

## CASE STUDY

# U.S. Navy Adopts V-Cone Flow Meter For EMALS Duty on Next-Generation Carriers

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Defense contractor General Atomics (GA) is developing the next generation of aircraft catapult launch systems for United States Navy's new Gerald R. Ford-class aircraft carriers. The Electromagnetic Aircraft Launch System, or EMALS, utilizes a breakthrough linear motor technology instead of conventional steam pistons.

A technological advance, EMALS provides a controlled acceleration of aircraft to takeoff speed. Other advantages of EMALS in comparison to conventional steam systems include lower weight, reduced operations and support costs, and expansion of the operational envelope to launch a greater range of aircraft weights and reduce fresh water requirements.



*An F/A-18F Super Hornet launches off the flight deck aboard the carrier USS Dwight D. Eisenhower during sunset flight operation. United States Navy photo by Photographer's Mate Airman Christopher Molinari (Released)*

### The Challenge

Accelerating a fully loaded strike aircraft to its launch endspeed using linear motor technology generates heat in both the power system and the motors, which must then be dissipated by a cooling system. The cooling water in the system needs to be actively monitored and controlled to ensure proper cooling of these systems, which requires an accurate and dependable flow meter.

GA reviewed the available flow meter technologies on the market in terms of their measurement accuracy, dependability and installation space requirements. The space aboard a ship is always a limited environment and must be used efficiently. A key consideration in the selection of the flow meter was the fact that the coolant piping system layout included elbows in and out of plane, causing swirl and cavitation that affects the accuracy of many flow meter sensing technologies.

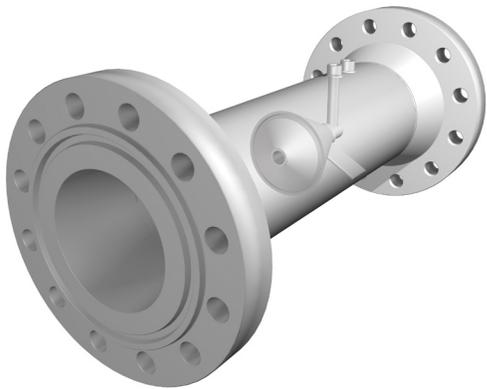
A failure to accurately report the flow of cooling water is serious because it indicates the power system and/or drive motors are not being cooled and could potentially impact the system's ability to meet operational requirements. The U.S. Navy has one of the strictest testing requirements in the world, designed to ensure key systems will remain operational in all weather, seas and combat operations.

After evaluating and testing various flow meter technologies, GA's engineers contacted McCrometer to discuss the problem of finding a flow meter technology that is highly resistant to flow swirl and cavitation. The

McCrometer applications team recommended the V-Cone® flow meter. Sample V-Cone flow meters were purchased for evaluation and rigorous testing.

## The Solution

McCrometer's rugged differential pressure (dP) V-Cone flow meter is well suited for the EMALS coolant monitoring system. With its built-in flow conditioning technology, the V-Cone flow meter eliminates the need for long straight pipe runs to provide accurate, repeatable flow measurement in swirl and cavitation prone piping environments.



*V-Cone flow meter cut-away view shows its V-shaped conical intrusion, which directs flow to the outside inner wall of the pipe where it is conditioned for a smooth flow profile.*

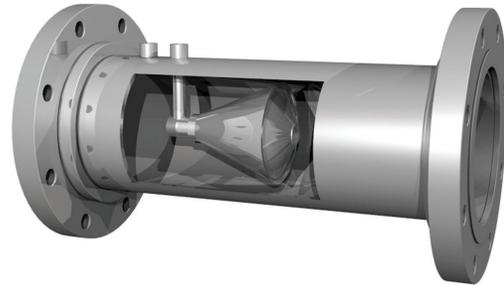
At the same time, the V-Cone flow meter's compact design reduces installation real estate requirements, allowing for more flexible instrumentation layouts and making it an ideal match for the constrained shipboard environment.

The V-Cone flow meter 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. The V-Cone flow meter requires straight pipe runs of only 0 to 3 pipe diameters upstream and 0 to 1 pipe diameters downstream.

The V-Cone flow meter's smaller footprint, requiring up to 70 percent less straight pipe without being affected by flow disturbing equipment up or down stream, allows the EMALS team to place the flow meter exactly where it's needed without the costly addition of extra pipe, external flow conditioners or complicated space-

consuming layouts. Installing a lesser amount of pipe also reduces overall system weight.

The V-Cone flow meter 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. According to the  $PV=nRT$  equation, pressure multiplied by volume equals temperature while "n" and "R" are constants. Imposing a volume change within the pipeline, results in a differential pressure drop that can be measured directly.



*V-Cone flow meter cut-away side view shows the meter's V-shaped conical intrusion in the center of the pipe.*

McCrometer's V-Cone flow meter 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. The V-Cone flow meter maintains  $\pm 0.5$  percent accuracy and  $\pm 0.1$  percent repeatability over a 10 to 1 turndown, and the cone conditions the fluid such that there is relatively low permanent head loss.

The low permanent head-loss achieved by the V-Cone flow meter results from the shape of the cone itself. The shape of the cone minimizes energy losses commonly caused by areas of low flow, cavitation and erratic flows. Each V-Cone flow meter 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 flow meter is minimized because of its inherent characteristics.

The rugged, no moving parts V-Cone flow meter 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 flow is laminar or turbulent.

The turbulent vortices produced by the V-Cone flow meter 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. Shear stress occurs in laminar and unstable turbulent flows.

The V-Cone flow meter'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 little chance of cavitation on the backside of the cone to erode the surface.

## Conclusions

McCrometer's V-Cone flow meter solved the fluid flow measurement challenge presented by the EMALS cooling system. The V-Cone flow meter's minimal space and straight pipe run requirements worked well within the tight-fit shipboard environment with exceptional accuracy. It combines exceptional performance, piping configuration flexibility, and low maintenance for superior value.

After a short and successful preliminary test period, the V-Cone flow meters were adopted for all EMALS cooling water metering. The first four batches of V-Cone flow meters were supplied to General Atomics in 2011.