Getting more from the reservoir

1 A multilateral well in a subsea completion can typically look like this. Beneath the subsea wellhead, the completion branches out into a number of production zones.

Advanced downhole monitoring and reservoir control

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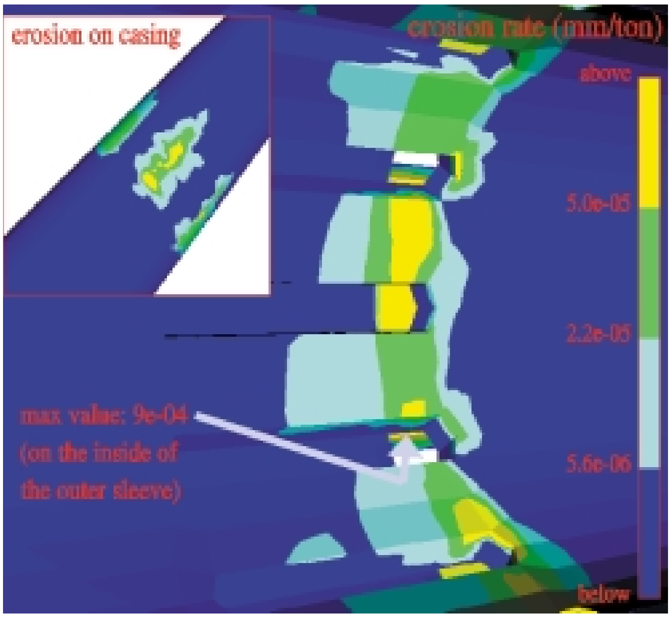
Producing oil and gas from subsea reservoirs via seabed-mounted equipment has presented technical challenges to the offshore industry for more than two decades. Recently, attention has been shifting towards introducing control and instrumentation technology into the oilwell itself, into what is called the 'downhole environment'. The reason is that this technology offers the prospect of 'gamechanging' economics for the oilfield operator. The use of such equipment promises a very significant improvement in the percentage of available oil and gas reserves that can be recovered from the reservoir. It has been typical for some 30 – 35% of the available reserves to be recovered through conventional methods, and even a small increase represents a massive improvement in the efficient use of resources for the oil companies. A technological leader in this field, ABB developed the Advanced Downhole Monitoring and Reservoir Control (ADMARC) system during 1998 and 1999.

2 A 3D model of a downhole choke showing how the various functions are stacked on the outside of the flow-path



3 A flow of reservoir fluids will remove some sand particles from the reservoir rock. The particles will be carried with the fluids through the downhole control valves and 'sand-blast' the internals of these devices. This picture depicts the minute erosion of the device resulting from such severe conditions.

ADMARC is typical of a new generation of 'intelligent well completions' able to provide integrated control of the reservoir from an offshore production platform. The technology is equally applicable to platform- and landwells, but is expected to see its first realization in subsea wells. The equipment offers the prospect of real-time control over the reservoir in multi-zone and multi-lateral wells 1.

Flow control

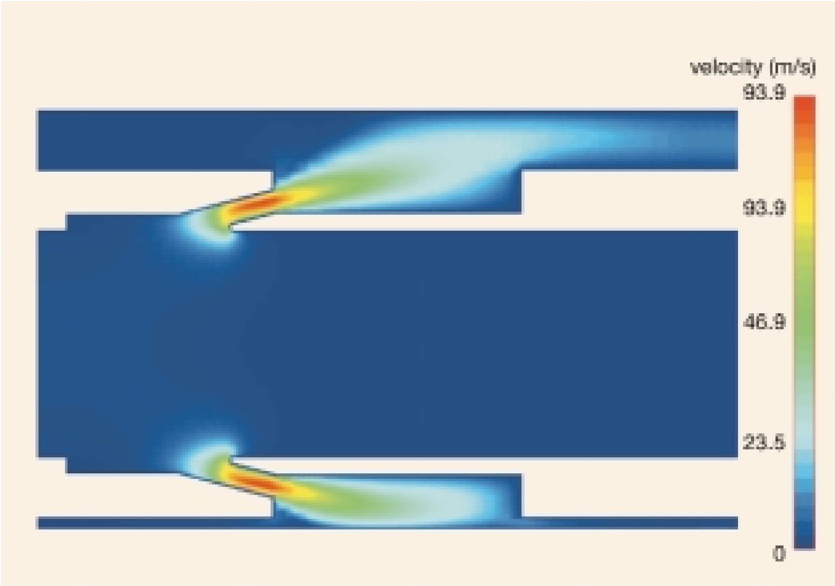
At the heart of the technology is a downhole choke valve which allows hydrocarbon products from the reservoir to be co-mingled in the wellbore, and the flow rate and pressure to be controlled. 2 illustrates how this device has to be implemented – as a long, cylindrical package with a full, unobstructed axial flow.

A typical wellbore diameter will be 5 or 7 inches (12.6 or 17.8 cm). The actuator and control electronics has to be packaged in the annular space between the cylindrical device and casing of the oil-well.

As regards the choke orifice itself, great attention has to be paid to its physical geometry, so that the inflow can be very carefully controlled. CFD analysis and other modeling and prediction techniques have been used extensively to refine the mechanical dimensions of the choke orifice. Main topics for consideration have been the flow control characteristics and sand erosion.

The control characteristics express the relationship between the valve position and a production throughput parameter. As for any choke valve, this relationship has been designed to be smooth and predictable throughout the adjustment range of the unit. Sand erosion has been predicted using recognized methods in CFD (Computational Fluid Dynamics). 3 illustrates a typical output from the erosion analysis.

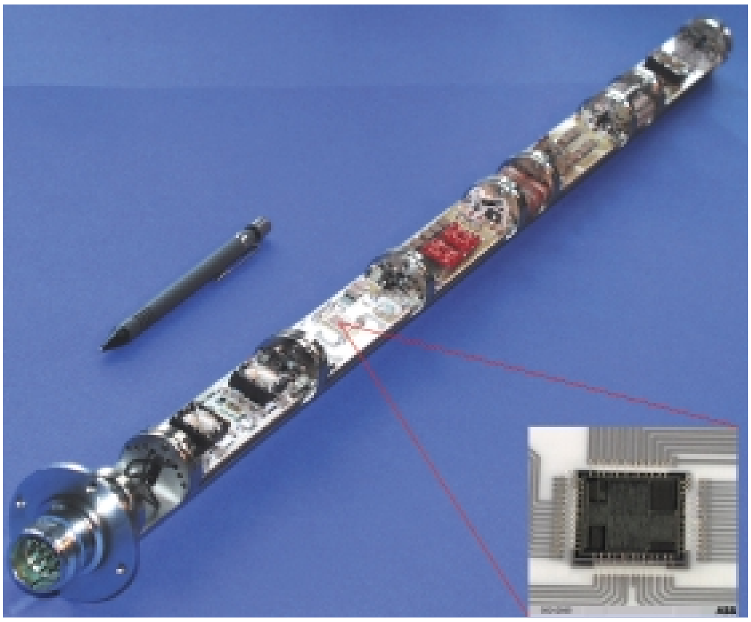
The simulations have to deal with flow in both directions as the choke orifice can also be used to control the flow of reservoir fluids from the annular space into the wellbore. In the latter scenario it is important to distribute the flow so that the casings, or, alternatively, the rock formations, are not eroded. 4 shows the flow velocities through the choke during high rate water injection service.



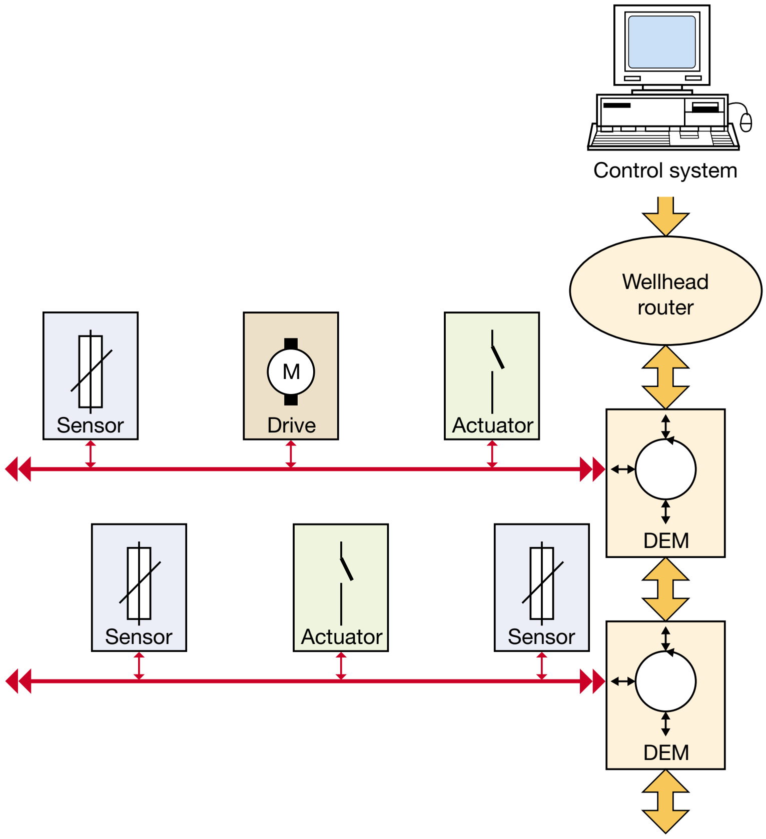
4 Injection water flows through the central pipe and the annular choke orifices, and is delivered in a distributed low-energy manner to the well annulus. The velocity field through the choke shows how the high-energy area (red) is contained in the choke internals.

Communication system

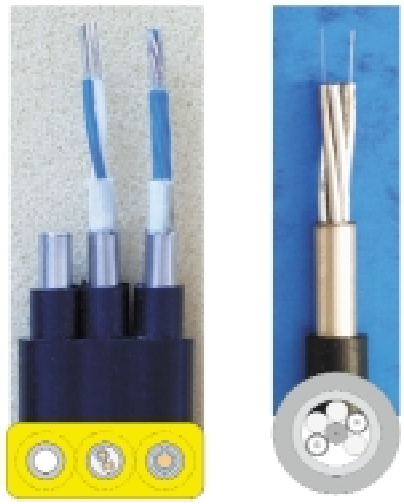
The choke itself (and other downhole instrumentation) requires downhole electronics modules 5 to be packaged to meet the physical design constraints, but also to be able to operate in very high temperature environments, ie above 150 °C. ABB Corporate Research Centers have developed high-temperature ASICs [1] using both silicon-on-insulator and silicon-carbide technology which have solved this problem. A downhole electronics module handles the AC electrical supply from a



5 Complete electronics unit with power supply and the integrated circuit for communication (inset). The unit is capable of operating continuously at temperatures well above 150 °C and is essential for application of smart functionality in oilwells.



6 The ADMARC communication system has a local bus architecture downhole. This industry standard bus allows easy interfacing with third-party sensors and actuators.



7 Special downhole cables for electrical, hydraulic and optical signals are an integral part of the downhole control system. The cable on the left is a 'flat-pack' for two electrical and one hydraulic lines, that on the right a stand-alone fiber-optic cable.

downhole cable, as well as command and control data communications and the feedback of position and measured information to the subsea wellhead via an open architecture communications scheme 6.

The downhole cable system itself 7 embodies innovative material and design technology developed by ABB Power in Norway.

These technologies have also been very extensively researched at the ABB Corporate Research Centre in Heidelberg, as well as in ABB's US facility at Raleigh, North Carolina, which specializes in the packaging of optical fibers for communication with downhole optical sensor systems.

Instrumentation

During the two-year project, considerable attention was also given to the downhole instrumentation, an example of which is the downhole water-cut meter in 8.

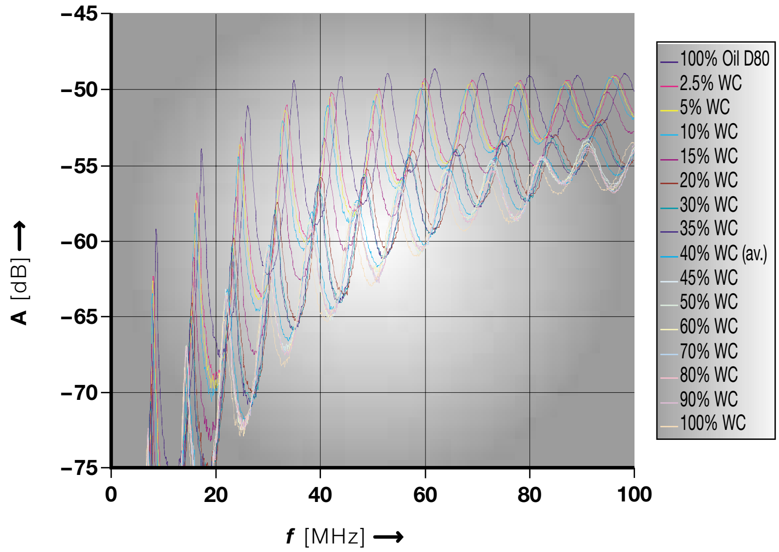
This meter is intended for installation in a producing oilwell as part of the production tubing and is an entirely non-intrusive water-cut meter, ie it measures the water content of the produced liquids (which increases during the well's lifetime due to drainage of the aquifer into the producing zones) and thus enables better control strategies to be implemented by the oilfield operator. The device uses a radio-frequency resonant cavity technique, developed with the ABB Corporate Research Center in Heidelberg, and has already been extensively tested in flow-rig test facilities in the UK, Norway and Holland. Significant operator interest is being shown in the device, for land-well and offshore oilfield use.

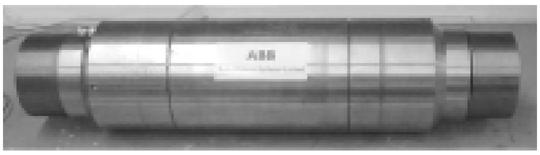
The complete ADMARC system instrumentation, including downhole cables, choke, sensors and flow meters, has been developed through very close

8 The downhole water-cut meter uses innovative signal processing based on a radio-frequency resonant cavity technique to derive the water content of the reservoir fluids. As shown in the signal plot, different water cuts present unique frequency / attenuation signatures.

A *Signal attenuation*

f *Frequency*





collaboration between ABB Offshore Systems and the Special Cables Division of ABB Power, and is underpinned by a very significant science base which has undertaken a root-and-branch review of choice of materials and technologies to deliver very high reliability in a downhole environment.

Industry significance

The ADMARC system is consistent with ABB's integrated approach to Flow Assurance for the oil and gas industry. This approach emphasizes the *3 M's* of oilfield operation: *Modeling*, *Monitoring* and *Management* of product flow from the reservoir to the process facilities.

For an efficient oil and gas industry, it is necessary to focus on adding value for the oilfield operators, in field development, capital expenditure and in the ongoing life-of-field costs.

We expect that the described developments will produce significant value for the end-user, and that these new products will become firmly established in the product portfolio for ABB Oil, Gas and Petrochemicals.

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