MASTER

FABRICATION OF SHOCK PRESSURE TRANSDUCERS

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UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT** Contract W-7405 eng 26

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Date Issued: July 17, 1969

Document Y-1674

TID-4500

UNION CARBIDE CORPORATION
Nuclear Division

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Contract W-7405-eng-26
With the US Atomic Energy Commission

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ABSTRACT

The strontium, lithium, and calcium transducers, which are the subject of this report, have distinct improvements over the strontium and sodium transducers described in an earlier companion report (Sodium and Strontium Shock Pressure Transducers, Y-1673). Some of the principal changes from the earlier models are: (1) a very thin sensing grid is vapor deposited on the surface rather than forming a metallic grid; (2) the grid is backed by fused quartz rather than beryllium oxide-loaded epoxy; (3) the connecting pins are made of magnesium rather than copper. Other minor improvements were also made.

The changes that were made were intended to improve transducer output, reduce the electrical noise level with respect to the output signal, and improve the shelf life.

CONTENTS

SUMMARY	7
INTRODUCTION	8
FABRICATION AND TESTING OF THE TRANSDUCERS	11
Basic Design	11
Fabrication Environment	12
Transducer Fabrication	12
Transducer Testing	15
Vacuum and Pulse Testing	16
Corrosion Testing	16
APPENDIX A	21
Fabrication Sequence	21
APPENDIX B	23
Initial Transducer Design and Changes	23
APPENDIX C	26
Vacuum Evaporation of the Materials Used in Transducer Fabrication	26
APPENDIX D	28
Pulse Circuit	28
APPENDIX E	29
Corrosion Testing	29
Introduction	29
Corrosion after Fabrication	30
REFERENCES	33

SUMMARY

Transducers have been made of strontium, lithium, and calcium and differ from the strontium and sodium transducers described in an earlier companion report in the following areas: (1) a very thin pressure sensing grid is vapor deposited rather than being of a relatively thick disc; (2) the pressure sensing grid is backed by a layer of fused quartz rather than a layer of beryllium oxide-loaded epoxy; (3) electrical connecting pins are made of magnesium instead of copper; (4) the front of the grid is covered with a two-mil layer of aluminum in place of the copper cap that was used on the earlier models; (5) these transducers are sealed with urethane instead of epoxy.

These design changes were made in an attempt to improve the transducer output, to reduce the electrical noise level with respect to the output signal, and to improve the shelf life.

Very little shock performance data have been obtained to date. The Lawrence Radiation Laboratory indicated that two strontium transducers were shock tested at ~ 10 - 12 kilobars. A commercial quartz transducer indicated 10 - 13 kilobars and the two strontium units indicated 10.8 and 11.9 kilobars.

INTRODUCTION

All materials undergo resistivity changes when subjected to sufficient pressure. Strontium, calcium, lithium, and sodium are only four of numerous materials which undergo significant resistivity changes with pressure and consequently may be suitable for shock pressure transducer use. Figure 1 shows Bridgman's static pressure calibration results for these four metals. (1,2) Note that, statically, strontium provides a large resistivity change up to approximately 46 kilobars after which it falls off, both lithium and calcium provide continuous increases in resistivity with pressures up to the 100-kilobar level (limit of Bridgman's data), and sodium provides a decrease in resistance in going to 30 - 40 kilobars after which it levels off. These metals can be utilized for shock pressure measurement by fabricating very thin, noninductive resistance grids and encapsulating them with appropriate electrical leads attached to the pressure sensor grid. It is desirable, in order to eliminate the effects of contact resistance, to excite the pressure sensing grid with a constant current requiring two current leads, and to monitor the voltage drop across the grid (ie, its resistance change) during a pressure wave. To accomplish this goal, two separate voltage leads are also required. The thinner the pressure sensing grid, the better the pressure resolution for shock pressure inputs; whereas, for static pressures, grid thickness is not important. Transducer output increases for shock pressure monitoring by pulsing (exciting) the transducer with a square-wave current input while the pressure wave is being monitored

Figure 1. RELATIVE RESISTANCE OF STRONTIUM, CALCIUM, LITHIUM, AND SODIUM AS A FUNCTION OF THE PRESSURE. (Data Taken from Bridgman)

(in contrast to a steady current flow). Using this technique, much higher currents can be utilized without damage to the transducer, thus providing a higher IR (voltage) drop across the grid. A steady-state current of 2 - 3 amperes is sufficient to cause significant heating of the transducer grid. For dynamic, or shock pressure monitoring, the shock impedance of electrical leads, encapsulation, and pressure sensor metal need to be approximately matched to reduce undesirable shock reflections within the transducer, thus confusing output or destroying the transducer before monitoring the full pressure wave form. Material compatibility in terms of corrosion or allowing diffusion of oxygen, nitrogen, or moisture to take place also becomes extremely important when working with such reactive metals as strontium, lithium, and calcium. It is necessary to perform the fabrication in a high-purity argon environment to protect the reactive sensor metals.

Design changes proposed in this series of transducers were intended to improve transducer output, reduce the electrical noise level with respect to the output signal, and improve shelf life. General transducer design, pertinent fabrication details, and shelf-life indications are described in this report with specific details being summarized in appropriate appendixes.

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FABRICATION AND TESTING OF THE TRANSDUCERS

BASIC DESIGN

Except for the pressure sensor metal, the basic design for the strontium, lithium, and calcium transducers was the same. Only the details of the strontium units will be described since they will hold true for the other transducers. Figure 2 presents a schematic drawing of the transducers. In general, a transducer consists of a quartz case or encapsulation, two 1/8-inch magnesium current pins for exciting the transducer with current, two 1/16-inch voltage pins for monitoring the signal from the transducer, a vapor-deposited strontium grid approximately 1/2 mil thick, a cap of 2-mil aluminum sheet bonded over the strontium grid as a diffusion barrier, and a 1/4-mil-thick sheet of Mylar between the strontium grid and aluminum foil as electrical insulation. Magnesium pins with a quartz case provide a relatively good acoustic impedance match which should reduce the chance of the pressure wave shearing the grid at the quartz/pin interface due to differential particle velocities in the pins and quartz. Pins and aluminum caps are bonded in place with a urethane rubber adhesive, as outlined in Appendix A.

Figure 2. DETAILS OF THE TRANSDUCER DESIGN.

FABRICATION ENVIRONMENT

All transducers were fabricated inside a glove box with a high-purity argon atmosphere obtained as described in an earlier report.⁽³⁾ The glove box has a recirculating argon system with a 700° C uranium chip unit for gettering oxygen, nitrogen, and moisture and thus maintaining clean argon. A typical sample from the box had approximately 10 ppm oxygen, 12 ppm nitrogen plus carbon monoxide, 6 ppm hydrogen, 6 ppm carbon dioxide, 4 ppm methane, the balance argon. An independent moisture monitor indicated a 2 ppm moisture content.

TRANSDUCER FABRICATION

Figure 3 is a photograph showing the individual components of a transducer prior to assembly. (The two O rings are used as an aid for potting the pins into the case with urethane and are not part of the final transducer.) The case is made of high-purity, bubble-free (of visible bubbles) fused quartz^(a) having no impurities with an atomic number greater than that of strontium. A detailed sketch is given in Appendix B.

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Figure 3. TRANSDUCER COMPONENTS.

(a) Quartz cases were purchased from Amersil, Inc of Hillside, New Jersey.

Electrical pins are made of 1/8 and 1/16-inch magnesium welding rods,^(b) type AZ61-A. The magnesium metal has impurities of approximately 5.5 percent aluminum, 1 percent zinc, and 0.2 percent manganese.

Prior to assembly, all components were thoroughly cleaned and transferred to the glove box. Cleaning procedures are outlined in Appendix A. Electrical pin tips were wet with lithium prior to bonding in the quartz case. After bonding the pins in the case, the lithium was smeared out over the quartz surface, as shown in Figure 4. (Note: Lighting was such when the photographs were taken that the smeared lithium appears dark; however, it was a clean, metallic surface.) After smearing, all excess lithium was removed, thus forming a smooth coating over the pin tip and quartz around the pins such that the pin/quartz interface cannot be seen. The smearing step is very important to the success of the transducer as it aids in forming a low contact resistance between the pins and the vapor-deposited strontium grid, and also eliminates a high resistance area around the pins. Without the smeared lithium, the transducers can withstand only low-level current pulsing. Following the smearing operation, the

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Figure 4. TRANSDUCER BEFORE AND AFTER SMEARING THE LITHIUM OVER THE PIN/QUARTZ INTERFACE.

(b) Magnesium Weldrod purchased from Hubble Metals, Atlanta, Georgia.

strontium grid was deposited immediately (after evacuating). Deposition was carried out as fast as possible, generally taking less than one or two minutes for the plating. Longer deposition times result in impure coatings as evidenced by thicker, darker coatings for the same resistance grid.

Figure 5 shows a typical strontium grid after vapor deposition. Transducer resistance was monitored during deposition in a way that permitted controlled deposition. A

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Figure 5. TRANSDUCER WITH VAPOR-DEPOSITED STRONTIUM GRID.

nominal resistance of 50 milliohms was desired. In the early transducers, resistances deviated significantly from 50; however, as more experience was gained, faster deposition techniques were acquired so that better control was possible. With the improved control, resistances of 50 ± 10 milliohms were obtained on a routine basis. In fact, it was possible, with care, to control to 50 ± 5 milliohms with the possibility of rejecting some transducers. This work is described in more detail in Appendix C.

Following deposition of the grid, the transducers were capped by bonding a 2-mil-thick layer of aluminum foil with an intermediate 1/4-mil-thick Mylar sheet between the strontium grid and aluminum foil. Figure 6 shows a typical transducer appearance after assembly. Note that the strontium grid stands out on the transducer face.

TRANSDUCER TESTING

Transducer testing at Y-12 consisted of relatively simple-vacuum, current-pulse, and corrosion tests.

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Figure 6. COMPLETED STRONTIUM SHOCK PRESSURE TRANSDUCER.

Vacuum and Pulse Testing

After assembly, each transducer was pumped down to 100 microns as a performance test. Each one was also subjected to ten 100-ampere current pulses on 15-second intervals with a power input of approximately 0.61 watt-seconds per pulse. (Appendix D discusses and gives details of the pulse circuit that was used for the test.) No transducers failed the vacuum test; however, five of twenty-two failed the 100-ampere pulse test and two failed a similar 125-ampere pulse test. These transducers were redeposited.

Corrosion Testing

The bulk of the transducers fabricated (17 strontium and 1 lithium) were shipped to the Lawrence Radiation Laboratory for shock testing. Very little corrosion data were obtained from these transducers prior to shipping; however, one calcium and five extra strontium transducers were fabricated for corrosion testing at Y-12 and data are being accumulated.

Results of the resistance checks to date on all transducers are given in Table E-2, Appendix E. For Transducers SrQ-6, SrQ-8, SrQ-13, SrQ-14, SrQ-24, and Transducer CaQ-1, data on resistance through the current pin circuit and sensor grid resistance are plotted in Figures 7 through 12. Figures 13 and 14 give data obtained from Transducers SrQ-3 and SrQ-4 prior to shipping to the LRL for shock testing. These transducers represent the corrosion versus time data obtained over a period of 20 days or more. In general, contact resistances between the strontium grid and magnesium

Figure 7. RESISTANCES OF STRONTIUM TRANSDUCER SrQ-6 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO AIR.

Figure 8. RESISTANCES OF STRONTIUM TRANSDUCER SrQ-8 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO ARGON.

pins appear to be relatively stable, whereas the resistance of the strontium deposit changes with time.

Transducers SrQ-8 and SrQ-13 were stored under argon; the remaining transducers were stored in air. The transducers stored under argon were removed for making resistance measurements in air; however, exposure to air was generally limited to less than 30 minutes each time. Resistances of both Units SrQ-8 and SrQ-13 were

Figure 9. RESISTANCES OF STRONTIUM TRANSDUCER SrQ-13 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO ARGON.

relatively stable—SrQ-8 being very stable and SrQ-13 climbing very slowly; however, all other transducers have slowly corroded over time periods of up to 39 days.

The outer current pin circuit corroded at a faster rate than the other resistances, as shown in Figures 7 through 14. This situation apparently results from the short diffusion path through the urethane adhesive into the current pins. Moving the current pins inward should improve the diffusion resistance. At least one transducer (SrQ-24) corroded very rapidly, implying that the grid was probably not completely sealed from the atmosphere. The data available are insufficient to determine transducer shelf life; however, it does indicate that shelf life should be improved significantly by storing the transducers in argon until ready for use. A limited exposure to air of several weeks or maybe even several months may be practical after removal from an argon atmosphere. For long-range stability in air (ie, periods of months or years) further work in the areas of corrosion resistance and diffusion-resistant adhesives for sealing the transducer is required.

Figure 10. RESISTANCES OF STRONTIUM TRANSDUCER SrQ-14 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO AIR.

Figure 11. RESISTANCES OF STRONTIUM TRANSDUCER SrQ-24 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO AIR.

Figure 12. RESISTANCES OF CALCIUM TRANSDUCER CaQ-1 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO AIR.

Figure 13. RESISTANCES OF STRONTIUM TRANSDUCER SrQ-3 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO AIR.

Figure 14. RESISTANCES OF STRONTIUM TRANSDUCER SrQ-4 AS A FUNCTION OF THE TIME IT WAS EXPOSED TO AIR.

corroded very rapidly, implying that the grid was probably not completely sealed from the atmosphere. The data available are insufficient to determine transducer shelf life; however, it does indicate that shelf life should be improved significantly by storing the transducers in argon until ready for use. A limited exposure to air of several weeks or maybe even several months may be practical after removal from an argon atmosphere. For long-range stability in air (ie, periods of months or years) further work in the areas of corrosion resistance and diffusion-resistant adhesives for sealing the transducer is required.

APPENDIX A

FABRICATION SEQUENCE

The following step-by-step procedure was followed for assembling each transducer:

1. Transducers were numbered with a graphite pencil.
2. Outside diameter and length were measured and recorded.
3. Front surface of the quartz case was sand blasted.
4. Pins were polished to fit each quartz case with approximately 10 to 20 mils for lithium on the pin tips.
5. Quartz case and pins were washed in Knox 60 detergent, followed by washes of demineralized water and ethyl alcohol. Clean pins and quartz were placed in a clean plastic bottle with cap. White gloves were used in order to keep all items clean.
6. Aluminum foil was washed in dilute Knox 60 detergent followed by washes in demineralized water, phosphoric acid solution (14 parts H_3PO_4 , 5 parts H_2SO_4 , 1 part HNO_3 , 100 parts H_2O), demineralized water, and ethyl alcohol. Foil was then transferred to the glove box in a clean dry bottle with cap.
7. Mylar was washed in ethyl alcohol and transferred to the glove box in a glass bottle with cap.
8. Individual quartz cases and pins were transferred to the argon box in plastic bottles and lids placed on the bottles after transferring to the box.
9. Quartz was heated to approximately 250° C on a hot plate for 30 minutes.
10. O rings (prewet with Garan 225 mold release)^(c) were cemented around where the magnesium pins go in the quartz case with rubber cement. ^(d) One O ring was cemented at a time without the pins in the hole, then the pins were replaced and the process repeated with the next O ring. Care must be taken not to touch or get the front face of the quartz dirty or get cement around the pins.
11. Two pins were removed from one side of a transducer and wet with lithium. (The lithium must form a good bond and be at least 50 mils or so thick.) Excess lithium was removed from the pin diameter as required to get it to fit into the hole in

(c) Manufactured by Ram Chemical Company.

(d) Manufactured by Carter Ink Company.

the quartz. The pins were then replaced in the quartz, the next two pins removed, and the process repeated.

12. Pins were cemented in the transducer case using Adiprene^(e) (mix 50 grams L-100 urethane with 6 grams Moca; heat Moca to 122° C). Pins must be wetted over the full length with Adiprene. Case and pins were allowed to set at least 24 hours before using.
13. O rings were removed from around the pins.
14. Lithium was smeared on the pin tips out over the quartz. After smearing the lithium, a razor blade knife was used to trim the lithium back down smooth with the quartz.
15. The strontium grid was vapor deposited (see Appendix C).
16. The transducer was capped with 1/4-mil-thick Mylar and 2-mil aluminum foil using Adiprene adhesive. The transducer was clamped in a vise against a silicone rubber pad for approximately 24 hours until it set. (Note: The resistance from the cap to the pins was checked before the adhesive set. If a short was detected, recapping was necessary.)
17. The transducer was removed from the vise and transferred to a desiccator and pumped down as a performance test to see if the aluminum foil came off or the transducer opened up.
18. The transducer was then transferred out of the argon box in a plastic bottle.
19. The resistances in the transducer were checked (see Appendix E, Figure E-1; check Resistances I14V14, I13V23, I24V23, and I14V23).
20. The transducer was pumped down to < 100 microns as a performance test.
21. The resistances were checked again.
22. Each transducer was pulse tested ten times at 100 amperes on 15-second intervals with a power input of 0.61 watt-seconds/pulse.
23. Resistances were rechecked.
24. Transducers were shipped in sealed cans under argon. A card was attached with the date the transducer was made and the resistances on each transducer.

(e) Du Pont trade name.

APPENDIX B

INITIAL TRANSDUCER DESIGN AND CHANGES

The initial transducer design is shown schematically in Figure B-1. The basic design included: (1) a vapor-deposited strontium, lithium, or sodium grid; (2) an alumina backing; (3) a vapor-deposited layer of silicon monoxide over the grid for insulation; (4) a vapor-deposited layer of aluminum over the silicon monoxide as a diffusion barrier; and (5) copper electrical pins.

A number of attempts were made to vapor deposit diffusion-resistant aluminum coatings, but in all cases corrosion of the strontium grid was almost immediate upon exposure of the transducer to air. A commercial 2-mil-thick aluminized plastic (having a thin layer of vapor-deposited aluminum on one side) was also tried without complete success, although diffusion resistance did improve significantly. A 2-mil layer of aluminum foil was then bonded over the strontium with a 1/4-mil layer of Mylar insulation and found to be a very successful diffusion barrier. This technique was used on all subsequent transducers.

Initial development work was done using fused quartz discs because of their availability at Y-12. Magnesium pins provided a relatively good acoustic impedance match with quartz, as shown in Table B-1; hence, they were used instead of copper. Magnesium pin tips were also found to wet with lithium much easier than copper. Final transducers were all fabricated with fused quartz cases and magnesium pins. The surface of the quartz was sandblasted to aid in bonding the aluminum foil and providing a good bond between the quartz and vapor-deposited strontium, lithium,

Figure B-1. INITIAL TRANSDUCER DESIGN.

Table B-1
SHOCK IMPEDANCE CHARACTERISTICS OF SEVERAL TRANSDUCER BACKINGS AND PINS

Material	Atomic Number	Density (ρ) (lb/in ³)	Young's Modulus (E) (psi x 10 ⁻⁶)	Longitudinal Sonic Wave Velocity (V) (in/sec x 10 ⁻⁵)	ρE lb ² /in ⁵ (x 10 ⁻⁶)	ρV lb/in ² sec (x 10 ⁻⁵)
Magnesium	12	0.064	6.5	2.28	0.416	0.146
Zinc	30	0.258	11.4 - 14.9	1.66	0.294 - 0.384	0.428
Beryllium	4	0.067	44	5.04	2.95	0.338
Copper	29	0.322	17	1.83	5.48	0.589
Vespel	-	0.051 - 0.057	0.46 - 0.61	-	0.024 - 0.035	-
Epi-Rez	-	0.043	0.36	1.034	0.016	0.044
Fused Quartz	-	0.079	10.4	2.33	0.128	0.184
Alumina	-	0.143	56	-	8.032	-
Beryllium Oxide	-	0.109	49	-	5.329	-
Strontium	38	0.094	1.69	1.071	0.159	0.101
Lithium	3	-	-	-	-	-
Calcium	20	-	-	-	-	-

or calcium. A schematic drawing of the final transducer design is given in Figure 2; a more detailed sketch of the fused quartz case is given in Figure B-2. Other minor alterations included such things as relocating the pins.

Notes:

1. All edges and corners on surface "A" are to be sharp and chip free within 0.002 inch; on surface "B" to be sharp and chip free within 0.010 inch.
2. Surfaces "A" and "B" are to be flat and parallel within 0.002 inch TIR and perpendicular to surface "C" within 0.002 inch TIR.
3. Smooth satin finish - all surfaces.
4. Material is to be fused quartz with no impurities having a higher atomic number than 38 and homogenous and free of visible voids and inclusions.

Figure B-2. SHOCK TRANSDUCER CASE. (Phase I)

A number of corrosion or compatibility tests were run between lithium and strontium and various epoxies and urethanes, as is described in Appendix E. As a result of these tests, transducer pins and the aluminum foil were bonded in place using urethane rather than epoxy.

APPENDIX C

VACUUM EVAPORATION OF THE MATERIALS USED IN TRANSDUCER FABRICATION

The basic problems of the vacuum evaporation of strontium, calcium, and lithium are: (1) the need for working in an inert atmosphere; (2) construction of an evaporation chamber small enough to pass through the ports of a glove box; (3) preparation of filaments and boats for evaporation, and (4) evaporation parameters. These were discussed in the previous report.⁽³⁾ The goal of the previous work was to deposit a layer of strontium 24 mils thick, whereas the design of the present transducers specifies a thin film that will have a resistance of 50 milliohms. The size of the charge of alkali metal and the power requirements of the evaporation unit were reduced considerably. In addition, the charge could be heated and evaporated more rapidly, producing a layer of higher purity with improved physical properties.

To deposit a film with a resistance of 50 ± 10 milliohms, it was necessary to measure the resistance of the film as it was being deposited. To accomplish this, the lids of the two evaporation chambers were equipped with feedthroughs, wires, and clamps to connect the electrical contacts of the transducer to a Kelvin bridge. Thus, during the evaporation process, one person would operate the Kelvin bridge to monitor the resistance of the film and advise another person operating the power controls to the evaporation source of the progress of the deposition. Power was cut off 5 to 10 milliohms above the required 50, for the material continued to plate briefly until the temperature of the boat dropped. The resistance continued to drop as the transducer itself cooled off. Since calcium required more heat than lithium or strontium, the resistance drop was greatest with this element.

The average conditions for evaporation were: strontium - 100 amperes for one to three minutes; lithium - 165 amperes for eleven minutes; calcium - 225 amperes for six minutes.

After the evaporation process was completed, the chamber was moved back into the glove box for completion of the transducer, as described in Appendix A. This work consisted of covering the alkali with a thin piece of plastic electrical insulator and then cementing down a piece of two-mil aluminum foil with urethane rubber.

The original request asked that polyethylene be vacuum evaporated over the alkali for electrical insulation and then the aluminum vacuum evaporated over the polyethylene for protection from the atmosphere. Experimentally, it was learned that polyethylene could be vacuum evaporated by loading a silicon monoxide-type source box with polyethylene powder and heating slowly. Thick coatings were produced which adhered well to a glass substrate. However, it was not possible to cover the

polyethylene with a thick (1 or 2-mil) layer of aluminum in the small evaporator. There were two reasons for this: (1) the amount of heat required for the deposition of aluminum would melt or burn off the previous coat of polyethylene; (2) no method of handling sufficient aluminum at one time in the evaporator could be found. Tungsten wires dissolved in an excess of molten aluminum, and filament life was short. Not enough power could be used to melt the aluminum in a boron nitride crucible. An improved filament was constructed out of several strands of tungsten/26 percent rhenium thermocouple wire. Several loadings were still required to deposit an appreciable thickness of aluminum. Two transducers were constructed by this method, but they deteriorated within half an hour upon removal from the inert atmosphere.

APPENDIX D

PULSE CIRCUIT

Transducers shipped to the LRL for shock testing were pulsed ten times at 100 amperes on 15-second intervals prior to shipping. Figure D-1 is a schematic drawing of the arrangement of the pulser used. A typical current wave form obtained from an oscilloscope trace is shown in Figure D-2.

Figure D-1. COMPONENTS OF THE PULSING CIRCUIT.

Figure D-2. CURRENT PULSE WAVEFORM.

APPENDIX E

CORROSION TESTING

Introduction

Corrosion testing consisted of: (1) preliminary testing to determine an adhesive which was compatible with lithium and strontium, and (2) transducer resistance checks after fabrication was completed.

The first transducers fabricated were sealed with an epoxy adhesive composed of Shell 815 resin with a U cure and Versimide 140 to flexibilize the adhesive; however, it corroded the strontium grids and provided poor seal strength between the aluminum foil and quartz. In searching for a substitute, the compatibility of strontium and lithium in a number of adhesives and curing agents was checked and they were found to react with all epoxies checked, as shown in Table E-1. Compatibility was checked by submerging strontium and lithium metal in the adhesive and rating any discoloration, gas evolution, or deterioration of the metal surface. In general, reaction with the epoxies was immediate. Strontium and lithium did not react with Eastman 910 or with Adiprene (composed of L-100 urethane plus a Moca curing agent) even after

Table E-1
COMPATIBILITY OF LITHIUM AND STRONTIUM METAL
WITH VARIOUS ADHESIVES

Materials		Compatibility
Metal	Adhesive	
Li, Sr	Shell 815 Epoxy Resin	Reacts immediately evolving a gas.
Li, Sr	Shell 828 Epoxy Resin	Reacts immediately evolving a gas.
Li, Sr	Epi-Rez 5101 Epoxy Resin ⁽¹⁾	Does not appear to react.
Li, Sr	TEPA Epoxy Curing Agent	Reacts immediately evolving a gas.
Li, Sr	Z Epoxy Curing Agent	Reacts immediately evolving a gas.
Li, Sr	TETA Epoxy Curing Agent	Reacts immediately evolving a gas.
Li, Sr	MPDA-MDA Epoxy Curing Agent ⁽¹⁾	Reacts very slowly.
Li, Sr	Versimide 140 Epoxy Curing Agent	Does not appear to react.
Li, Sr	Eastman 910	Does not appear to react.
Li, Sr	Adiprene	Does not appear to react.

(1) MPDA-MDA is the curing agent generally used with Epi-Rez 5101 Resin.

several days of exposure. Since the adiprene was better adapted to bonding pins and aluminum foil in place, it was used for the final transducers.

Corrosion after Fabrication

Corrosion after fabrication provides an indication of the transducer shelf life. Corrosion was determined by making resistance measurements of the transducer resistances and comparing over a period of time. Very little data were obtained from the 17 transducers shipped to the LRL; however, the data which were obtained are recorded in Table E-2 along with data from one calcium and five strontium transducers kept at Y-12 for corrosion testing. Two of the strontium transducers kept for corrosion tests (SrQ-8 and SrQ-13) were stored under argon; the remaining three strontium transducers (SrQ-6, SrQ-14, and SrQ-24) and one calcium transducer (CaQ-1) were stored in air. Resistance changes in the transducers stored in argon provide a good indication of the degree of corrosion of the grid by neighboring material (eg, quartz, Mylar, and urethane), whereas those stored in air give some indication of the corrosion resulting from the diffusion of oxygen, nitrogen, and moisture into the grid as well as corrosion by neighboring material. Resistance measurements are coded in the form I14V23 meaning that the resistances were read on a Kelvin bridge with current leads (I) attached to Pins 1 and 4 and volt leads (V) attached to Pins 2 and 3. Pins are numbered consecutively from left to right across the transducer. Figure E-1 shows a simulated transducer and the resistances present between pins (R) and at pin-to-grid junctions (J). Resistance through the current pin circuit (I14V14), sensor grid (I14V23), and junctions (J2 and J3) were recorded for corrosion purposes.

Results of the resistance checks to date are given in Table E-2.

Figure E-1. TRANSDUCER RESISTANCES.

Table E-2
TRANSDUCER RESISTANCES AS A FUNCTION OF TIME IN AIR AND ARGON

Transducer ⁽¹⁾	Environment	Time Elapsed (days)	Resistances (milliohms)			
			Current Pin Circuit (I14V14)	Voltage Pin Circuit (I14V23)	Junction 2 (I24V23- I14V23)	Junction 3 (I13V23- I14V23)
SrQ-1	Air	0	61.50	52.10	3.80	3.60
		1	61.90	52.30	3.75	3.45
SrQ-2	Air	0	72.25	63.05	3.85	4.10
SrQ-3	Air	0	72.90	67.90	4.15	4.60
		1	73.30	68.50	4.00	4.20
		7	74.75	69.90	4.45	4.10
		13	80.45	75.10	4.35	4.50
		14	80.25	74.95	4.15	3.95
		15	80.80	76.25	4.70	3.70
		20	84.50	79.30	4.50	3.70
SrQ-4	Air	0	72.90	67.90	4.15	4.60
		1	73.30	68.50	4.00	4.20
		7	74.75	69.90	4.45	4.10
		13	80.45	75.10	4.35	4.50
		14	80.25	74.95	4.15	3.95
		15	80.80	76.25	4.70	3.70
		20	84.50	79.30	4.50	3.70
SrQ-5	Air	0	51.55	46.72	3.58	3.76
SrQ-6 ⁽²⁾	Air	0	41.28	35.38	3.60	3.28
		2	41.20	35.00	3.90	4.20
		6	40.56	34.40	3.36	4.00
		7	40.98	35.48	4.58	4.14
		12	41.82	34.66	3.60	4.20
		20	43.98	36.08	3.54	3.22
		22	44.72	36.80	2.12	2.90
		27	46.16	36.46	4.12	4.20
		34	47.48	37.14	4.30	4.40
		39	47.92	37.28	4.08	4.28
SrQ-8 ⁽²⁾	Argon	0	37.66	26.78	4.04	4.84
		4	35.76	26.04	3.32	3.82
		5	35.26	25.70	3.44	3.62
		6	35.40	25.86	3.42	-
		11	35.36	25.76	3.50	3.64
		19	35.86	25.78	3.30	3.84
		21	36.40	25.90	3.86	3.02
		26	36.36	25.98	3.90	3.98
		33	36.60	26.06	4.28	4.22
		38	36.38	25.90	4.08	4.08
SrQ-9	Argon	0	46.30	41.86	3.32	3.64
SrQ-10	Argon	0	75.75	54.10	4.95	9.60
		3	76.90	54.00	4.40	10.30
		4	76.30	53.40	5.15	10.85
		5 ⁽³⁾	76.70	53.70	4.60	10.80
		6	79.40	54.80	5.20	13.20
		10	79.75	54.80	5.60	13.00

(1) All transducers except SrQ-1 were shipped to the LRL canned under argon.

(2) These transducers were kept at Y-12 for continuous corrosion study.

(3) SrQ-10 repulsed 10 times at 100 amperes prior to reading on the fifth day.

Table E-2 (continued)

Transducer(1)	Environment	Time Elapsed (days)	Resistances (milliohms)			
			Current Pin Circuit (I14V14)	Voltage Pin Circuit (I14V23)	Junction 2 (I24V23-I14V23)	Junction 3 (I13V23-I14V23)
SrQ-11	Argon	0	57.15	43.12	3.58	3.48
		1	56.65	42.16	3.82	3.94
		2	57.00	42.50	3.66	3.64
		7	58.20	42.24	3.86	3.92
SrQ-12	Argon	0	37.46	28.20	5.36	4.00
		1	37.72	28.32	3.98	3.74
		6	37.88	28.40	3.44	3.64
SrQ-13(2)	Argon	0	58.60	54.40	3.85	3.25
		5	59.05	54.20	3.80	3.80
		7	59.45	54.55	3.75	3.75
		12	60.26	55.31	3.82	3.91
		19	62.14	55.98	3.98	3.86
		24	63.29	56.29	3.96	4.01
SrQ-14(2)	Air	0	51.44	46.74	3.36	3.64
		5	51.85	46.98	3.32	3.87
		7	52.76	47.32	3.74	3.96
		12	54.90	48.48	3.96	4.20
		19	57.65	49.58	4.01	4.10
		24	59.70	50.54	3.91	4.11
SrQ-15	Argon	0	48.70	42.16	3.32	3.52
		5	49.52	43.04	3.80	3.96
SrQ-16	Argon	0	47.26	42.06	3.66	3.40
		4	45.64	40.12	3.78	3.60
SrQ-18	Argon	0	47.76	43.56	3.50	3.48
		4	46.90	42.60	4.06	3.88
SrQ-19	Argon	0	64.90	61.30	3.55	3.35
SrQ-20	Argon	0	46.76	43.42	3.40	3.46
		4	45.98	42.60	3.80	3.72
SrQ-21	Argon	0	54.10	50.28	3.52	3.77
SrQ-23	Argon	0	53.40	50.12	3.48	3.68
SrQ-24(2)	Air	0	50.20	46.26	3.32	3.32
		5	91.70	87.45	3.40	3.70
		7	310.00	304.40	4.40	4.40
		12	> 26 ohms			
SrQ-25	Argon	0	48.24	43.98	3.60	3.70
LiQ-1	Air	0	43.70	39.08	3.90	3.50
CaQ-1(2)	Air	0	64.25	55.68	3.83	3.73
		1	62.70	55.75	3.90	3.80
		2	63.13	56.12	4.11	3.88
		9	67.14	59.80	4.08	3.99
		14	70.80	62.55	3.90	4.00

(1) All transducers except SrQ-1 were shipped to the LRL canned under argon.

(2) These transducers were kept at Y-12 for continuous corrosion study.

REFERENCES

- (1) Bridgman, P. W.; Collected Experimental Papers, V, pp 3203 - 3250, Harvard Press (1964).
- (2) Bridgman, P. W.; Collected Experimental Papers, VII, pp 4113 - 4197 and 4213 - 4230; Harvard Press (1964).
- (3) Huddleston, R. L. and Sladky, R. E.; Sodium and Strontium Shock Pressure Transducers, Y-1673; Union Carbide Corporation-Nuclear Division, Y-12 Plant, Oak Ridge, Tennessee; (1969).