WHITE PAPER

Providing Solutions to Differential Pressure Flow Measurement Problems

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INTRODUCTION:

Issues in DP flow measurement have been present since DP flow measurement began. Pipeline managers, drillers, plant operators, and other industry professional constantly seek to minimize measurement error and increase efficiency, longevity and, most importantly, safety. The importance and need for involvement with severe service, widely fluctuating flow rates and heterogeneous process have opened the door to measurement certainty and increased need for ROI. Identifying, correcting, and providing a solution to some of these conditions has become a key to providing ROI and increased profit.
There are several solutions in the marketplace for certain levels of these issues. However, research seems to indicate that there is only one flow measurement device that addresses all of these issues.

THE ISSUES:

While some fail-safes exist, flow measurement errors can be introduced when *in situ* conditions are ignored in favor of short-term financial gain, ignorance of proper installation procedures or, one of the most common issues – human error. Beyond the simplest problems, human error can also present safety concerns.

One of the easiest mistakes to make is installing the primary element backwards. Backward facing orifice plates, for example, can yield errors in the range of 10% - 20% (Witte). The knife-edge must be oriented correctly. In a custody transfer situation, this backward installation would be a costly mistake.

Likewise, venturis, cone meters, and some turbine meters would all be expected to yield inaccurate results. All flow measurement devices come with instruction manuals, and most employers offer some type of training. Unfortunately, training and instruction are frequently ignored. As the chart below indicates, backwards facing orifice plates can cause an under-measurement of fluid. Measurement error can range from 10% to 20%.

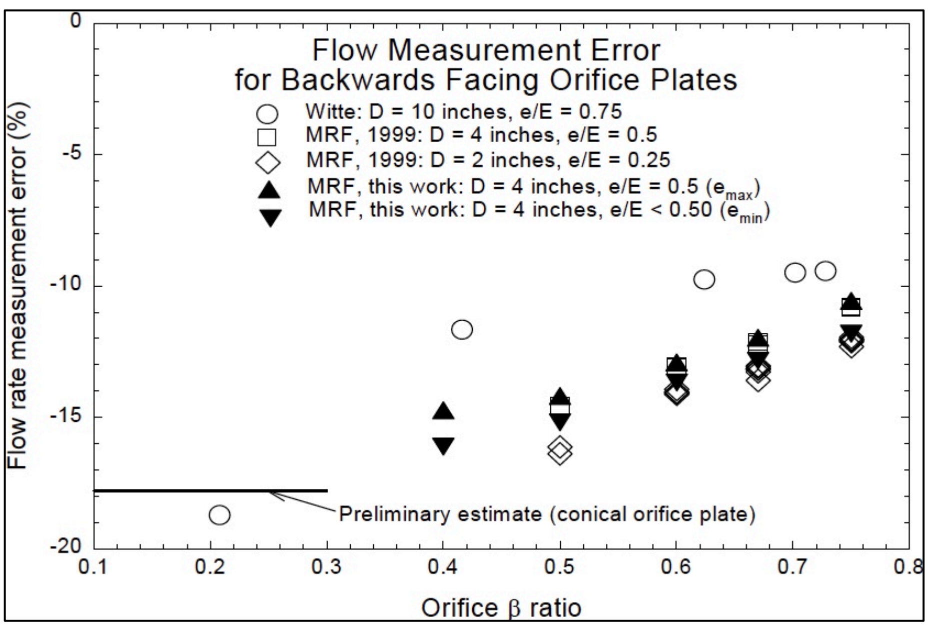
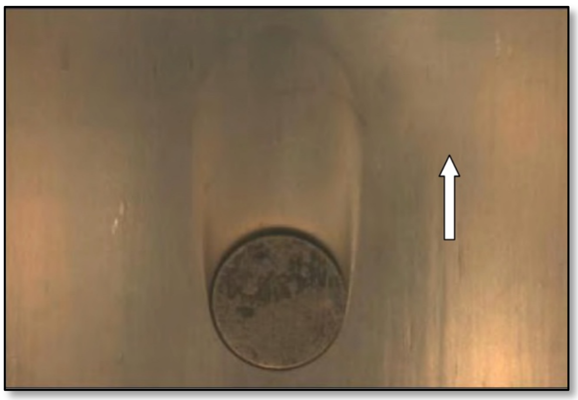


Chart credit: Measurement Research Facility, J.N. Witte

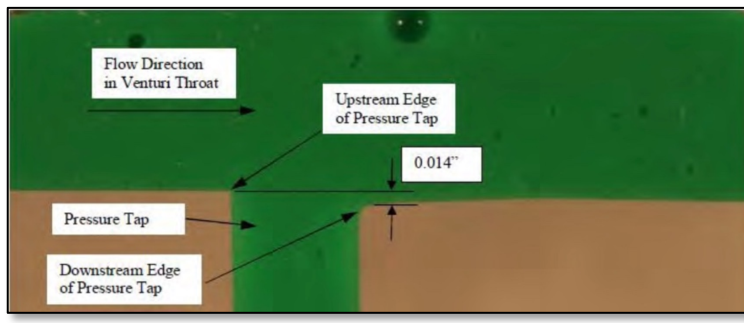
Also with regard to element insertion is the hazard presented to the worker by the process being under possibly under pressure. Typically, the plate is cranked out of its chamber while process is allowed to flow. If proper safety protocols are ignored, injury or death to workers is possible.

A second issue to consider is that flow conditions upstream of the primary element must be taken into account. A primary element can sometimes be placed too close to a source of turbulence (elbow, partially closed valve, rough pipe wall, etc.). Turbulence can cause differences in flow velocity as the process encounters the primary element and can yield measurement error in the 2% - 4% range (Ouazzane and Benhadj). If the primary element is a custody transfer device, either the buyer or the seller will be shortchanged. Solutions include the installation of a flow conditioner and moving the primary element ten pipe diameters from the source of turbulence.

Next, you must note that most tools are designed and built with one purpose in mind. Flow meters are no different. Should a flow meter be placed in a process condition for which it is incompatible, inaccurate measurement readings can occur quite rapidly. Drilling mud and other abrasive slurries tend to erode most DP meters. This is especially true if the meter is placed too close to a source of turbulence and in an abrasive process (Zanker, 2011). In the following image examples, a venturi, a cone meter and a wedge meter were all placed in an air/sand flow stream, and a separate water/sand flow stream to test their susceptibility to erosion. In a test designed to mimic the offshore flow measurement environment, all three showed noticeable signs of wear.



Photograph of throat tap after erosion. Courtesy of 07121-1301-FR Improvements Deepwater Subsea Measurements 12-30-11.



Photograph of a cross-sectional slice cut from a casting of throat tap. Courtesy of 07121-1301-FR Improvements Deepwater Subsea Measurements 12-30-11.

Over-pressurization can have a negative measurement impact on orifice plates as shown in the chart and photo below. Actual measurement errors of up to 1.5% were observed vs. theoretical errors of 4%.

Bent Orifice Plate. Courtesy of Paul La Nasa.

In order to function correctly, differential pressure primary flow elements find themselves at the mercy of the flow stream. With few exceptions, whatever goes down the pipe must eventually impact the flow element or pass through it. No matter how carefully a meter is designed and installed, foreign materials can always enter the pipeline. Numerous examples in published literature paint a graphic portrait of the tortured lives of orifice plates, turbine meters and other DP measurement devices. Dead animals, welding slag, grease, tools, and more can impact the primary and cause varying degrees of measurement inaccuracy. The following charts illustrate the serious measurement degradation of orifice plates coated with varying thicknesses of valve lubricant.

EFFECT OF VARIOUS CONDITIONS IN PRIMARY ELEMENT OF ORIFICE METER MEASUREMENT:

		TYPE	Condition	% Difference Flange Taps-Pipe Taps
I.		**LEAKS AROUND ORIFICE PLATE**		
	A	**WITH ONE CUT THROUGH SEALING UNIT 1/16”**		
		1.) Cut on Top Side of Fitting	(0.2)	0.8
		2.) Cut Next to Tap Holes	0.2	0.9
	B	**WITH “V” NOTCH CUT THROUGH SEALING UNIT ¼” WIDE AT TOP OF “V”**		
		1.) “V” Notch on Top of Run	2.0	2.5
		2.) “V” Notch on Bottom of Run	1.0	1.0
		3.) “V” Notch on Opposite Side From Tap	2.5	1.0
		4.) “V” Notch on Tap Side	(2.0)	3.0
II		**DIRTY PLATE**		
	A	**VALVE LUBRICANT ON UPSTREAM SIDE OF PLATE**		
		1.) Three Deposits	0	0
		2.) Nine deposits	(0.6)	1.9
		3.) Inner half of face uniformly coated 1/16” thick	(3.8)	(3.1)
		4.) Orifice plate uniformly coated over full face 1/16” thick	(4.7)	(3.5)
	B	**VALVE LUBRICANT ON DOWNSTREAM SIDE OF PLATE**		
		1.) Bottom Half of Plate Coated 1/16” Thick	3.0	0.3
		2.) Inner Half of Plate Downstream Side Coated 1/16” Thick	(1.1)	0.3
		3.) Orifice Plate Uniformly Coated Over Full Face 1/16” Thick	(1.0)	0.6
	C	**VALVE LUBRICANT ON BOTH SIDES OF PLATE**		
		1.) Plate Uniformly Coated Full Face on Upstream Side & Inner Half of Circle	(8.0)	(14.0)
		2.) Plate Uniformly Coated Full Face Upstream & Downstream 1/16” Thick	(13.0)	(10.0)
		3.) Lubricant on Bottom Half Both Sides 1/8” Thick	(4.0)	(5.0)

*Chart courtesy of “Installation and Operation Errors in Gas Measurement” by Paul J. La Nasa, CEESI Measurement Solutions, Inc.

A SOLUTION:

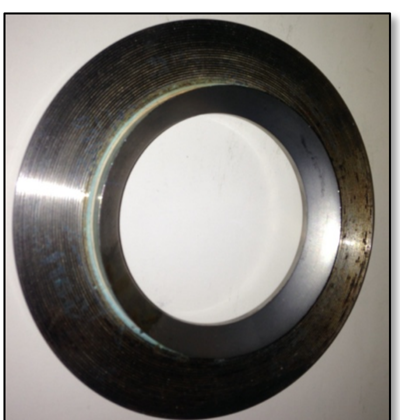
Research to date indicates that no flow meter can function correctly when best practices are ignored or some catastrophic event occurs. However, one device permits a greater range of installation environments without significant measurement degradation.

That device, called the **TORUSWEDGE**, has unique circumferential ramps that take the energy of the flow stream from the pipe wall and focus it toward the bore (beta) of the meter. This conditioning process allows the **TORUSWEDGE** to be placed closer to sources of turbulence than most other DP elements.

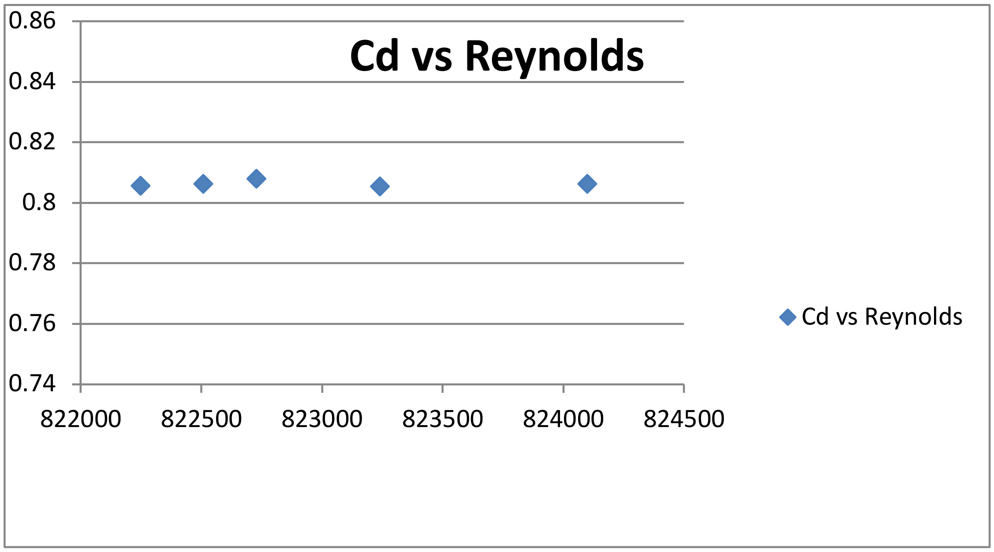
Since the fluid impacts the element at a reduced angle compared to an orifice plate, resistance to erosion is much greater. The flow stream is gathered from the pipe walls and forced through the bore and then released in a controlled fashion. This design makes the **TORUSWEDGE** suitable for processes which were previously un-measureable by conventional DP elements. Furthermore, the **TORUSWEDGE** is bi-directional so it cannot be inserted incorrectly by field personnel.

TESTING:

A test performed by a major manufacturer of drilling equipment utilizing the **TORUSWEDGE** in high-pressure drilling mud over thirty-one days (see images below), resulted in virtually undetectable wear on the unit. The **TORUSWEDGE** was installed in a 5,000 lb. meter that utilized remote seals for differential pressure sensitivity. Ten-pound mud was circulated at 1,500 PSI through the unit to simulate normal wear and tear experienced while drilling a well. The **TORUSWEDGE** was installed at the outflow of a ninety-degree elbow, highlighting its effectiveness at removing swirl.



A second test at a Northwestern US power plant placed a **TORUSWEDGE** ANSI 150 meter in limestone slurry for approximately nine months. As shown in the picture below, there is virtually no wear on the device. With no sharp edge to wear, this flow meter performs well in many severe service applications. The image to the left shows a 4" ANSI 150 SS304 TORUSWEDGE in limestone service for 9 months.



The Colorado Engineering Experiment Station, Inc. (CEESI) performed tests with **TORUSWEDGE** flow elements of various sizes in an air flow loop. These results are shown in the table to the left in comparison to calculated orifice plates (API 14.3.1) of equivalent beta ratios. The results highlight the linearity and efficiency of the **TORUSWEDGE** over a range of Reynolds numbers. ***Reference***: *CEESI Report #09RN-CE08423, February 9, 2009.*

Beyond making the **TORUSWEDGE** extremely durable, the circumferential ramps allow the unit to be self-cleaning and self-centering, allowing it to require less inspection and maintenance. Lower maintenance and inspection cycles lead to a significantly safer work environment. As discussed above, orifice plates installed in custody transfer meters are usually checked on a routine basis to determine if the unit is worn, damaged or incorrectly inserted. This routine maintenance and equipment replacement exposes workers to increased injury possibilities. With a **TORUSWEDGE** installed, maintenance intervals become much longer – saving money, increasing profit and, most importantly, keeping personnel away from potentially hazardous pipeline processes.

CONCLUSION:

Numerous process conditions like drilling mud, superheated steam, mining slurry, and many other processes can take their toll on primary elements. The **TORUSWEDGE** flow meter addresses these harsh conditions and provides users in numerous industries and markets with a new tool for greater accuracy, durability, longevity, and safety. Its unique ramp design adds to its simplicity of use which also minimizes the need for additional field personnel training.

While "change" is usually considered a dirty word in flow measurement, it should be noted that in the current economic and safety atmosphere, it has been quite some time since the most popular primary device, the orifice plate, was invented. This new era in flow measurement as well as the issues and disasters both on and offshore, demand new solutions to age-old problems.

The **TORUSWEDGE** seems to deliver the answer.

the element allows the fluid to pass through while expending less energy."

IMPOSSIBLE MEASUREMENT MADE POSSIBLE

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