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DIFFERENTIAL PRESSURE (Δp) MEASUREMENTS USING A QUARTZDYNE TRANSDUCER

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INTRODUCTION

Determining the differential pressure (*Δp*) between two fluid sections is particularly valuable in various downhole measurement and control applications. The downhole flow calculation through a flowmeter requires a *Δp* measurement, as does controlling the *Δp* between the tubing and the annulus in drilling applications. The pressure difference between two Quartzdyne absolute pressure transducers is often used for critical downhole *Δp* measurements.

Most of our customers currently use two of our transducers to measure *Δp*. Presumably, the cumulative long-term drift occurring in the two transducers limits this approach. Drift between two gauges can be offset by periodically zeroing the two gauges, which requires shutting-in the well. In late 2000, we reduced the long-term drift by four to tenfold, and we continue to dedicate significant resources to eventually eliminate drift. This stability improvement allows for long-term *Δp* accuracies and less frequent rezeroing of transducers. This technote addresses the feasibility of using a single Quartzdyne® Pressure Transducer to measure a *Δp*, completely avoiding the drift issue altogether.

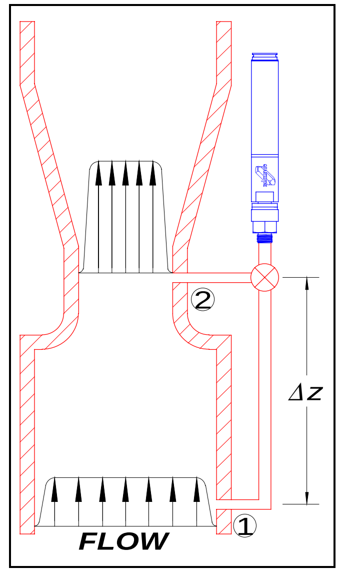

Figure 1: Venturi Flow Meter

The quartz pressure-sensing crystal housed inside a Quartzdyne® Pressure Transducer is well suited to measure a *Δp* as a standalone unit. In Figure 1, a venturi meter using a single pressure transducer to measure the inlet and throat pressures is depicted. Best accomplished by actuating a valve between the two fluid regions, a single Quartzdyne® Pressure Transducer provides several benefits over using two absolute pressure transducers:

- Achievable *Δp* accuracy of < 0.1 psi [690 Pa] (based on ≤ 5 psid tests)
- Resolves *Δp* measurements as small as 0.005 psi [34 Pa]
- Negates the effect of transducer drift
- Improved downhole flow (less constrictive Venturi construction)

EXPERIMENTAL DETAILS

In order to demonstrate the effectiveness of using a single Quartzdyne® Pressure Transducer, we designed a laboratory experiment to demonstrate the sensitivity and repeatability of our transducers to small pressure differentials.

We approached the test by selecting three different transducer designs (1.00” QH, 0.88” QM, and a 0.75” SXP), each having an installed bellows. All three transducers were previously calibrated to 16,000 psia [1100 bar].

Small pressure steps were generated by adding/removing small masses to/from a DH Instruments Deadweight Tester (DWT). A Theta Systems automated screw press maintained the float level of the weights spinning on the DWT using the feedback control on the DWT’s piston position sensor. (The NIST-traceable certification on the DWT specifies an accuracy within ±0.01% of the pressure reading, which is ±1.0 psia [±6.9 kPa] at 10,000 psia [689 bar].) Pressure steps of 0.5, 1.0, 1.5, 2.5, and 5.0 psid [3.4, 6.9, 10.3, 17.2, 34.5 kPa] were performed several times, to establish the repeatability of each measurement. During the experiment, the temperature around the transducers was held constant at 174.803 ± 0.005°C (346.645 ± 0.009°F) by a Hart Scientific liquid bath.

Figure 2: Three transducers, nominally at 10,000 psi [689 bar] and 175°C [350°F]. Positive and negative pressure steps of 0.5, 1.0, 1.5, 2.5, and 5.0 psid [3.4, 6.9, 10.3, 17.2, 34.5 kPa] at 1 minute intervals are shown.

Figure 3: Continuation of test in Figure 1. Positive and negative pressure steps of 2.5 psid [17.2 kPa] at 10 minute intervals over a 5 hour period is shown.

Figure 4: Following an extended period of drift at constant pressure and temperature, positive and negative pressure steps of 2.5 psid [17.2 kPa] at 1 minute intervals were repeated.

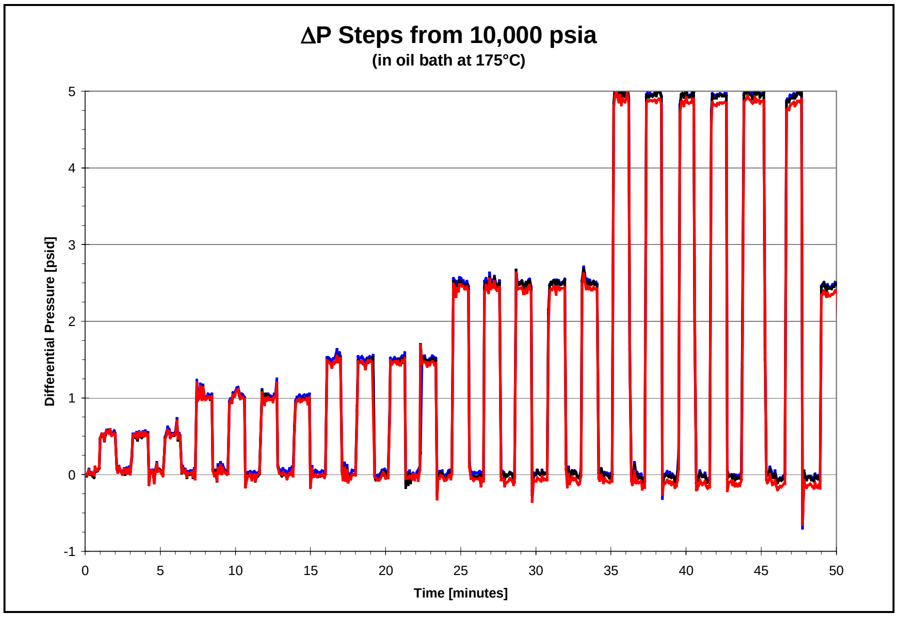

Figure 2

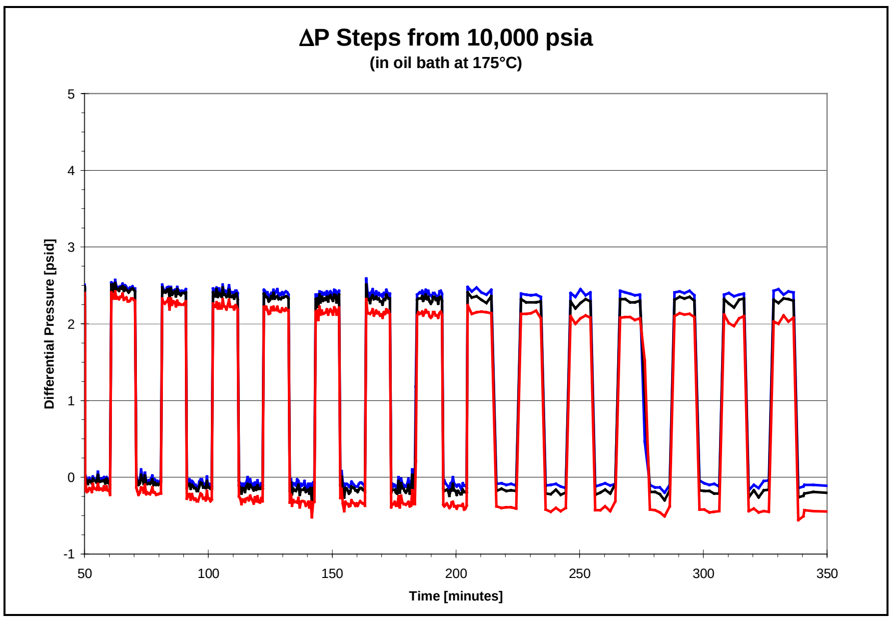

Figure 3

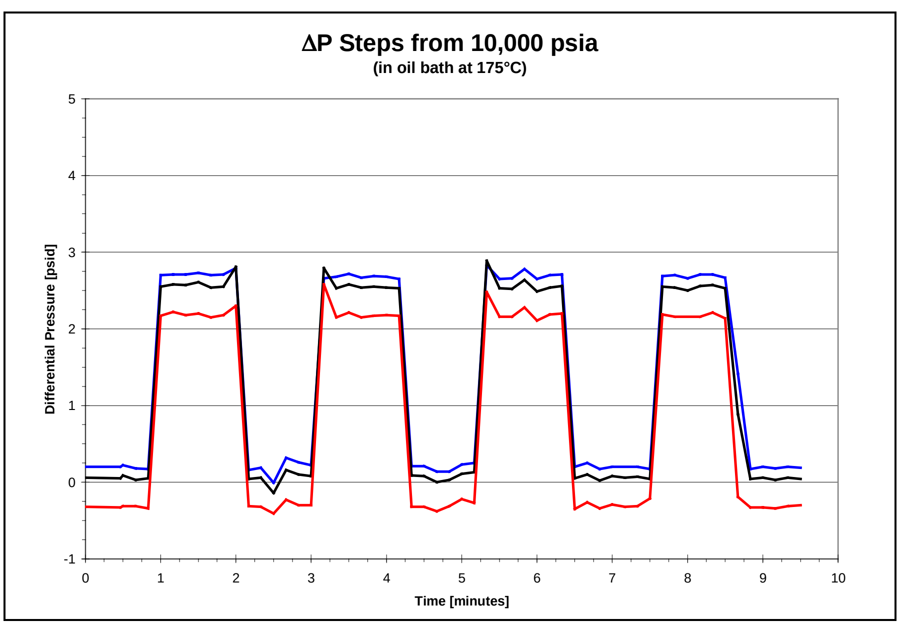

Figure 4

RESULTS AND CONCLUSIONS

Interpretation of the data proved challenging due to system noise. We discovered that our transducers were very sensitive to the 0.1 psi [690 Pa] noise throughout the testing. (Although a 0.1 psi noise band is negligible on a full scale pressure reading of 10,000 psi, it significantly affects a 2 psi Δp.) There were two sources of pressure noise: (a) oscillatory noise arising from an acute imbalance of weights spinning on the DWT, and (b) random noise generated by the screwpress' periodic adjustments to maintain the float level. However, all three transducers agreed remarkably well with each other. The three transducers reported system noise (micro pressure pulses) at the same time with similar magnitudes.

We concluded to analyze the data using two methods. First, for each transducer, we averaged the measurements during each interval, and calculated the Δp as the difference between those averages. Unfortunately, this approach produced Δp accuracies nearly as poor as the system noise band, as shown in Table 1.

Table 1: Δp Measurement Results

(Data smoothed to reduce noise.)

Δp psid [kPa]	Max. Measured Error psi [Pa]	[% of Δp]
0.5 [3.4]	0.033 [228]	6.6
1.0 [6.9]	0.060 [414]	6.0
1.5 [10.3]	0.067 [462]	4.5
2.5 [17.2]	0.056 [386]	2.2
5.0 [34.5]	0.048 [331]	1.0

For our second approach, we applied a method that filtered out the system noise. We theorized that a coincident response in all three transducers was a valid indicator of pressure noise. Therefore, by averaging the transducer responses together, and then comparing each transducer to that average, we succeeded in eliminating most of the noise from the Δp calculation, as shown in Table 2:

Table 2: Δp Measurement Results

(Data filtered to eliminate noise.)

Δp psid [kPa]	Max. Measured Error psi [Pa]	[% of Δp]
0.5 [3.4]	0.008 [55]	1.6
1.0 [6.9]	0.005 [34]	0.5
1.5 [10.3]	0.010 [69]	0.7
2.5 [17.2]	0.010 [69]	0.4
5.0 [34.5]	0.005 [34]	0.1

A close inspection of Figure 4 reveals that each transducer varied in drift over time. However, we observed that drift did not affect the transducers ability to accurately and repeatably measure Δp over an extended period of time. The explanation: drift in a quartz pressure crystal causes a permanent offset in frequency, but drift has negligible effect on the sensitivity (scale factor) of the pressure crystal. We believe this to be the strongest argument for using a single Quartzdyne® Pressure Transducer to measure Δp.