CASE STUDY

Subsea Flow Measurement

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Flow measurement in subsea production systems, modules and templates is a challenge for flow meters. The complexity of subsea production systems ranges from simple satellite wells with one line to complex multiple well sites with a network of lines. Several pipe lines join together below the surface and will eventually extend to a fixed platform, Floating Production Storage and Offloading Vessel (FPSO), or perhaps a pipeline running to a land-based operation.

Flow measurement is required in all phases of these operations, especially at well heads and where lines merge. Flow meters monitor critical processes and directly measure gases and liquids including crude, gas condensate, water, chemicals such as MEG (methyl ethyl glycol), gas for gas injection and gas lift, and many others. Subsea oil and gas production requires highly specialized and reliable precision equipment and instrumentation.

The Problem

In addition to normal considerations for selecting a flow meter such as accuracy and repeatability, subsea module manufacturers are highly space constrained and must plan for transportation and implementation on the ocean floor. There is only so much real estate available for module manufacturers. When equipment such as flow meters need to condition the fluid for accurate measurement, the required space for straight pipe runs adds unnecessary complications.

In order to obtain the required space for straight pipe runs, module manufacturers must juggle moving other equipment to accommodate the additional piping. This usually leads to a domino effect whereby other pieces of equipment must be rearranged as well. This rearrangement compounds over and over creating ridiculously 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. Transportation costs increase dynamically and the logistics of installation on the ocean floor become more rigorous.

Turndown, maintenance, and life expectancy are critical in the dynamic, harsh and inaccessible subsea operating environment where modules are designed to last 25 years or more with no maintenance. While the general oil/gas industry requires good accuracy and repeatability over a wide flow range, subsea modules can require tighter standards over a longer life with consistent accuracy and repeatability. It is imperative that equipment installed on the ocean floor is reliable over a long life. Maintenance not only means production down time but also means transportation logistics and work below the surface, which may not be practical and is most times prohibitively expensive.

Although several flow meter technologies meet these requirements, nearly all require an average of 10 or more diameters straight pipe upstream and 1 to 5 diameters straight pipe downstream from the meter to condition the flow for measurement. Elbows, valves, compressors, and other equipment in the pipeline disturb the fluid flow creating swirls and irregularities that degrade flow meter measurement accuracy. In crowded subsea modules where every bit of added real estate 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.

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. McCrometer's uniquely designed differential pressure V-Cone® Flow Meter is now frequently utilized by the industry's four major Subsea Module manufacturers.

The V-Cone® utilizes a centrally located intrusion that redirects the flow to the outside of the pipe and conditions the flow by reshaping the velocity profile, all but eliminating the need for straight pipe runs.

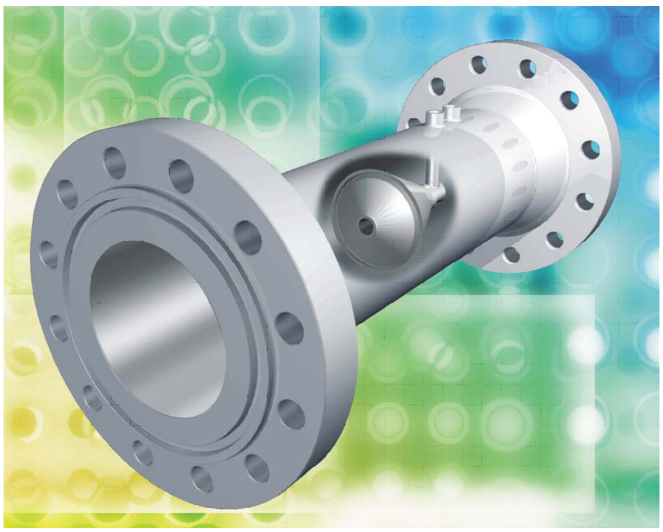

Figure 1: V-Cone Flow Meter

The V-Cone requires straight pipe runs of only 0 to 3 pipe diameters upstream and 0 to 1 pipe diameters downstream. This smaller footprint, requiring up to 70% less straight pipe without being affected by flow disturbing equipment up or down stream, is more compact than any other differential pressure meter suitable for subsea use. This allows manufacturers to place the flow meter exactly where it's needed without the costly addition of extra pipe and complicated space consuming layouts.

The V-Cone measures fluid flow by utilizing the conservation of energy theory, which basically states that in a closed system, energy can be neither gained nor lost. With this in mind we can utilize the PV=nRT equation where pressure multiplied by volume equals temperature while n and R are constants. Therefore, imposing a volume change within the pipe line results in a differential pressure drop that can be measured directly.

The V-Cone places a "V-shaped" conical intrusion centrally in the line redirecting the fluid to the outside of the pipe and around the cone. 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 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.

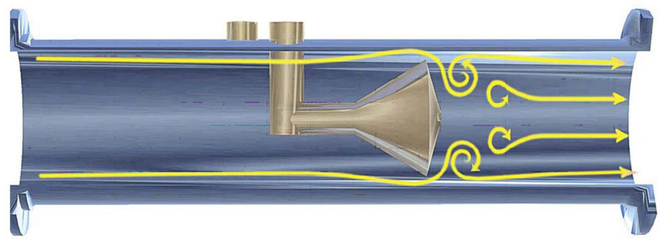

Figure 2: The V-Cone's Vortices

The V-Cone 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.

Low permanent head loss achieved by the V-Cone results 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 or low head loss. Regardless, the overall energy consumed by the V-Cone is minimized because if its inherent characteristics.

The rugged, no moving parts V-Cone measures abrasive, dirty, and particle-laden fluids over a wide range of Reynolds numbers without wear or clogging concerns, resulting in an unprecedented standard 25 year operating life with generally no need for maintenance. Reynolds numbers are a measure of whether the flow is laminar or turbulent.

The turbulent vortices produced by the V-Cone condition the fluid flow to be homogeneously distributed and extremely stable. It is this turbulent flow that actually protects the cone as well as the surrounding pipe. The turbulent flow forms a boundary layer against the pipe wall and cone protecting it from particle impingement which can cause deterioration or buildup on the surfaces.

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 so 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.

In subsea operations, as with land based operations, there are many locations where flow is measured. At wellheads flow is measured 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 specific 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.

The Results

Subsea applications require what McCrometer's V-Cone Flow Meter has to offer: stable operation at internal pressures up to ANSI 15,000 psi, no moving parts, no wear along the beta edge or pipe resulting in no need for physical calibration, high accuracy and repeatability over a long life, and small weight and space footprint. The V-Cone Flow Meter supports line sizes from 0.5" to 120" or greater with most types of end connections, can be manufactured out of almost any material and to almost any pressure rating. It can be installed within a Subsea Module, Tree or Metering Station with less weight and space making it possible for manufacturers to stay within design limitations without the usual flow meter constraints.

The V-Cone Flow Meter by McCrometer delivers highly accurate, dependable flow measurement for rugged operating environments. Its measurement versatility, innovative design, simple installation, low maintenance, and proven long-life provide users with low cost-of-ownership while delivering exceptional return-on-investment.