resulting in a lower pressure, which in turn provides aerodynamic lift. This lift increases as the velocity of the air increases.

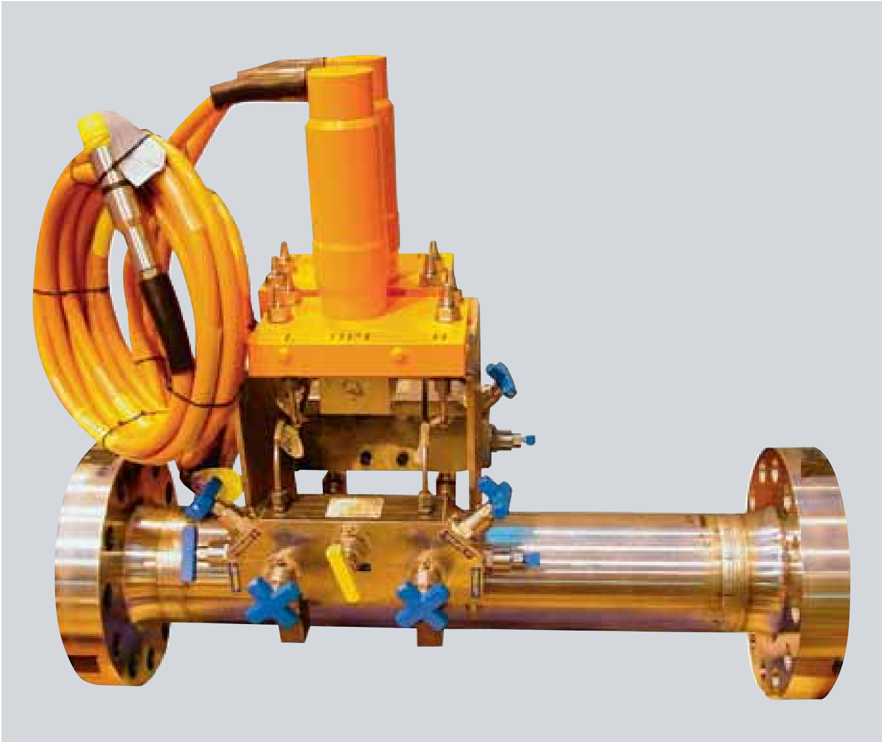
A DP primary element uses this effect to measure the rate of flow of a liquid or gas. The fluid is passed through a restriction – for example the hole in an orifice plate or the throat of a Venturi tube. By measuring the pressure difference across the restriction, the flowrate can be determined.

The flowrate Q and the pressure difference h are related by the much – simplified equation:

$$Q \propto \sqrt{h}$$

Why measure in a sub-sea environment?

The offshore oil and gas production sector has traditionally used technology that was originally developed for exploration and production on the mainland. This equipment was modified for use on an offshore platform. In recent years, however, the industry



has had to seek ways of tapping oil and gas more cost-effectively. Factors leading to this include:
- the historically low price of oil (which is frequently low, even if this has not been the case recently!)
- the increasing depth of offshore oil and gas discoveries, as most of the shallow fields have been exploited

> Every DeepSeaMaster is different – it is custom designed to the customer's project specification.

The latter factor in particular leads to one of the economic solutions being implemented – the installation of some of the equipment (and also performing some of the processes) on the seabed itself, rather than on a platform at the surface. This is where ABB DP flow meters can be applied to great effect.

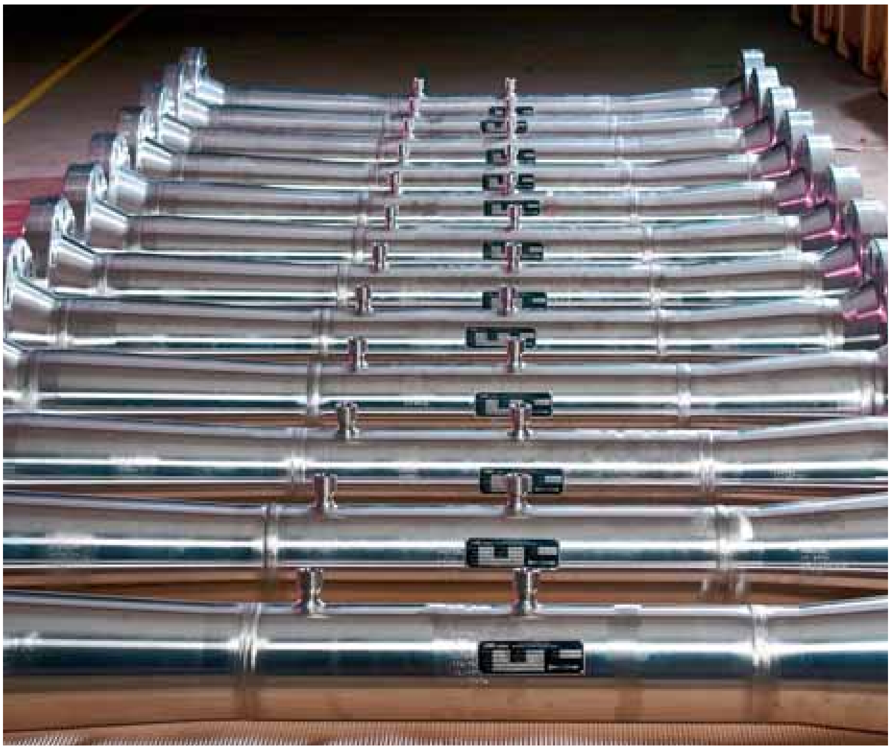
The increasing need to tap these deepwater fields has led to the use of a vessel referred to as an FPSO (Floating Production, Storage and Offloading vessel). FPSOs are ship-like in appearance and, in fact, are sometimes created by converting existing tankers. They are effectively floating oil/gas tanks and designed to store the oil or gas produced by the field/wells.

Oil from offshore installations can be transported to the mainland either via a fixed pipeline or by tanker. When a tanker is used, the oil or gas is stored in the FPSO as it is produced until there is sufficient stock to fill a transport tanker. Some FPSOs have the capability for oil separation in locations where seabed pipelines are not cost effective.

The FPSOs are anchored to the seabed in a fixed location – sometimes even pivoting on a pylon rising up from the seabed. This system allows the vessel to do what a normal tanker would do in bad weather – that is to point its bow into the prevailing sea. The deepwater fields are often subject to weather and currents every bit as bad – and sometimes much worse – than those experienced by fixed production facilities. They are fed via flexible pipes from the oil wells on the seabed, via a network of sub-sea valve manifolds that are commonly referred to as "Christmas trees".

What is special about sub-sea application requirements?

Sub-sea equipment needs to meet the normal oil field operating conditions



and design codes, including the containment of corrosive liquids or gases at high pressure and temperature.

Consequently, special construction materials, such as super duplex steel alloys are commonly used. In some cases, an even-more exotic alloy (eg, Inconel 625[1)]) is laid over the base alloy to provide additional corrosion resistance.

In addition, external pressure increases with the depths of water above the equipment. In approximate terms, for every 10 metres of water depth, the pressure rises by 1 bar. So when the equipment is, say, 300 metres under the water surface, the pressure on it is approximately 30 times the pressure at the surface. This high pressure, coupled with the need to be able to disconnect/reconnect electrical components underwater, requires that the differential pressure transmitters used with the meters are fitted with "umbilicals" (cables) and electrical connectors designed for use under sea water and at high pressure. This equipment needs to be serviced by a diver in a heavy suit with gloved hands. If the seabed is at an extreme depth, such servicing would be performed using a remotely operated vehicle (ROV).

Footnote

[1)] An alloy of nickel, chromium and iron

The ABB solution to sub-sea metering

ABB's DeepSeaMaster is a differential-pressure flowmeter, usually based upon the Venturi tube element. It is designed to operate at the bottom of the sea under high external and internal pressure. The meter is usually supplied with one (or more, for redundancy or large flow ranges) special integral DP transmitters designed for sub-sea operation, and special manifolds designed to be manipulated by a heavily-suited and gloved diver in mind.

Every DeepSeaMaster is designed to the customer's project specification. Typically, this specification (albeit expressed in very basic terms) conforms to the following:

- A Venturi tube measuring element (or a metering-pipe run fitted with a conical entrance orifice plate when the application involves flowing conditions that are too low for a Venturi tube)
- Pipe sizes typically in the range 2" to 6" (DN 50 to DN150)
- Constructed from Super Duplex (eg, UNS32760)
- Pressure rating of 10,000 lbf/in^2 (690 bar)
- Designed to American Petroleum Institute standards for wellhead/sub-sea equipment (API 6A; API 17D)
- Fitted with a single DP transmitter (or duplicate transmitters for operational redundancy)
- Manifold or double block & bleed valves (optionally removable)

Sub-sea applications for ABB DeepSeaMaster

Examples of applications for which DeepSeaMaster has been used to date include:

- Measurement of dry or wet production gas
- Measurement of light or heavy oil at low Reynolds Numbers and/or low flow rates
- Water injection Textbox 1
- Injection of MEG (Mono ethylene glycol) to combat well blocking caused by hydrate formation Textbox 2

Customer peace of mind based on technical excellence and verification

In common with all DP flowmeters manufactured at Workington, DeepSeaMaster is supplied with comprehensive certification and documentation and is subject to stringent testing. ABB supply the material traceability certificates that the oil and gas industry needs. These ensure the quality and suitability of the material used in the manufacture of all of these DP flow elements.

ABB's Workington facility offers a wide range of certification and testing, including:

- Chemical and physical property certificates
- Hydrostatic pressure test

Textbox 1 **Water injection**

When it is necessary to force oil and gas out of older wells, water can be injected. This works in two ways: increasing the well pressure to force the product out and also by helping to "lift" out the oil, as it has a lower density and therefore floats on water. Sometimes some of the gas produced is compressed and re-injected to keep the oil flowing.

Textbox 2 Mono ethylene glycol

Gas hydrates are crystalline molecular complexes formed from mixtures of water and suitably sized gas molecules. The water molecules associate in a lattice-like pattern. Such formations are unstable and have many cavities within them. The gas molecules can occupy these cavities and once a certain number (or percentage) of these cavities have been filled, the lattice crystal becomes stable and forms a solid (gas hydrate). This happens at low temperatures, but above 0 °C (the temperature normally needed to form solids from water – ie, ice!).

These hydrates can appear only if gas molecules (of the appropriate size) and water are both present. Gases such as methane and carbon dioxide are known to behave in this way. In oil exploration and production, they are a serious problem on both cost and safety grounds. Hydrates are formed under a suitable combination of high pressure and low temperature – exactly what is found in many sub-sea applications. They can block pipelines or sub-sea transfer lines and can actually form in the well itself and associated pipe work. They can lead to huge losses in revenue through lost production.

One solution to the problem is to inject a chemical that prevents the formation of hydrates. MEG (mono ethylene glycol – better known as the basis of antifreeze) is such an inhibitor. The more water there is in the oil stream, the more inhibitor is needed to treat it. However, simply saturating the oil with inhibitor is not the answer, as the water and inhibitor both need to be separated from the product later in the process. Adding more than is really needed is doubly costly – addition and removal! The solution is to add just the right amount. This is complicated by the fact that the oil/water ratio changes as the well "matures", so a fixed ratio cannot be used.

In this application, DeepSeaMaster is used to measure the flow rate in the MEG injection line to ensure that the injection rate is in the correct ratio to the flow rate of water in the oil.

- Radiographic inspection
- Magnetic particle inspection
- Dye-penetrant inspection
- Ultrasonic examination
- Positive Material Identification
- Flow calibration
- Independent authority inspection

These are supplemented by the availability of comprehensive customer documentation packages, including:
- Throat bore calculations
- Welding and weld procedure qualifications
- NDE certificates and procedures
- Quality plans

ABB has supplied DP flow meters to many of the leading global oil and gas exploration companies – including BP, Chevron Texaco, Shell and Statoil – for use in the North Sea and other global fields.

One of the economic solutions being implemented is the installation of equipment on the seabed itself.

ABB, via its Workington facility, has the products that the oil and gas industry demands for harsh sub-sea applications. This factory also has an enviable capability in the key support fields and disciplines (engineering, manufacture, documentation and testing) that are as important to the Oil and Gas industry as the products themselves.

Harry Lawrence
ABB Ltd
Stonehouse, UK
harry.lawrence@gb.abb.com