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## **Subsea Flow Measurement**

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# *White Paper*

# *Case Study*

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## **Subsea Flow Measurement**

With depths as deep as 10,000ft (3,000m) flow measurement in subsea oil and gas production systems represents a challenge for flow measurement. The complexity of subsea production systems ranges from single satellite wells with independent tie back lines to complex multiple well sites with a network of lines, manifolds and other modules. Often times multiple production lines feed a single vertical riser leading to the surface and eventually extend to a fixed platform, floating production storage and offloading vessel (FPSO), or a pipeline running to a land-based operation. At the same time, enhanced oil recovery (EOR) techniques push gas and liquid back to the ocean floor and deeper to more well sites and tie backs.

Flow measurement is required in all phases of these operations, especially at well heads and where lines merge or diverge. Flow meters allocate production liquids, gases and gas condensates to specific wells, monitor critical processes and directly measure enhanced oil recovery techniques such as water injection, chemical injection such as MEG (methyl ethyl glycol), and dry gas for injection and

gas lift. New technology is making subsea compression a reality as well, adding the need for subsea compressor control and anti-surge systems. Subsea oil and gas production requires the vanguard of reliable precision equipment and instrumentation.

### **The Challenge**

In addition to normal considerations for selecting a flow meter such as accuracy and repeatability, subsea module manufacturers face demanding space constraints and must plan for transportation and implementation on the ocean floor. There is only so much space available within subsea modules. When equipment such as flow meters need extensive upstream and downstream metering runs for accurate flow measurement module builders are faced with unnecessary complications.

In order to obtain the required space for straight pipe runs, piping engineers must juggle moving other equipment to accommodate the metering runs. This usually leads to a domino effect whereby other vital pieces of equipment must be

rearranged as well within the module or re-configuring the layout of multiple modules. This rearrangement compounds over and over creating highly complicated layouts not to mention the additional weight and space of extra piping. The added weight required by additional piping and complex layouts further complicates other considerations such as transportation and installation.

Turndown, maintenance needs, and life expectancy are critical topics in the harsh and remote subsea operating environment where modules are designed to last 25 years or more with no maintenance or retrieval. While the general oil/gas industry requires high accuracy and repeatability over a wide flow range, subsea systems require even tighter standards of quality to ensure long life with consistent accuracy and repeatability. It is imperative that equipment installed on the ocean floor is designed to such a degree that the operator never need to actually see it again after it is installed. Failure of a single component in a subsea system not only means production down time and lost revenue but also means logistics utilizing remote operated vehicles (ROVs) and support ships costing hundreds of thousands of dollars per day.

Although several flow meter technologies meet these requirements, nearly all require a minimum of 10 or more diameters straight pipe upstream and five diameters straight pipe downstream from the subsea flow

meter to accurately measure the flow. Elbows, T-Junctions, valves, manifolds, and other equipment in the pipeline disturb the fluid flow creating swirls and other irregular velocity profiles that degrade flow meter measurement accuracy. In densely-packed subsea modules where every fraction of added volume escalates complexity and costs, the addition of 10 to 15 diameters of heavy space-consuming straight pipe for each flow meter is a major issue. When multiplied across the multitude of metering points in the system, major expenditures in both engineering time and piping quickly add up to significant revenue reduction.

### The Solution

The ability to eliminate the required straight pipe runs for flow meters while meeting or exceeding the necessary technical specifications reduces/shrinks installation real estate and allows for flexible layouts while cutting overall pipe weight, material, and installation costs.

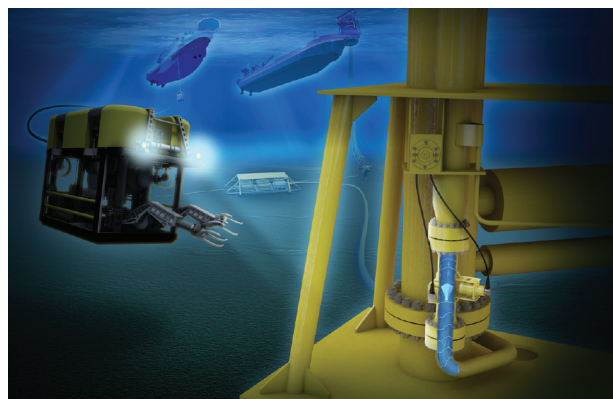


Figure 1: V-Cone® In A Subsea Application

The V-Cone® requires straight pipe runs of only zero to three pipe diameters upstream and zero to one pipe diameters downstream. This smaller footprint, requires up to 70% less straight pipe without being affected by flow disturbing equipment up stream or downstream, and is more compact than any other differential pressure meter suitable for subsea use. This allows manufacturers to place the flow meter exactly where it is needed without the addition of extra pipe and complicated space consuming layouts.

The V-Cone measures fluid flow by utilizing the conservation of mass theory, which states that in a closed system, the mass entering into the system must equal the mass exiting the system ( $m_{in} = m_{out}$ ). In the case of a flow meter, the mass entering the flow meter must equal the mass exiting the flow meter. Similar to other DP technologies, a restriction is placed in the pipe forcing the fluid to accelerate and thus a pressure drop to maintain mass conservation. Unlike other DP technologies, the V-Cone positions a V-shaped conical intrusion centrally in the line redirecting the fluid to the outside of the pipe and around the cone instead of forcing fluid through an orifice at the center of the pipe. One pressure sensing tap located upstream from the cone measures static pressure while another pressure sensing tap measures the low pressure created by the cone on the downstream face of the cone itself. This pressure difference is incorporated into a derivation of the Bernoulli equation to

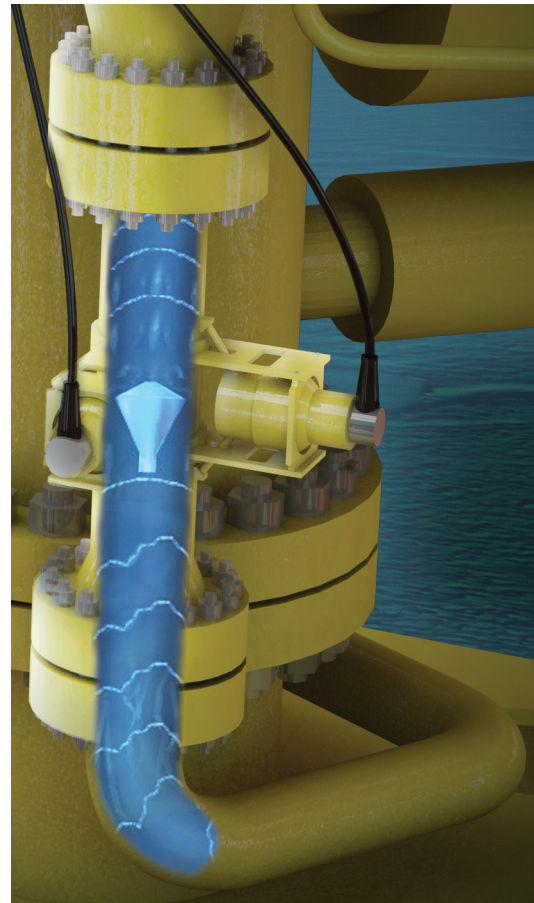


Figure 2: V-Cone Flattening Disturbed Flow Profile

determine fluid flow. As the fluid moves past the cone, very short vortices are formed that result in a low-amplitude, high-frequency signal optimal for excellent signal stability.

The V-Cone primary element maintains +/- 0.5% accuracy and +/-0.1% repeatability over a 10 to 1 turndown and the cone conditions the fluid such that there is relatively low permanent head loss with system accuracy better than +/-2.0%. Low permanent head loss achieved by the V-Cone is derived from the shape of the cone itself, which minimizes energy losses commonly caused by areas of

low flow, cavitation and erratic flows. Each V-Cone is sized to meet desired application requirements and may be specifically designed to have high rangeability or low head loss. Regardless, the overall energy consumed by the V-Cone is minimized because of its inherent characteristics.

The rugged V-Cone employs no moving parts and measures abrasive, dirty, and particle-laden fluids over a wide range of flow without wear or clogging concerns, delivering a standard 25 year operating life with generally no need for maintenance. The turbulent vortices produced by the V-Cone condition the fluid flow to be homogeneously distributed and extremely stable. Accelerating the fluid up the cone and ejecting it past the beta or metering edge forms a protective boundary layer. This prevents wear of the beta edge from erosion as well as particle buildup that would cause metering errors in other flow technologies.

Normal surface deterioration in flow meters, piping, and other equipment occurs as a result of fluid shear stress. Shear stress creates a problem where there is a solid boundary layer in direct contact with the walls of the pipe. This solid boundary layer occurs in laminar flows and erratic turbulent flows. The V-Cone's very stable turbulent flow all but eliminates this shear stress and consequently results in no surface deterioration. Additionally, due to the shape of the cone, there is no cavitation

on the backside of the cone to erode the surface. Each V-Cone is calibrated during the manufacturing process and because the design is robust, there is never a need for regular maintenance or recalibration after installation.

Given the substantial distances between the well head and final destination of the fluid being moved, the V-Cone's low permanent head loss results in much lower energy requirements to move the product. Cavitation, eddies, and areas of zero flow that can form on the downstream side of differential pressure devices are actually energy consumers. This energy loss directly equates to the need for larger pumps to move the desired amount of fluid. This can be avoided by using the V-Cone. In subsea operations, as with land based operations, there are many locations where flow is measured. Flow is measured at wellheads to ensure production efficiency, monitor the life of wells, and provide information for allocation/custody transfers. For custody transfer information, it is also imperative to measure flows in each tributary where lines merge together. Subsea operations require the ability to sustain high pressures, resist corrosion, meet stringent standards, arrive pre-tested, and couple with pipe and umbilical connections alike. The McCrometer V-Cone can be manufactured to meet all these requirements.

Versatility, lower energy consumption combined with little to no maintenance and tremendous space and weight savings means a much lower cost of ownership and a trustworthy flow meter on the ocean floor.

## **Conclusion**

Subsea applications can be served effectively by the McCrometer Subsea V-Cone Flow Meter due to its stable operation at internal pressures up to 15,000 psi (1035 bar), absence of moving parts, no wear along the beta edge or pipe resulting in no requirement for scheduled inspection or re-calibration, high accuracy and repeatability over a long life. Operators and piping engineers alike will recognize the benefits of the space and weight savings of the Subsea V-Cone technology. The Subsea V-Cone Flow Meter has been supplied in line sizes from 2" to 16" with most types of end connections, can be manufactured out of various materials, and to almost any pressure rating. It has been installed within subsea modules, trees and other units commonly used subsea.