RUGGEDIZED QUARTZ OSCILLATOR CRYSTALS FOR GUN-LAUNCHED VEHICLES

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Summary This paper describes a small hermetically sealed quartz oscillator crystal assembly capable of withstanding gun-launch accelerations of 30,000 g and some larger experimental units that have survived accelerations up to 70,000 g.

Introduction Harry Diamond Laboratories (HDL) is engaged in the design of high-g telemetry systems for use in research and fuze testing programs. Environments encountered by telemeters in research vehicles, such as those used in the High Altitude Research Probe (HARP) program and its offshoot the Low Altitude-High Velocity (LAHIVE) program, are more severe than those encountered in the fuze testing programs. In the HARP 5-in. gun application, for example, the telemeter must survive a peak launch acceleration of 50,000 g; whereas in the most severe fuze testing program, the survival requirements are approximately 23,000 peak acceleration with a 360-rps spin. The accuracy and stability of these systems have been limited by the performance of conventional LC oscillator circuitry. To improve the performance of high-g telemeters and to meet IRIG telemetry standards on Department of Defense missile test ranges, a program was initiated to ruggedize quartz crystal assemblies.

Method of Testing Survival tests covered in this paper were made by potting the crystals in a test projectile and firing the projectile into a recovery trough filled with a sawdust-styrafoam mixture. Peak accelerations were obtained from standard copper-ball crusher gages. In the 70,000 g peak acceleration test performed in an 80-mm smooth-bore test gun (a rebored 75-mm howitzer), the crystal is g loaded for a period of 2 msec. When fired at 30,000 g, the loading period is increased to about 5 msec.

Techniques Gun-launched tests on commercially available pin-mounted and pressure-mounted crystals indicated that the units could withstand peak accelerations of 1000 to 3000 g. Pressure-mounted units failed because the clamping electrodes were inadequately supported. Pin-mounted units failed because the crystal became detached from its supporting pins. The crystal blanks themselves survived firings up to 14,000 g, however, so it became apparent that survival at higher g levels would be obtained if a more rugged mounting scheme could be devised. The ruggedizing effort was centered around modification of a pressure-mounted unit, since the crystal in this unit is already supported by discs whose surfaces can be ruggedly supported.

In the unmodified CR 24/U-type mounting shown in figure 1, the crystal is placed between two quartz discs and the assembly clamped in an HC-10/U metal holder. The surfaces of the discs are made slightly concave to prevent pressure on the central portion of the crystal. Electrical continuity between the plated electrode on the crystal side of the disc and the plated contact surface on the opposite side is established by plating through a notch in the disc.

In the first attempt to modify the CR 24/U unit, the crystal sandwich was removed from its metal holder and epoxy applied around its edge. Leads were attached with silver paste and the unit was dipped in wax before being potted in a test projectile.[1] The three crystal units on the left in figure 2 illustrate this type of packaging. Thirteen units were fired at 35,000 g and five at 70,000 g without a single failure.

Frequency stability tests at room temperature were made in the 50-MHz oscillator shown in figure 3. The stability of the unmodified units was 5×10^{-4} percent, while that of the epoxy-potted units ranged from 1×10^{-3} to 2×10^{-2} percent. When the oscillator was tested over the temperature range from -40° to +90°C, the maximum frequency deviation with factory-mounted crystals was about 0.004 percent. The epoxy-potted units behaved erratically with temperature and were unable to control the oscillator frequency over the entire temperature range. Their performance at room temperature also deteriorated a few days after potting.

The crystal unit in the extreme right in figure 2 was fabricated by inserting the crystal sandwich in a molded silastic enclosure and sealing the package with epoxy. The temperature characteristics of these units are similar to those of the unmodified units but the series resistance is pressure-sensitive. For this reason, it was necessary to mold the silastic in a metal can, apply pressure to the can until the proper series resistance was obtained, and then solder-seal the can. Only two units were tested at 70,000 g. Both survived but the packaging process was not pursued further because of its complexity.

A screw-adjustable fixture was designed to facilitate the crystal pressure adjustment. In this scheme, the crystal assembly is sandwiched between two pieces of 1/16-in. silicone rubber and placed in an aluminum can. Pressure is then applied to the unit by a screw-adjustable fixture. The complete unit and its frequency-versus-temperature characteristic before and after a 61,000 g gun launch is shown in figure 4. Three of the four units test fired at 70,000 g survived. Failure of the fourth unit resulted from crystal breakage. In a fourth mounting scheme the screw-adjustable aluminum case was replaced with a nylon

[1] HDL Patent Application Number 5795807 filed by Frank Vrataric, Jr.

case of the same dimensions. This unit is shown on the left side of figure 5. Four out of five units tested at 65,000 g survived. Electrode continuity was lost on the fifth unit when the plating chipped in the plating notch. One of the surviving nylon units was potted in the crystal oscillator section of a synchronized 250-MHz transmitter. This transmitter survived a gun launch at 30,000 g and functioned normally during a spin test at 360-rps. The crystal units were rather large, however, so work was initiated to reduce their size.

The first size reduction was achieved by replacing the adjustable nylon pressure cases with modified HC10/U cases. The modification consisted in shortening the can length from 3/8- to 1/4-in. and replacing the top and bottom of the can with 1/16-in. brass discs. This unit is shown on the right-hand side of figure 5. Five units were fired twice at 20,000 g and two units at 30,000 g with no apparent change in electrical characteristics. Six units failed to survive test firings at 65,000 g. Frequency-versustemperature characteristics were obtained on ten units over the temperature range -40° to +90°C. The frequency stability of these units ranged from 0.003 to 0.005 percent. A typical temperature run is shown in figure 6.

Periodic measurements are being made on one of the units to determine whether or not the packaging materials have a deteriorating effect on the electrical characteristics of the crystal. No deterioration has been observed in the ten-month interval that has elapsed since the crystal was packaged.

Final Version Since the 30,000 g test was considered an adequate overtest for our most severe 23,000 g fuzing requirement, a contract was awarded to Midland-Wright to fabricate 110 hermetically sealed versions of this ruggedized package. The Midland-Wright unit is shown in figure 7. In this unit, the plating notch was replaced by a flat surface on the electrode disc and the crystal diameter was reduced from 0.5 to 0.4-in. As shown in figure 8, the complete ruggedized package is slightly smaller than the commercially available CR 24/U unit. Ten units have been received and tests have started. Five out of six units fired at 26,000 g survived with no apparent change in electrical characteristics. Failure of a solder joint in the hermetic seal of the sixth unit resulted in an intermittent contact. The unit functioned normally when the solder joint was resealed. In each of three units test fired at 70,000 9, failure resulted from crystal breakage.

Future plans call for a supplemental effort to improve the mechanical structure of the crystal assembly by replacing the heavy contact assembly with a conducting ribbon. This should permit the unit to be flown at g levels approaching those used in testing the larger screw-adjustable nylon units.

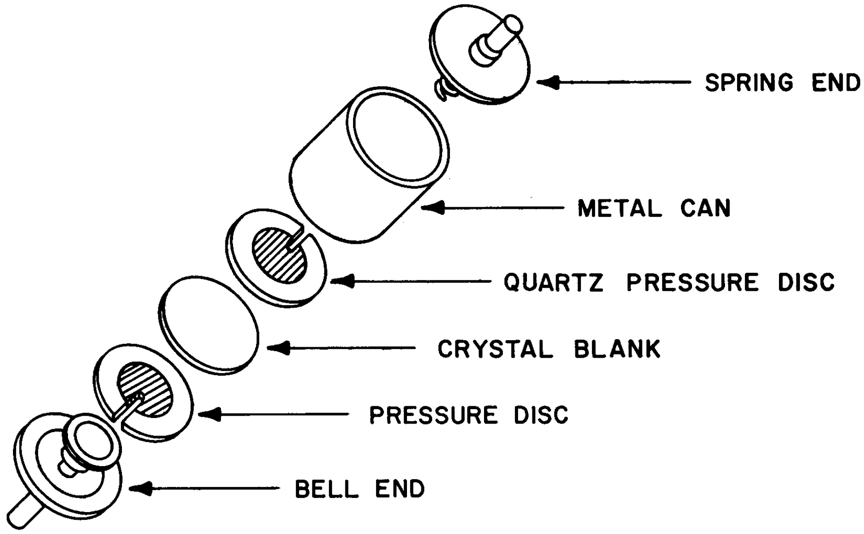

Figure 1 - CR24/U Crystal Unit.

Figure 2 - Epoxy and Silastic Units.

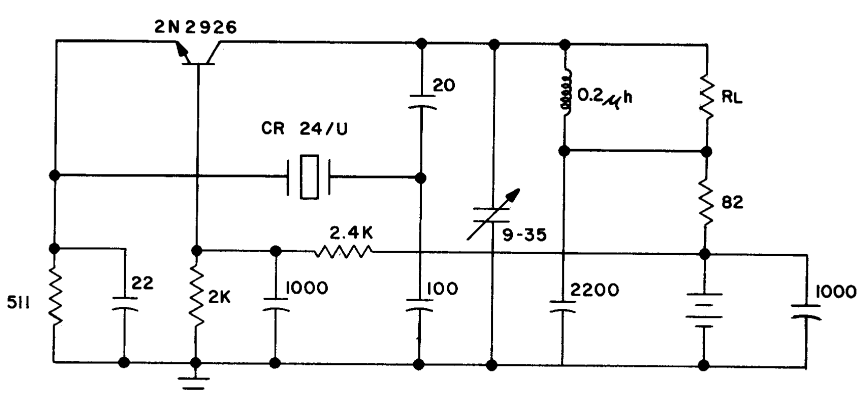

Figure 3 - 50 MHz Crystal Oscillator.

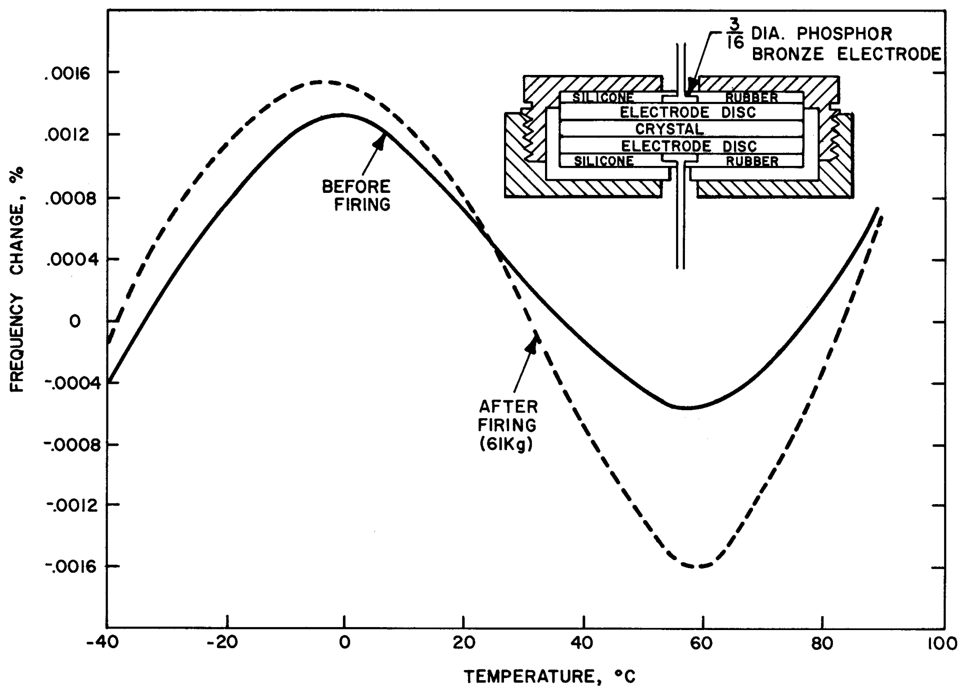

Figure 4 - Adjustable Fixture and Temperature Curve.

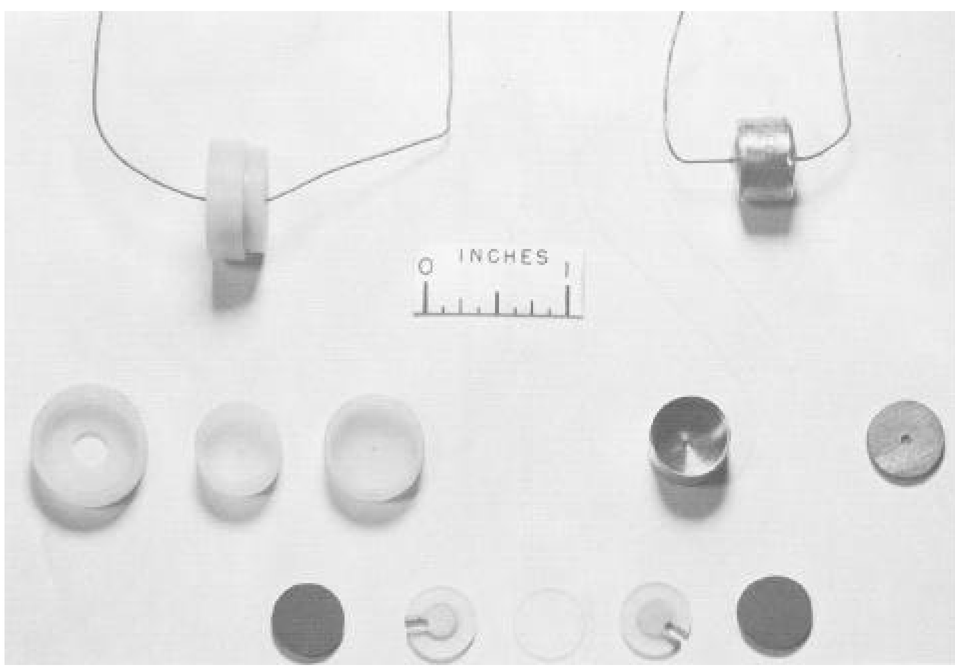

Figure 5 - Nylon and Metal Cased Units.

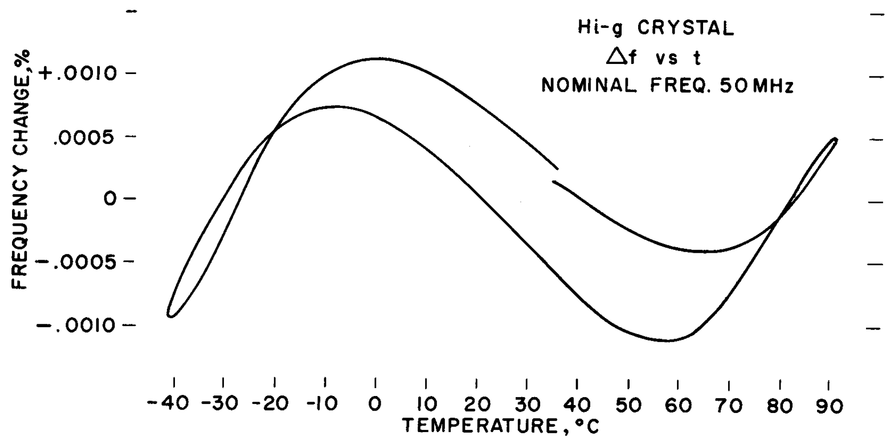

Figure 6 - Hi-G Crystal Temperature Curve.

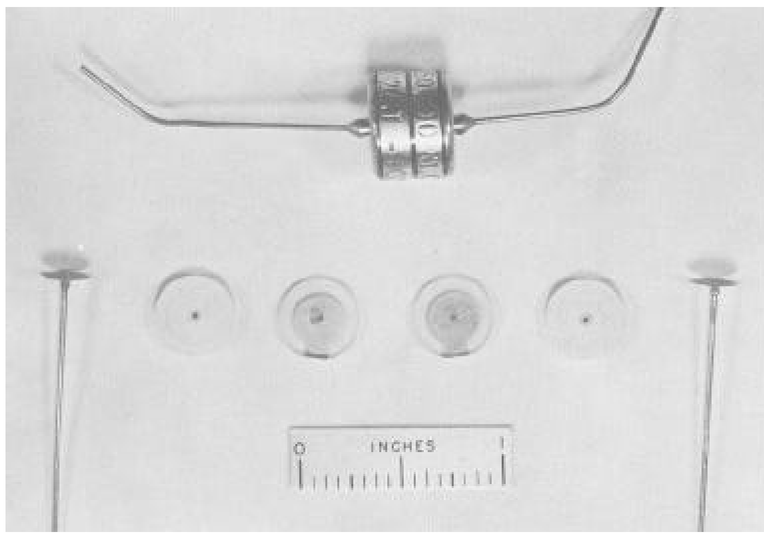

Figure 7 - Midland-Wright Unit.

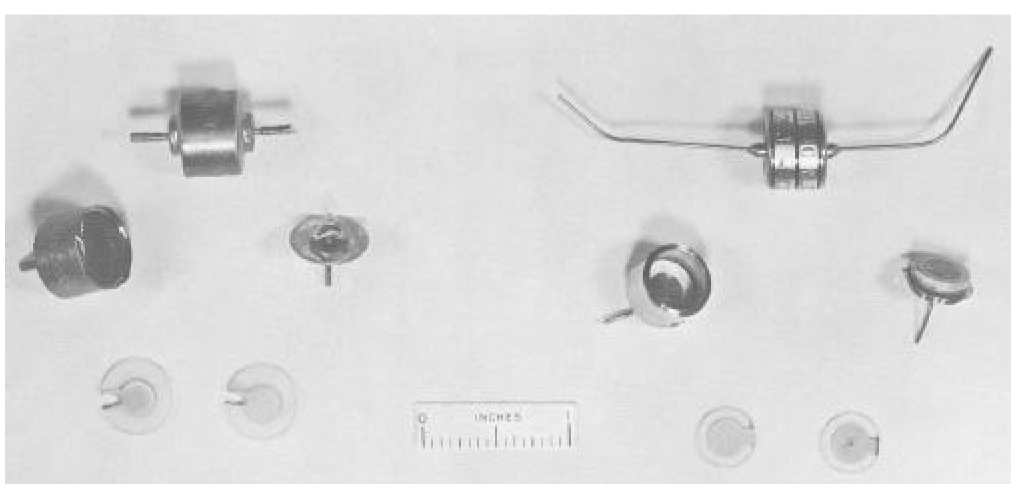

Figure 8 - CR24/U and Ruggedized Crystal Units.