Gauge Selection for Pressure Transient Testing

Strain Gauge vs. Capacitance vs. Quartz

When conducting pressure transient tests (PTA) on high permeability reservoirs or for diagnostic fracture injection tests, the importance of pressure gauge quality cannot be overstated. There are three primary considerations in gauge selection:

1. resolution
2. sample rate
3. thermal response of the gauge.

The three major classes of gauges used in PTA testing are strain gauges, quartz capacitance and quartz crystal gauges. Strain gauges are popular because of their very low costs compared to quartz gauges. The cost ratio can be greater than 10 to 1. Strain gauges are basically non-conductive surfaces or membranes onto which a conductive pattern has been applied. When pressure is applied to the surface opposite the conductive pattern, the conductive pattern is distorted or "strained" which causes its resistance to change.
The change in resistance is proportional to the applied pressure. The simplicity of the system leads to its relatively low cost. However this type of gauge has low resolution (0.5 psi) and is difficult to compensate for changes in the temperature of the gauge elements. Additionally strain gauges are slow to respond and stabilize to pressure changes so the accompanying electronics are rarely capable of sampling at the 1 second sample rates that are essential for high permeability reservoirs and frac design.

Quartz gauges utilize quartz as the active sensing element because it is the most nearly perfectly elastic material known. The technical definition of elastic is that for an applied stress or pressure, the quartz sensing element will always give the same distortion or strain. The stress/strain response is repeatable over an almost infinite number of cycles. There are two main classes of quartz gauges, the capacitance gauge which relies on the mechanical properties of quartz and the resonant gauge which relies on the electrical as well as the mechanical properties.

Quartz Capacitance gauges utilize parallel plates with conductive surfaces. One of the surfaces is subject to external pressure which results in a reduction in the capacitive gap. The resultant capacitive change is converted into a frequency that is proportional to the pressure change. If the reactive plate is a fused quartz element with a conductive surface, the gauge will exhibit much better repeatability than the same design gauge with a simple metal reactive plate. Quartz capacitance gauges have much better resolution (0.1 psi) than strain gauges but are also difficult to thermally compensate.

Quartz Crystal gauges, also called Quartz Resonators, are the most accurate electronic transducers and the best of them are classified as “Secondary Standards”. A secondary standard can be used as a substitute for a high precision laboratory Dead-Weight Tester. The quartz crystal resonator will generate a frequency that is proportional to the applied force or pressure. Quartz crystal gauges can deliver 0.01 psi resolution and when built with dual quartz crystals can also provide the most effective temperature compensation of any class of pressure gauge.
As the illustration shows, the dual crystal quartz gauge employs one quartz crystal to only sense pressure while the second quartz crystal only senses temperature. The two crystals are embedded in close proximity to one another the same module so that the temperature of the two crystals are nearly identical and change in unison. The temperature crystal output frequency is used to compensate for thermally induced changes in the pressure crystal output frequency. The design of the dual quartz crystal resonator gauge requires sophisticated electronics which contributes to the cost of the gauge but it also allows one second and faster sampling frequencies.

When selecting a pressure gauge for a PTA test or pre-frac test, the cost of the gauge is only a fraction of the total cost of all other equipment required at the well site during the test. Even more important, the cost of incorrect interpretation of reservoir properties as a result of poor quality data can be catastrophic. Considering the consequences of poor quality data, it is logical to always select the dual quartz crystal gauge. However, it is important to always keep in mind that the suppliers of each class of gauge described above, can and do describe their gauges as quartz.

If the strain gauge uses a quartz substrate as the non-conductive element in the sensor, the manufacturer describes his gauge as "quartz". If the capacitance gauge supplier utilizes a fused quartz substrate as the sensing element, they also describe their gauge as quartz. It is important to keep in mind that all "quartz" pressure gauges are not equivalent and that only the dual quartz crystal resonator satisfies the PTA test requirements of high permeability reservoirs or pre-frac injection tests.