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RECENT IMPROVEMENTS TO MAKE QUARTZDYNE® PRESSURE TRANSDUCERS MORE RUGGED

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I. ABSTRACT

Since 1991, Quartzdyne has been manufacturing various models of quartz pressure transducers for the downhole market. Known for their durable construction, our pressure gauges have been used during perforating shots and even in MWD (**M**easurement **W**hile **D**rilling) applications.

After diagnosing the failures encountered in severe shock and vibration applications, Quartzdyne developed an extremely ruggedized Series QU, which has the following features:

- Stiffer mounting joints in temperature and reference crystals.
- Encapsulated wires to prevent movement (work hardening) and subsequent breakage of wires.
- Full length, edgewise support of the circuit board, preventing out-of-plane flexing.

II. TEMPERATURE AND REFERENCE CRYSTALS

The majority of the improvement arises from toughening the mounting joints within the temperature and reference crystals. As illustrated in Figure 1, a thin quartz resonator is mounted via four V-clips. An electrically conductive adhesive is responsible for making contact between the V-clip and the quartz resonator: two of the joints are necessary for oscillation, while the other two are for structural mounting only.

For many years, these TO-5 packaged crystals have served as a “shock detector” in the pressure transducer. A small percentage of downhole transducers are returned with broken temperature and reference crystals, but these returned units often have other structural damage (i.e., sheared screws, twisted rails, deformed metal). These symptoms generally indicate severe transducer abuse.

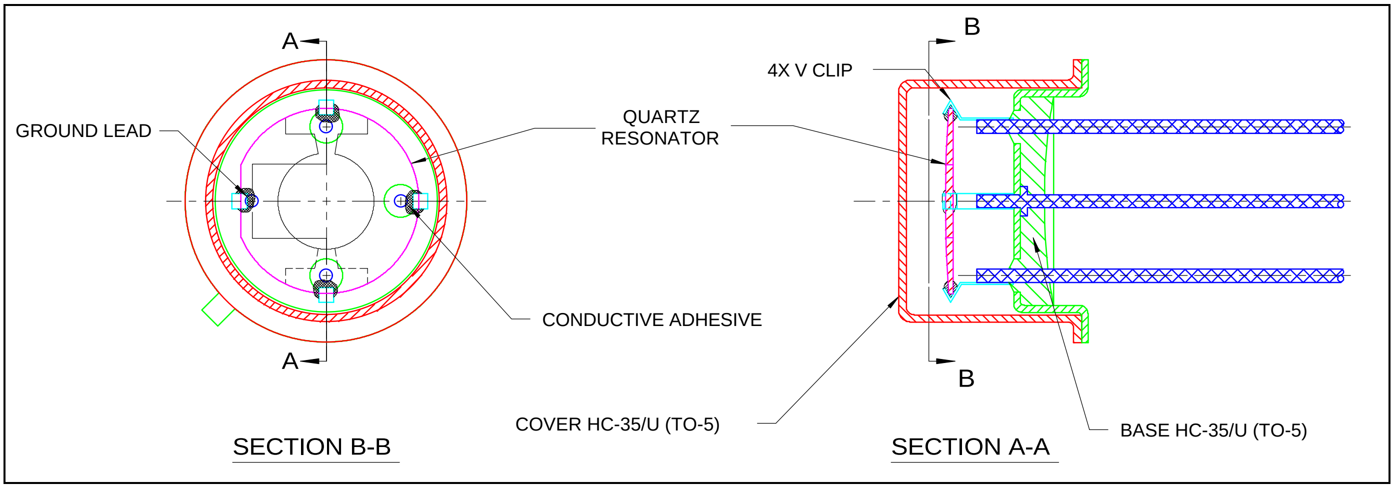

Figure 1: Cross Section of a Temperature or Reference Oscillator Crystal

In order to reduce, or possibly eliminate, temperature and reference crystal failures, we created a destructive test to qualify and quantify proposed improvements to the crystals. In Figure 2, we modified our drop stand to hold nine crystals simultaneously in a cube. The testing apparatus shown in Figure 2 was placed directly on a concrete floor. The fixture was allowed to drop directly onto a 2" thick aluminum plate with no padding.

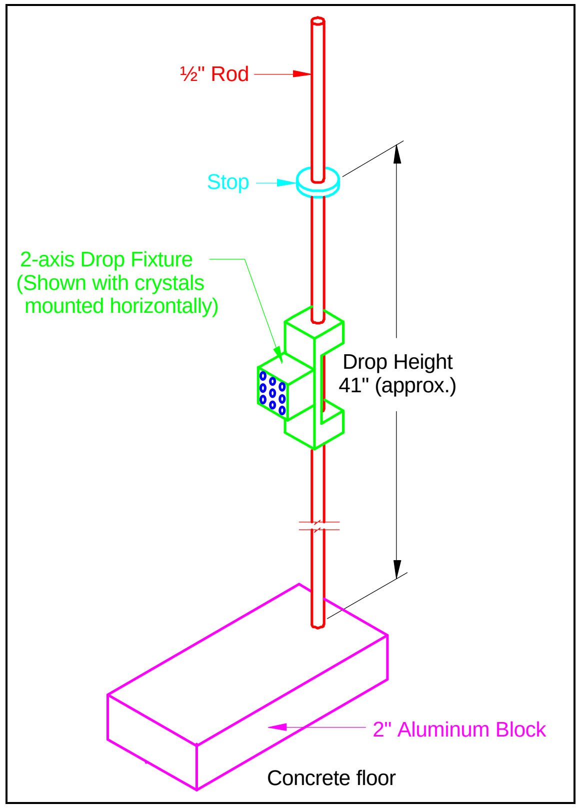

Figure 2: Drop Stand for Shocking Crystals

The resulting high frequency, metal to metal, impact-type shocks were not measured using an accelerometer, because it proved to be inadequate in this application. The accelerometer actually broke after several drops at approximately 6 inches! Prior to failing, however, its signal clipped at 10,000 g! After discarding the accelerometer, we set the drop height to roughly 41 inches. At this height, we estimate several hundred thousand g's are transferred to the crystal.

In order to establish the nominal shock resistance baseline of crystals manufactured throughout the 1991 - 1996 timeframe, we selected both temperature and reference crystals from past lots. After scanning the crystals using an HP 3577A network analyzer, 25 drops were delivered to each crystal, each shock taking place parallel to the surface of the quartz resonator. The crystals were tested between each sequence of 25 drops. Failure criteria was based on a significant increase in impedance.

In Figure 3, the "Rec'd < 5/98" bar (red on color copies) indicates the results, showing that over half of these old-style crystals had failed by the first 25 drops, and another 25% had failed by the second 25 drops! There was, however, a very small percentage that survived over 100 drops. The data was sorted according to the lot date code, and according to the crystal type, but neither correlated with crystal robustness.

Upon opening the failed specimens, we overwhelmingly observed cracked adhesive between the V-clip and the resonator. Furthermore, when comparing the three best crystals (100+ drops with no failure), with the three worst crystals (<25 drops to failure), it was very apparent that the quantity and quality of conductive adhesive over the joint is <u>absolutely critical</u>. Those crystals that survived had an adequate amount of adhesive over the joint, while those crystals that failed early exhibited only a very small amount of conductive adhesive over the joint. See the comparative photographs shown in Figure 4 and Figure 5.

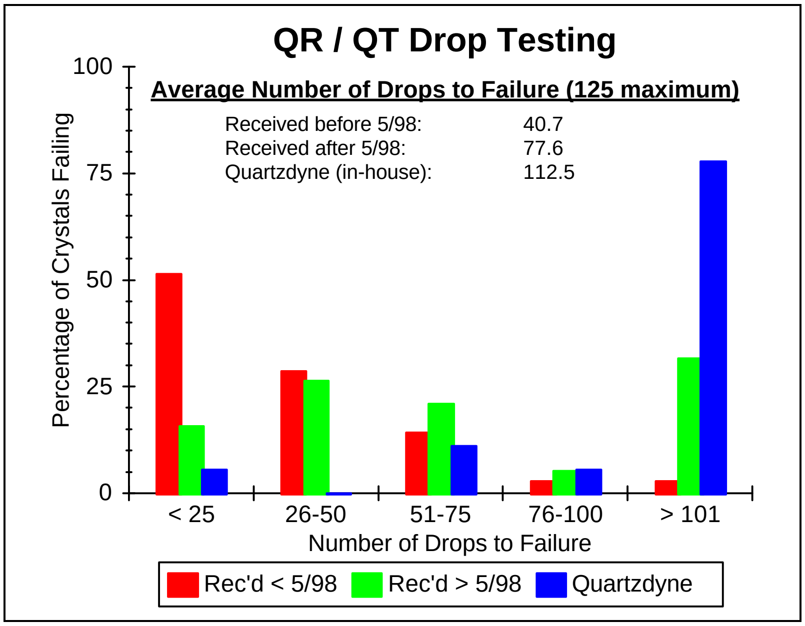

Figure 3: Drop Testing Results

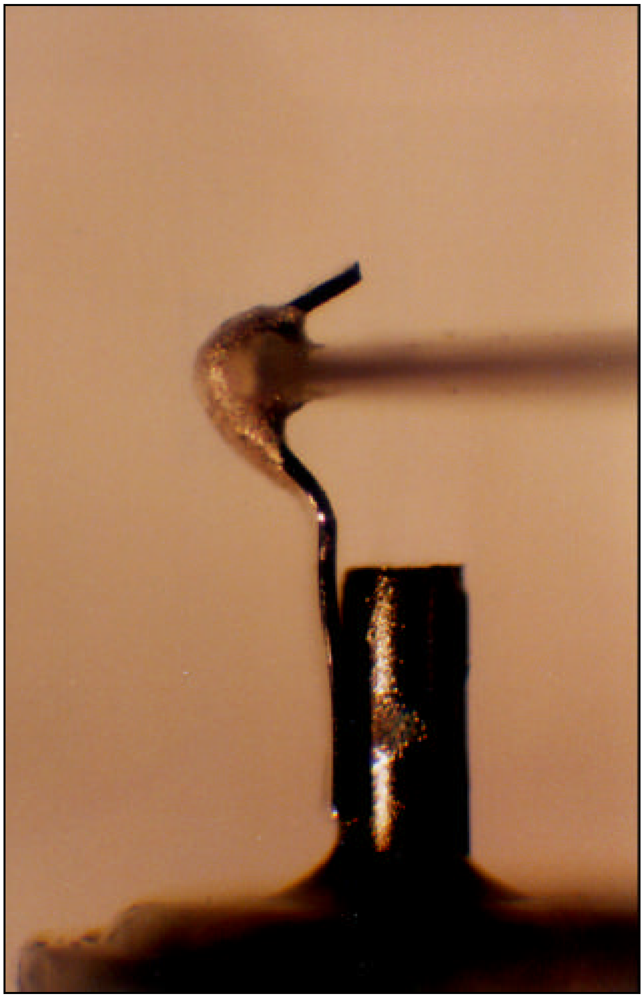

Figure 4: Photograph of side view showing adequate adhesive fillets.

Figure 5: Photograph of side view showing insufficient adhesive.

In order to achieve more uniform, high end results, Quartzdyne drafted a workmanship standard in April 1998 to govern the physical appearance of the internal joints in the temperature and reference crystals. Preliminary lots provided to Quartzdyne based upon this workmanship standard showed an average improvement of 90% in the average number of drops a canned crystal will withstand before failure. These crystals are shown as “Rec’d > 5/98” (green in color copies) in Figure 3.

Quartzdyne has recently brought the capability of manufacturing temperature and reference crystals in-house. Additional process changes in the construction of these crystals has led to the results shown as “Quartzdyne” (blue in color copies) in Figure 3. We were able to accomplish this improved robustness without sacrificing any long-term aging of the temperature and reference crystals.

The “Rec’d > 5/98” (green) crystals are currently incorporated into all standard Quartzdyne® pressure transducers, and are adequate for normal wire-line and permanently installed applications. The “Quartzdyne” (blue) crystals are included in selected units upon request, where an extreme shock and vibration environment is expected (see Appendix).

III. ENCAPSULATION OF WIRES

Another contribution to the ruggedness of the Series QU pressure transducer is to capture the wires and prevent their movement.

Whenever a soldering operation takes place with insulated stranded wires, the solder wicks up the strands a short distance. The solder robs the wire of its flexibility, and if allowed to vibrate, the wire will break. On the ruggedized version of the Series QU, we have captured the soldered wires using an elastomer potting material, or heat shrink tubing.

IV. CIRCUIT BOARD MOUNTING

The final trademark of the ruggedized Series QU is the circuit board mounting scheme. Unlike other versions, which hold the circuit at the ends or at selected locations in the middle, the ruggedized Series QU nestles the circuit in a slot along its entire length (see Figure 6). Conformal coating along the edges and stiff springs located at the ends prevent the board from rattling in the slot. This edgewise support has proven to be superior in severe shock and vibration environments.

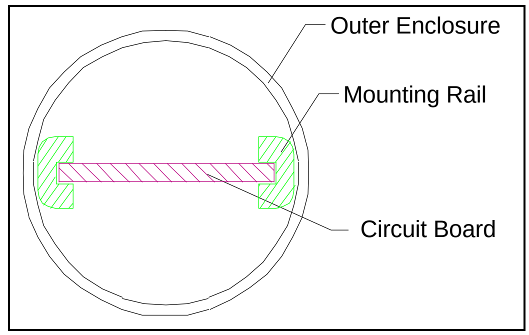

Figure 6: Cross section of circuit mounting

Unfortunately, not all of our circuit boards can be mounted in this fashion. For example the large through-hole components on the Series QL require a wider PC board, which will not fit inside the slots in a 1" O.D. enclosure. Our future high temperature products will include a hybrid circuit, which will have superior shock resistance, due to its small size and mass.

V. APPENDIX

The improvements outlined above have led to the release of the ruggedized version of the Series QU in November of 1998. For our nominal flat rate repair fee, Quartzdyne can upgrade previous versions of the Series QU to the ruggedized version.

The ruggedized Series QU have part numbers in the form of QUy009-zz, where "y" is a "B" for bellows, and "X" for non-bellows. The letters "zz" refer to the pressure range, i.e., "16" for 16,000 psi, "20" for 20,000 psi. Early in 1999, Quartzdyne began identifying the transducer part number on the product to help our customers determine the model version they were receiving. If you are unsure whether certain serial numbers are "ruggedized" or not, provide us a listing of serial numbers, and we will relay this information back to you.

With these improvements, our customers should not interpret that all products except for the ruggedized Series QU are inferior. Prototypes from every transducer design type have passed our standard suite of environmental tests, a copy of which is available on our webpage. This ruggedized version was developed specifically for the most severe and abusive of environments. Even with these improvements, however, the customer should continue to shock mount the transducer, preventing the gauge from banging or hitting any surrounding metalwork.