The Durability of Zedi's eTube™

A look at the durability of the eTube when dealing with unconventional gas production.

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Unconventional gas – the next horizon

With advances in multi-zone fracturing technology and the use of horizontal drilling applications, the North American Natural Gas Industry has seen an intense shift to securing and exploiting unconventional resource fields. Alberta, Saskatchewan, and Northeastern British Columbia have all experienced a radical shift from conventional, vertical well drills to a more capital intensive, but highly prolific, horizontal focus.

Although advances in technology have enabled higher initial production rates, it is still extremely important to measure the performance of these high cost wells and projects. Data and measurement enables producers to verify and determine how assets can be optimized and exploited with certainty. As unconventional gas production poses some serious challenges, maximizing data confidence should be a high priority for those investing a great deal of time and capital. Tight reservoirs are characterized by very low permeability, which often require a fracturing of the reservoir with a combination of very high pressures, frac fluids, and sand to simulate the reservoir and maximize the flow back capacity after the fracture. Although these reservoirs are a challenge to exploit, the reserves associated with these emerging fields are shifting the natural gas landscape.

As each well bore typically undergoes multiple, intense hydraulic fracturing processes, there is a need to clean out and flowback excessive frac liquids and sand that have not remained embedded in the reservoir. This clean out can take several days or even weeks to complete. Sand and formation flow back is a common problem experienced once the well is flowing under normal operating conditions. Separation, sand filters, and other means can minimize erosion and the risk associated with these less-than-optimal process situations. Similar to a commercial sand blaster, high velocities common to high rate gas production pose serious operational risks to process equipment, and as discussed in this paper, to measurement equipment.

Metering and accurate production data are essential to learn exactly what is being produced from each well in order to gain insight and make improvements. What are needed are some alternatives to traditional metering techniques that are resilient to these harsh operational circumstances, while providing accurate data that forms the basis for future decisions.

The producer's challenge

To illustrate some of the challenges posed by unconventional gas production, we'll examine the difficulties faced by one of Zedi's customers operating in the Montney formation. This customer brings their wells on at a very high initial production rate, which quickly decline, resulting in a wide range of differential pressures over the short term of the well.

Due to high gas velocities and large amounts of sand entering the flow line in this unconventional environment, the producer was forced to halt production at regular intervals to replace equipment damaged by the particulates (such as sand and other solids). The producer typically measured the gas rate and pressures with an orifice body and sharp edged plate to create differential pressure monitored and captured by Zedi's Smart-Alek production EFM system.

With the high decline rates, the producer would also have to constantly change plates to keep the differential in a proper measurement range. The producer would typically start with a 1.5-inch orifice plate in a two-inch line, hoping that this was the right plate from the initial flow test results. Until the well stabilized sufficiently, the producer was changing and/ or inspecting orifice plates daily to keep up with the decline and damage. If they did not inspect or change the plates with such regularity, the accuracy of measurement would have been drastically affected.

Figure 1: Damaged orifice plate removed from service – dented, worn, and concaved below shows an orifice plate removed from service from the producer's meter run. The plate is supposed to have a one millimeter flat edge along the bottom, as shown in the middle picture. With the exception of the two parts within the dented portion of the middle of the plate, this flat edge has been completely worn down. Note in the picture on the right the gap between the orifice and the surface beneath it due to the concaving of the plate. A normal orifice would be flush with the surface.

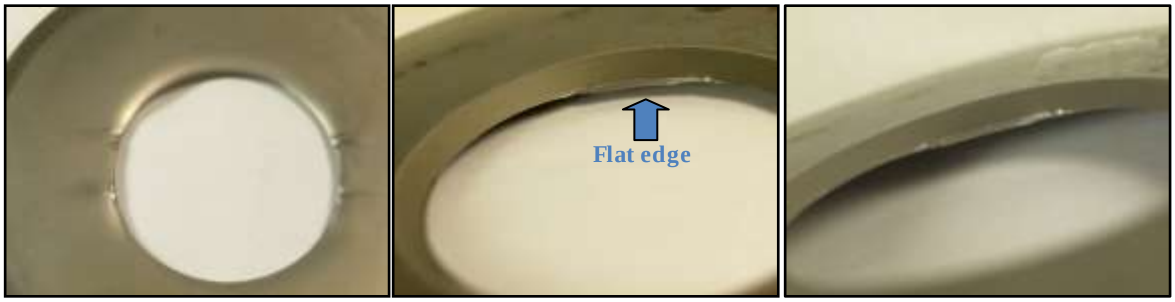

Figure 1: Damaged orifice plate removed from service – dented, worn, and concaved

Changing the orifice plates required two workers on location for approximately 1.5 hours, including paperwork. In addition to the work on site, the lead operator would have to change the meter information in the host-based web interface if a plate size was changed, as this producer's procedures do not allow operators access to changing orifice sizes or other meter parameters for audit and compliance reasons. With each plate change, which cost the producer approximately $50 each, the producer sacrificed the time of two to three employees, while negatively impacting the runtime of the well.

Zedi's solution: the eTube™

Zedi's eTube is a differential pressure-type flowmeter used for measuring gas by way of a flow restriction. With its smooth shaped throat, it is designed to efficiently produce stable differential pressure across a wide range of flows, while creating a minimum of permanent pressure loss. The throat is shaped like an ellipse, which is where its original name "elliptical tube" is derived. The meter has large pressure taps, which assist in minimizing the impact of liquids and other contaminants. The eTube works in conjunction with electronic flow measurement field devices produced by Zedi, such as the Smart-Alek® or Zedi EFM Walk-up™, with the measurements sent automatically to Zedi's secure web portal Zedi Access™.

Figure 2: Cutaway of the eTube

A key feature of eTube's innovative design is how it allows particulates like sand and other solids to easily pass through the restriction without excessive wear and damage. Unlike with the orifice plate, whose sharp edges can act as a trap for particulates, the eTube's elliptical design allows liquids or particulates to pass through easily without collecting at the device or wearing it down. Because there are no edges to maintain with the eTube, it does not need to be inspected or replaced as often as an orifice plate. In most cases, an eTube should only need to be changed once, or sometimes never, throughout the entire life cycle of a well.

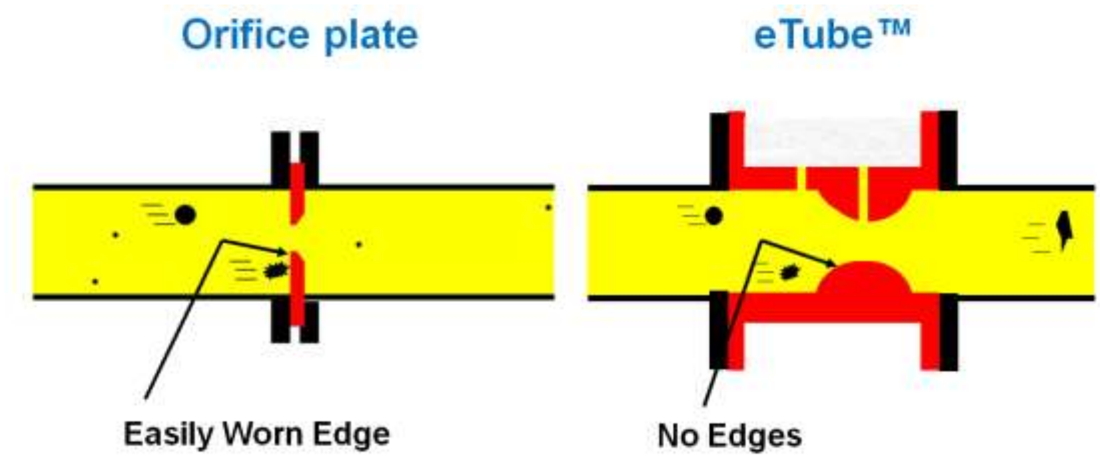

Figure 3: Comparing orifice plate design to the eTube

Using the eTube™

The producer had other wells with higher flow rates, higher sand counts, and more water in the flow. Given all the difficulty experienced with orifice plates in wells with less extreme levels of sand and water, the producer turned to the eTube as a solution to these more extreme applications. The subject well was brought on production with a 2-inch, 600 ANSI-rated flanged eTube with a 0.7 beta ratio and a Smart Alek EFM device. After three days on production, the dump valve on the separator and a flow joint failed due to sand cleaning out, with significant erosion to the piping. The well was shut down for three days to repair the dump valve and flow joint. After coming back online, the well flowed for a mere 16.5 hours before the flow joint had again eroded, downstream of the choke at the first change in direction.

Figure 4: Damaged dump valve removed from pipe

This resulted in the well being down for an additional period of time while the producer changed the downhole configuration. At this point, the producer removed the eTube for inspection, expecting significant wear given the damage incurred to the other pieces equipment. In the time that the eTube had been installed, the severe levels of sand in the meter had chewed out two extra heavy flow joints at the well head and one dump valve (pictured in Figure 4).

When the eTube was removed for inspection, the results were astonishing. After a quick visual inspection, the producer was shocked to discover that the eTube looked as though it could have remained in service with no visible wear or erosion. The only visual difference from an eTube in its original state was an inch-wide strip of rust, most likely due to stagnant saline liquid left in the bottom of the eTube for some period of time after the flow was stopped, and a slightly dulled interior finish.

Figure 5: External condition of the eTube after removal

Figure 6: Internal condition of the eTube with a slight rust strip due to saline liquid stagnation

The producer informed Zedi of the situation, and sent the eTube to Zedi's Edmonton Research Facility for a more detailed inspection to confirm their assumption that the eTube had incurred no significant damage. Measurements were taken by setting a caliper to the inner meter pipe and throat diameters per the manufacturer's specifications listed on the eTube data plate. A dial caliper gage was then set to the spacing of the caliper. The dial caliper gage was placed inside the eTube to check for variances from the listed diameters. Checks were performed at the tap hole locations in various orientations to check for any out-of-round condition. A fixed bore gage was used to check the condition of the tap holes.

Using these methods, no perceptible change was measured in the diameters, and no out-of-round condition was noticed. The fixed gage fit smoothly into the holes, without any wobbling. No significant change was observed on the upstream tap hole, which was visually inspected using a dental mirror. The downstream side of the low pressure tap hole had some minor wear, with a partial bevel formed of approximately 1.5 millimetres in length and 0.4 millimetres in depth. Extensive research by the Yamatake Corporation (the manufacturer of the eTube for Zedi) has shown that light abrasions to the downstream side of tap holes are not enough to affect measurement.

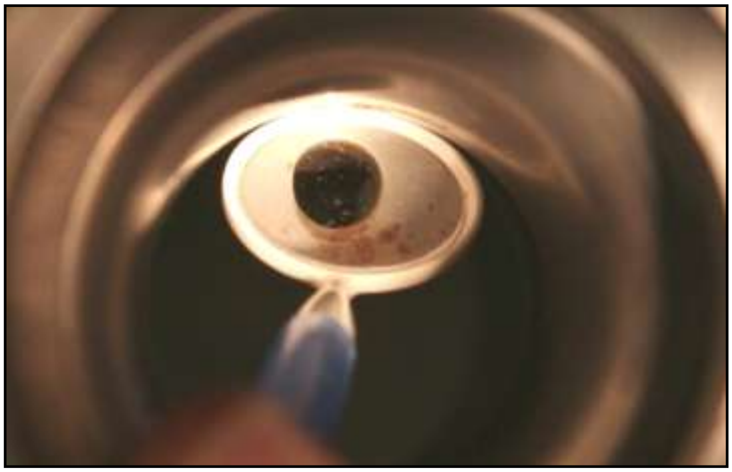

Figure 7: Slight erosion of downstream low pressure tap of eTube

Zedi's inspection confirmed the producer's initial observation: that despite enduring the same harsh conditions that had led to the failure of two extra heavy flow joints and a dump valve, conditions more extreme than those that led to the replacement of several orifice plates, this particular eTube was ready for re-installation as is, and did not need to be removed from the meter run.

The economic difference

The benefit of eTube's unmatched durability is obvious in terms of convenience and measurement certainty. Where once this producer was halting production on a daily basis to change out or inspect orifice plates, they could now leave eTubes in production with confidence in the accuracy of the measurement they were receiving, using the data from that measurement to base critical decisions in their operational processes. The two workers that were being used to change or inspect orifice plates 1.5 hours a day could be deployed in more useful ways, while the lead operator no longer had to worry about constant changes to the orifice size in Zedi's web application, Zedi Access.

The benefits become even more pronounced when the economic difference is examined. The initial capital costs between the eTube and the orifice plate installation fitting are about the same, so it is the additional costs that reveal the benefit.

In these unconventional circumstances, the producer was flowing at extremely high initial production rates, leading to daily orifice plate changes. After the rates declined to more regular levels, so too did the need to replace or inspect orifice plates. To extrapolate the costs for such a production, we'll project this to five orifice plate changes in the first week, followed by a single plate change for the next three.

At roughly $50 an orifice plate, the producer was incurring approximately an extra $250 in the first week on orifice plate costs, or $500 a month. Conservatively estimating the field operator's time at a cost of $100 per hour to the producer, a 1.5 hour installation time with two workers equals $300 in labour costs a day, $1500 a week, or $3000 a month. Lead operator time is a little more difficult to estimate, as not every orifice plate change requires input into Zedi Access (only changes in orifice plate size require updates, thus plates swapped out for the same size would not necessarily require intervention). Using another conservative estimate that a Lead Operator's time is worth $150 an hour and it takes 15 minutes of the Lead Operator's time to log and check the orifice plate changes, that calculates to $175 a day. Assuming that the Lead Operator has to perform this function at least once a week, this equals another $400 a month in labour costs and lost time opportunities on more value added activities.

The chart below summarizes the additional costs that could be incurred by using orifice plates in these extreme conditions that can be avoided by using the more durable eTube.

Cost	Per Day	Per Week	Per Month
Orifice Plate	$50	$250	$500
Field Operator	$300	$1500	$3000
Lead Operator	$175	$175	$400
Total	$525	$1925	$3900

Figure 8: Additional costs avoided with the eTube

Along with these fixed costs, there are also considerations to be made for the economic benefit to be had from the reliability provided by the eTube's superior design. Because the orifice plate has a flat upstream surface, more liquids and particulates can collect at its base, affecting the flow pattern and measurement results. Its sharp edges and flat surface are more susceptible to damage than the eTube, which conditions and allows particulates to pass through easily, reducing damage and maintenance to a minimum. As edges of the orifice plate become damaged or worn down, the fixed size that is to be used to determine flow rate is changed.

In the case of this producer, the risk to the gas measurement accuracy was minimized due to their frequent orifice plate inspections and/ or changes. However, if a producer is less diligent in managing their orifice plates to keep up with changes in declining flow rates and in beta calibration, or if the producer fails to log the changes of orifice plate size into the web application, the effect on the data is significant.

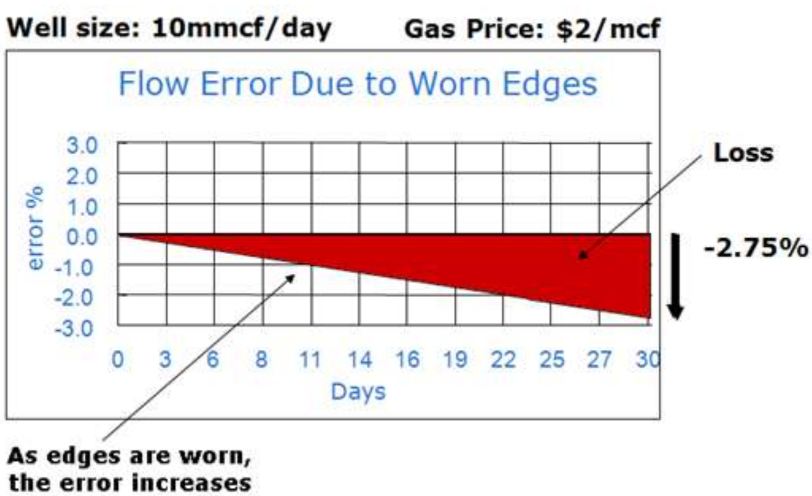

Figure 9: An example of flow error due to worn edges of only 2.75% under-reading

An orifice plate with an edge worn down by only one millimetre will see a cumulative drop in measurement accuracy of 2.75% over the course of a month. If that plate is measuring a well flowing at 10mmcf/ day (such as the ones at the site of this study), and gas is selling at $2/ mcf, then a producer would potentially experience an under-reading of $16,500 after one month of production. This is using an under-reading rate of 2.75%, which is conservative. The

ERCB’s *Directive 046 – Production Audit Handbook* indicates that the measurement impact of a dull edge on an orifice plate is -12.7%, which would be catastrophic to data capture and further reporting. The ERCB’s Enhanced Production Audit Program (EPAP) requirements are now putting increased focus on controls and measurement practices producers and their executives are going to be required to sign off on.

Alongside the substantial risk to loss of income, producers relying on the data produced by the orifice plate would be basing their exploitation strategies on potentially inaccurate measurements. For instance, if the producer initiated changes to the fracture strategy, they wouldn't know how those changes actually affected the production rate if the measurements they based those decisions on were incorrect. Going forward, frac procedures may be deployed in a wasteful manner, adding further unnecessary costs to the operation as a result of using the wrong tool for measurement.

Summary

Of course, this is an extreme example that many producers may never encounter. However, the fact that the eTube withstood punishing conditions that ruined two extra heavy flow joints and a dump valve, conditions more severe than those that required constant orifice plate changes, speaks well of its ability to withstand more conventional environments that producers routinely experience.

With the move toward more unconventional gas sources such as shale gas, producers may also need to move away from conventional methods of gas metering. As shown above, use of the industry’s traditional orifice flowmeter element can be a poor solution to the harsh conditions presented by unconventional shale, resulting in constant interruption, unnecessary labour, and additional expense. Instead, these extreme conditions call for the durability offered by Zedi’s eTube, whose innovative and proven design allows it to withstand punishing circumstances while providing accurate and critical data.

For more information on the eTube, please visit http://www.zedi.ca/products_services/product-etube.asp