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New F50 Sensor Design and Cable Seal Fabrication Procedures

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The USRD type F50 transducer has been a popular and useful transducer. Following the recommended sensor design improvements and cable seal fabrication procedures should remove several failure modes and make it a more reliable transducer.

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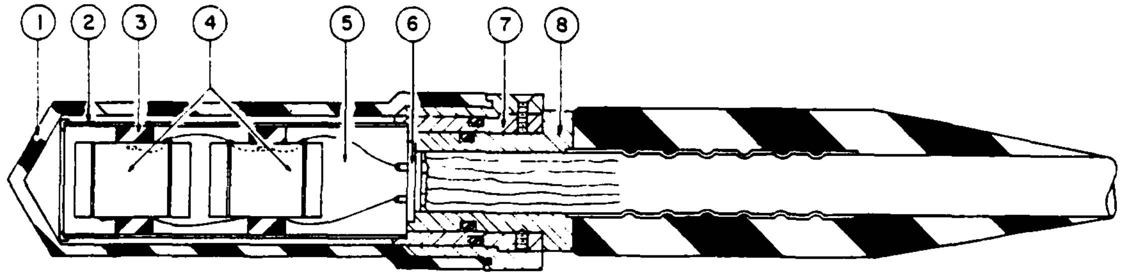
CONTENTS

NEW F50 SENSOR DESIGN, AND CABLE SEAL FABRICATION PROCEDURES

INTRODUCTION

The USRD type F50 transducer shown in a sectional view in Fig. 1, has been a popular and useful transducer. However, many years of experience have revealed several weak features in the design and assembly techniques that have led to the modifications reported herein. These improvements are expected to measurably increase the stability and reliability of the transducer.



1 BUTYL BOOT
2 EXPANDED-METAL FRAME
3 NATURAL RUBBER MOUNTS
4 SENSITIVE ELEMENTS
5 CASTOR OIL
6 GLASS-TO-METAL SEAL
7 ADAPTER RING
8 CABLE GLAND ASSEMBLY

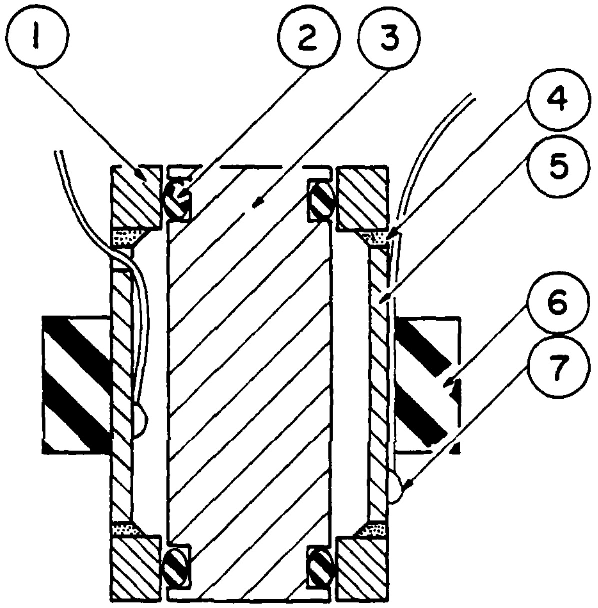
Fig. 1 — Section through an *USRD type F50 transducer*

Observations of numerous units that have been returned for repair show that two failure modes are most commonly encountered. The first failure mode is flooding of the interior of the sensitive elements with oil. In the five-year period 1976 to 1981, approximately 50% of the units had to have the sensitive elements rebuilt for this reason. The second is an electrical or mechanical failure of the glass-to-metal seal in the cable gland which caused oil leakage into the cable and a roll-off in sensitivity in the audio frequency range. In this same period, approximately 10% of the units required new cable glands. A less common failure mode, elements dislocated and leads broken due to rough use, occurred in 5% of the units in the same period. All of these problems have been solved by the changes described in this report.

Manuscript submitted August 24, 1981.

EXAMINATION OF FAILURES

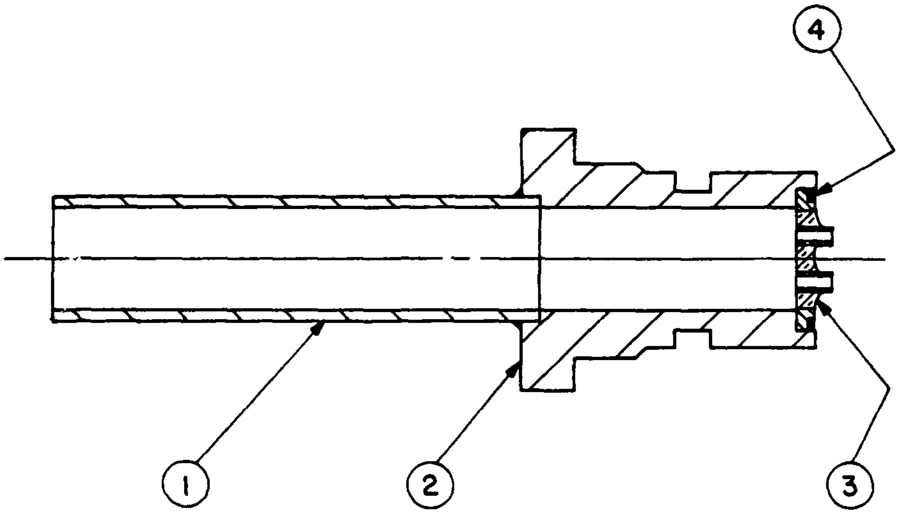
A careful study of flooded sensitive elements (Fig. 2) showed several reasons for the failures, most of which involved the O-ring seals. Some of the O-rings were sheared due to improper assembly procedures, or the magnesium ring had such a large chamfer that the O-ring had insufficient surface to seal on. Poor bonding, probably due to inadequate cleaning, allowed some of the magnesium end rings to come off easily, and could have leaked under pressure as well.



1 MAGNESIUM RING
2 O-RING SEAL
3 MAGNESIUM INSERT
4 EPOXY ADHESIVE
5 PIEZOELECTRIC CERAMIC CYLINDER
6 NATURAL RUBBER MOUNT
7 ELECTRODE CONTACT

Fig. 2 — Section through the sensitive element

A study of the glass-to-metal seal in the cable gland (Fig. 3) showed a variety of problems, most of which concern installation. Many were installed with epoxy or were cold soldered after the cable was installed. Both of these methods cause leaks, allowing oil to migrate up the cable. The epoxy method is not according to the specifications for the cable gland assembly. The cold solder method is an improper assembly procedure that also does not meet the specifications.



1 SOFT COPPER TUBE
2 ST.ST. END CAP
3 GLASS-TO-METAL SEAL
4 SPECIAL ALLOY SOLDER HERMETIC SEAL

Fig. 3 — Section through the cable gland metal subassembly

Many cable glands electrically short-out due to flux etching the glass seal material between terminals or between a terminal and the rim. The etching can also weaken the glass enough for it to break under pressure. Excessive heat applied trying to solder the seal in after the cable is installed can melt the insulation off the leads.

SOLUTIONS

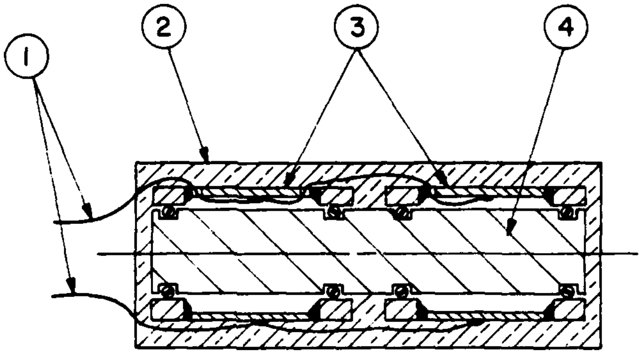
Proper O-ring installation, good bonding between the ceramic and the magnesium, and potting of the sensitive elements with suitable elastomers should keep them from flooding with oil. Adherence to a proper assembly procedure for the cable gland should prevent hermetic seal failures.

SENSOR DESIGN CHANGE

In order to seal the sensitive elements, and make assembly of the transducer easier, the design was changed as follows.

Both sensitive elements were mounted on one magnesium insert, as shown in Fig. 4, and then electrically connected in parallel. This insured proper positioning and alignment of the sensitive elements, both of which are critical for satisfactory operation of the transducer. This assembly was then potted (see Appendix B for potting procedure) in B.F. Goodrich

35075 RHO-C acoustic material. The only paths for leaks into this assembly are along the fine wire leads to the sensitive elements. These leads are not near the major areas of suspected leakage and, due to the excellent adhesion of this material, no bond failures or leaks are expected to develop. The outside diameter of the potted sensor assembly will match the inside diameter of the expanded metal frame and will provide an integral compliant mount to mechanically isolate the sensitive elements.



1 LEADS TO CABLE GLAND
2 COMPLIANT MOUNT AND SEAL POTTING
3 SENSITIVE ELEMENTS
4 MAGNESIUM INSERT

Fig. 4 — Section through the potted sensor assembly

This design removes several steps from the fabrication and assembly procedures formerly used to construct F50 transducers.

The theoretical sensitivity for the new sensor assembly is given by the same expression used for the former assembly [1],

$$\frac{e}{p} = -b \left\{ g_{33} \left(\frac{1-\rho}{1+\rho} \right) + g_{31} \left(\frac{2+\rho-\rho'^2}{1+\rho} \right) \right\}, \qquad (1)$$

where $\rho = a/b$ and a and b are the inside and outside radii respectively of the cylinder, and $\rho' = a'/b$ where a' is the inside radii of the magnesium end rings. The g_{33} and g_{31} are piezoelectric constants. The dimensions of the ceramic rings are $a = 5.56\times10^{-3}$ m, $b = 6.35\times10^{-3}$ m, and $a' = 4.31\times10^{-3}$ m. A MIL-STD 1376 (SHIPS) TYPE III ceramic is used for the cylinders where $g_{33} = 24.0\times10^{-3}$ Vm/N and $g_{31} = -10.2\times10^{-3}$ Vm/N. The free-field voltage sensitivity of the new sensor assembly expressed in dB re 1 V/μPa is -202.7.

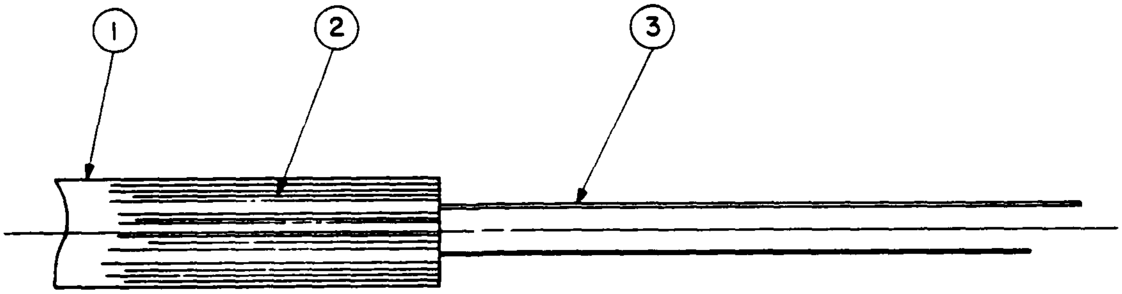
This is the theoretical open-circuit crystal voltage where the dimensions of the sensor are small compared to the acoustic wavelength. In practice, the shunt capacitance of the cable causes a loss in both receiving sensitivity and transmitting response. Therefore the calibration of the transducer is given for a specific length of cable.

CABLE GLAND SEAL FABRICATION

No design change has been made in the cable gland hermetic seal, but the following fabrication procedure must be adhered to.

Degrease the cable gland metal subassembly and then place it in a suitable fixture on a hot plate. The fixture should support the part upright and expose the cup which accepts the hermetic seal; the fixture should be of metal to transfer heat properly. Heat the metal subassembly to approximately 200°C. Use a stainless steel flux (usually highly acid) and solder without a flux core (see Appendix A - Type 1) to tin the cup in the subassembly, completely, but not excessively. After the solder has solidified, but while the assembly is still hot, rinse and wash it using lots of water. Reheat and then spread the tinned layer around some more to be sure it has completely wet the surface and no stainless flux remains. Thoroughly rinse, wash again, and dry.

Examine the hermetic seal for physical damage and measure the electrical resistance from each terminal to the rim. If the electrical resistance is low, clean as required to raise the resistance to $>10^{11}$ ohms. Reheat the metal subassembly and place the seal in the cup. Using a clean soldering iron, apply special alloy solder (see Appendix A - Type 2) to fill and complete the hermetic seal. Remove the fixture and subassembly from the hot plate, and place on a heat sink to cool. After it has cooled to ambient room temperature, rinse and wash again to clean off any soldering flux that may still be present. Repeat several times; it cannot get "too clean". Dry, and check the resistance to be sure electrical resistance has been maintained and that the seal has not been fractured. Prepare the end of the cable that goes into the cable gland, as shown in Fig. 5. Strip the cable back to expose approximately 13 cm of bare leads. Pull on the leads to straighten them and then tin them full length with TYPE 2 special alloy solder. Clean the excess flux off the leads and cut one lead approximately 1.5 cm shorter than the other. Insert the tinned leads through the terminals in the seal. Insert the cable straight into the copper tube, and swage as required. Be careful not to twist the cable and short the leads and be sure the cable is fully seated in the gland. Do not solder the leads to the terminal eyelets until after the rubber has been vulcanized to the metal subassembly. The last operation to complete the gland is to form small hooks on the leads and solder fill the eyelets with special alloy solder. Check the cable resistance; you should have a cable gland that will give years of service.



1 CABLE OUTER JACKET
2 FOLDED BACK SHIELD BRAID
3 STRAIGHTENED TINNED LEADS

Fig. 5 — Cable gland end of cable before insertion

CONCLUSION

In January 1980, USRD Type F50, Serial No. 113, was constructed using the methods set forth in this report. This transducer has been calibrated in both the Lake Facility and the Anechoic Tank Facility. A typical free-field voltage sensitivity curve is shown in Fig. 6 and is identical over the normal operating range, within the accuracy of measurements, to an F50 that has not had the modified sensor installed.

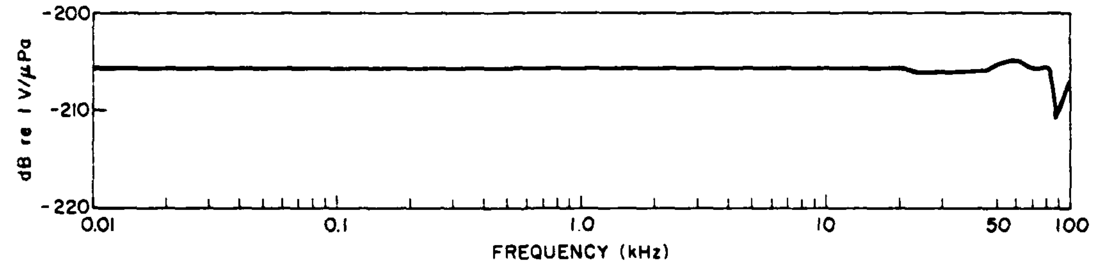


Fig. 6 — Free-field voltage sensitivity of an F50 transducer (open-circuit voltage measured at the end of a 30.5-m cable).

REFERENCE

1. A.C. Tims, "A New Capped-Cylinder Design for an Underwater Sound Transducer (USRD Type F50)", J. Acous. Soc. Am. p 1751-1758, 1972.

APPENDIX A

SOLDER SPECIFICATIONS

<u>TYPE 1</u> - <u>Soft Solder</u>

Solder compositions:

50% Tin		60% Tin
	OR	
50% Lead		40% Lead

Standard solid wire (no core) solder

<u>TYPE 2</u> - <u>Special Alloy Solder</u>

Solder compositions:

2% Silver
36% Lead
62% Tin

A typical example is Ersin multi-core solder LMP special alloy.

APPENDIX B

POTTING PROCEDURE

1. Apply release agent sparingly to mold surfaces exposed to potting (6075 Dry Flourocarbon Lubricant, Crown Industrial Products Co.).
2. Place transducer in mold and fill mold with B.F. Goodrich Co. RHO-C acoustical material (formerly 35075 Castable RHO-C) as follows:
    a. Bring temperature of mold assembly and part 1 of potting compound to 80°C.
    b. Mix part 1 and part 2 of the potting compound according to manufacturer's recommendations and degas for 15 minutes at 80°C in a vacuum of 10^{-3} torr minimum.
    c. Remove from vacuum and fill mold cavity with the mixed potting compound. Exercise care when filling mold to avoid as much entrapped air as possible.
    d. Place filled mold back into 80°C vacuum chamber and degas for 20 minutes with a 10^{-3} torr minimum.
    e. Release vacuum and cure assembly for 24 hours at 80°C.
    f. Remove mold from vaccum oven, cool, and carefully remove the transducer. Clean all excess potting compound from edges of mold cavity.