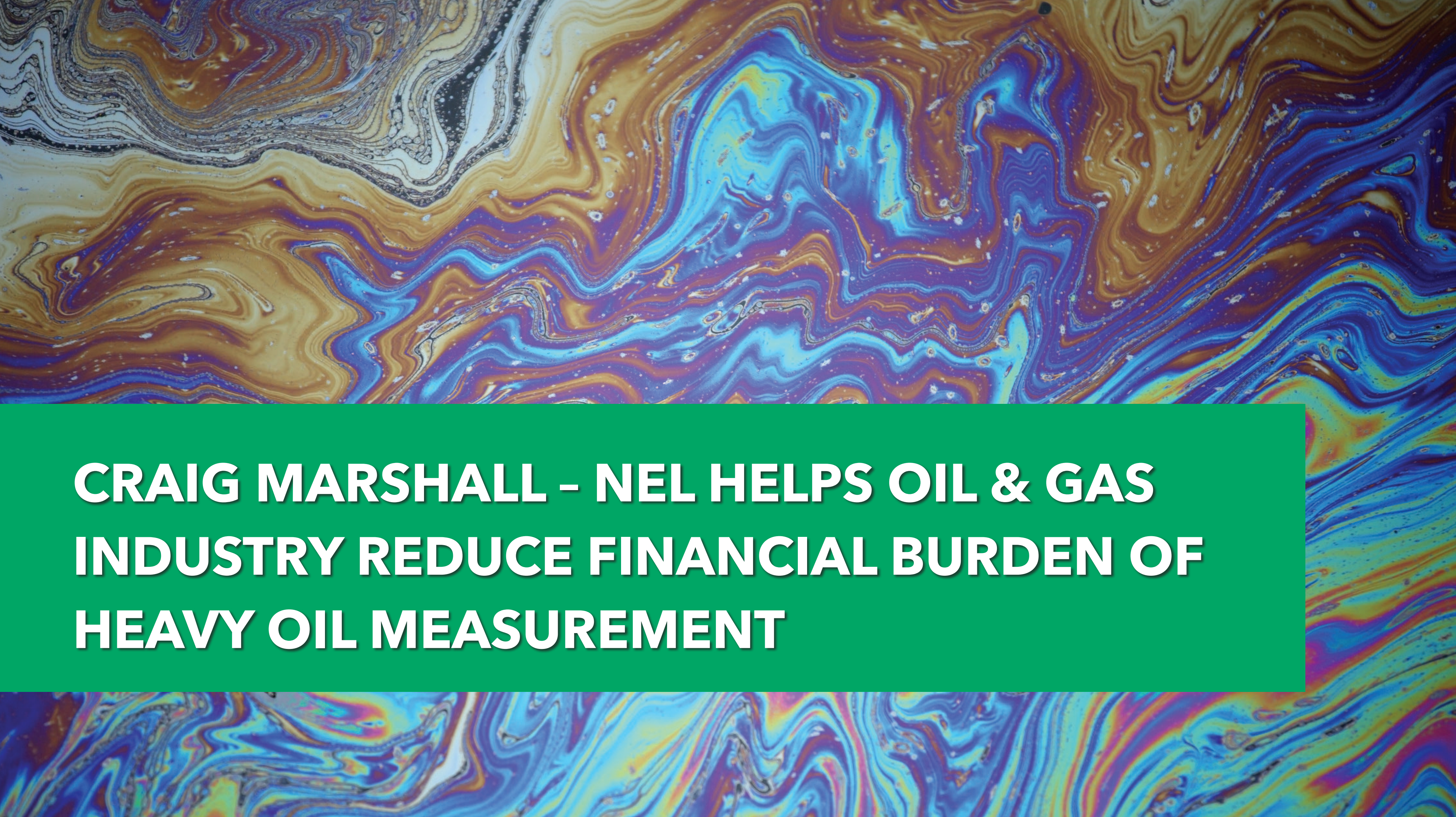

CRAIG MARSHALL – NEL HELPS OIL & GAS INDUSTRY REDUCE FINANCIAL BURDEN OF HEAVY OIL MEASUREMENT

Reynolds number, a dimensionless number used in fluid mechanics to indicate whether fluid flow past a body or in a duct is steady or turbulent, has long had an impact on the oil and gas industry. NEL, formerly the National Engineering Laboratory, has recently announced a new real-time measurement method for Reynolds number which they hope will reduce the financial burden of the measurement of heavy oil. PIN Editor Rachael Simpson spoke to NEL flow measurement engineer Craig Marshall about this new development, and what it means for the industry in years to come.

Rachael Simpson

1. Let's imagine that our readers are new to the concept of Reynolds number – can you explain what it is, and how it relates to the oil and gas industry?

Reynolds number is one of the fundamental things that we use in flow – it describes the nature and mechanism of how a fluid flows within a pipe. If it has a very low Reynolds number, roughly below two thousand, then it's classed as laminar flow and the flow is parabolic in shape in terms of its velocity profile; it moves faster in the middle of the pipe and slower at the outside walls. This is because of the frictional effects within the fluid itself.

If you increase the Reynolds number you go through a period of transition until you get to the other type of fluid mechanism called turbulent flow, normally around 4,000 or 5,000 and above. That is characterised by, as you would expect, a lot of turbulent eddies and also by a flattened velocity profile, where the viscous effects in the fluid itself don't have as great an impact as they do in laminar flow.

The vast majority of flows in oil and gas are in the turbulent region, more like gas or water - think light oils with low viscosity. The Reynolds number itself is a non-dimensional parameter which is a ratio of the inertial forces against the viscous forces. Depending on which force dominates, inertial or viscous, it dictates which type of flow is present. So, if inertial forces are dominant, the forces which drive the fluid down the pipe, such as momentum, velocity, mass and density, then that gives you turbulent flow. If more viscous forces dominate then that moves you more towards the laminar flow region.

In the current industry, as I've mentioned, the majority of fluids are flowing in the turbulent zone and are very much up into the millions of Reynolds number, or the high hundreds of thousands, whereas laminar flow tends to be very low, below two thousand. You start to see some effects below one hundred thousand or so and that's where the viscous forces start to not be insignificant compared with the inertial forces. As you go further down in Reynolds number, the frictional viscous forces become more and more dominant and this changes the way the fluid itself flows in the pipe. This can have a big effect on measurement technologies.

With changes in the oil and gas industry, in the future we will see a lot more heavy oil being produced – statistics show that seventy percent of the world's remaining oil reserves that have been found are classed as heavy oil, the highly viscous kind. I think we are going to be seeing flow in the laminar region where the viscous forces are dominant more readily.

2. Why does heavy oil compose such a large amount of remaining global reserves?

I'm not sure why when it's formed it forms a more viscous oil, but I do know that it's a lot easier to produce the lighter, more conventional fluids, and it's cheaper too as well. Over the past hundred years or so companies have been looking at the more conventional oils because it's easier to produce.

We will get to the point with increasing energy demands that the focus will be more on the reserves we have left, which will be heavy oils. In terms of why it's heavy, that's more a question for a geologist!

3. How have Reynolds numbers traditionally been measured in the oil & gas industry?

Well, they haven't really been measured at all. The calculation of Reynolds number, the most common type, is involved in a measurement of the velocity or flow rate in some respect, either volume or mass in order do the calculation. If you know what the Reynolds number was you wouldn't really need the flow meter to begin with.

You find in turbulent flow that things tend to be a bit more linear, they don't really change with large variations of Reynolds number. You can do a calibration of a flow meter over a velocity, flow, or volumetric flow rate range, rather than Reynolds number, and it wouldn't have a great effect on the overall result because the performance index (the K-factor, discharge co-efficient or meter factor for example) ensures that we know that at a particular flow rate the correction factor can be applied to the measured result, and should bring it up to what the calibrated reference value should be.

In high Reynolds numbers it tends not to be an issue as there's not very much variation with a changing Reynolds number so you can use the frequency output of a meter based on flow rate. The problem is that when you start to produce high viscosity fluids the linearity is no longer there and you'll find that the performance index changes quite dramatically with reducing Reynolds number (see Figure 1 for an 8 inch Venturi). The lower the Reynolds number, the greater the impact with a change in discharge coefficient of over 30% with a relatively small change in Reynolds number. At that point you can no longer calibrate on velocity or flow rate; if you did, and at some point your physical properties changed, if your viscosity increased or decreased or the density varied due to temperature for example, your Reynolds number range would change dramatically and you would therefore end up going outside the range the meter was calibrated under. That's where the errors start to creep in.

4. NEL (formerly the National Engineering Laboratory) estimates that current flow measurement methods could be costing $56 million per year per flow meter – how was this calculated?

NEL have flow facilities to do test work on these technologies, and we have one that we developed back in 2009 , one of the few facilities in the world at an industrial scale that has the capability of measuring fluid flow for fluid viscosity up to fifteen hundred centistokes, imagine honey in a jar, that kind of viscosity. We have the ability to test meters, and in this example we have tested a whole range of eight inch Venturi flow meters. We used the measurement error from those tests to get that value. So for that $56 million per year, if we went down to a Reynolds number of one thousand, and took a fluid with a viscosity of six hundred centistokes, so based on that fluid we can calculate what that flow rate is per year, and assuming an oil price of $40 per barrel and applying the incorrect discharge co-efficient, which would be given by using the standard outside of its applicable range, compared with what is should have been, then the error was $56 million.

5. In response to these inaccuracies, NEL has developed a new flow measurement method for tracking Reynolds numbers in real time – can you explain this method?

We have recently submitted a patent application for our new method. It involves the use of an additional piece of technology or equipment that we can use to make a measurement package, and this is then used to calculate extra bits of information about the flow. Basically, it combines measurement principles for differential pressures, and allows us to calculate through another mechanism what the physical properties and, therefore, the Reynolds number are. This also gives us what the corrected discharge co-efficient should be.

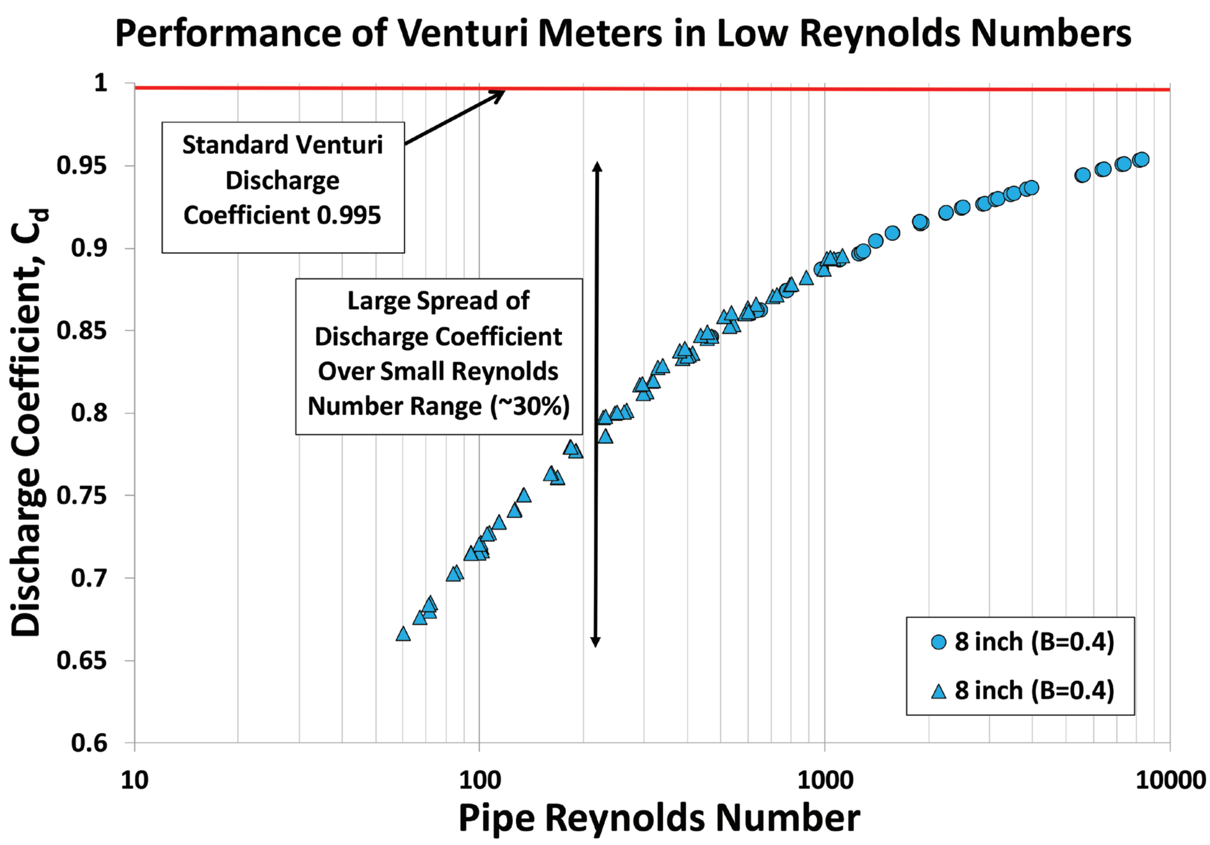

Figure 1: Performance of Venturi meters in low Reynolds numbers

6. To what extent do you hope this will positively impact the oil and gas industry? Is it something that can be rolled out globally?

I think so. There are different applications in flow measurement. You've got fiscal, custody transfer metering, general process measurement, control, and some other applications as well. I think this new method will be more prevalent in general process measurement due to the level of uncertainty it will deliver. I've not done my calculations yet to figure out what uncertainty values I will attain but from our initial testing and proof of concept work it's still a significant improvement on current traditional differential pressure technology.

7. Does NEL plan to expand upon these latest method developments – what is the next project in the pipeline?

We are looking to do more with it. Currently, the majority of meters will have a Reynolds number effect, so if you don't know what the Reynolds number is there will be a small error involved in the measurement. There is one meter type that can work quite well with this called a positive displacement meter, but they can be fairly expensive and quite bulky. Other meters include ultrasonic and Coriolis meters that still have a Reynolds number effect but it tends not to be as great as in differential pressure meters. However, they are more expensive as well. You'll get differential pressure meters very cheaply, perhaps only a few hundred pounds, whereas ultrasonic or Coriolis may be a few or tens of thousands of pounds. That's one of the big advantages of using differential pressure meters.

What I am planning to do in the future is speak with industry, both end-users and manufacturers and a range of other people, to see what the interest is in this technology, and to see if it's worthwhile exploring it in more detail. I am also doing a doctorate, and this is the main aspect of the project. I'm very interested in what people think about this topic and whether they would be willing to share their experience in terms of industry appetite, market size or any other comments on the technology.
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