(12) NRL Memorandum Report 4009

AD A071884

Sonar Transducer Reliability Improvement Program FY 79

LEVEL

Third Quarter Progress

A067943

R. W. TIMME

Materials Section
Transducer Branch
Underwater Sound Reference Detachment
P.O. Box 8337, Orlando, Fl 32856

DDC
RECEIVED
JUL 27 1979
C

July 1, 1979

DDC FILE COPY

NAVAL RESEARCH LABORATORY
Washington, D.C.

Approved for public release; distribution unlimited.

79 07 27 005

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NRL Memorandum Report 4009

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
[redacted] Sonar Transducer Reliability Improvement Program FY79 Third Quarter Progress

5. TYPE OF REPORT & PERIOD COVERED
Interim report [redacted]

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Robert W. Timme

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Underwater Sound Reference Detachment
Naval Research Laboratory
P.O. Box 8337, Orlando, FL 32856

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NRL Problem S02-43.801
Program Element 64503N

11. CONTROLLING OFFICE NAME AND ADDRESS

12. REPORT DATE
1 July 1979

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

The Sonar Transducer Reliability Improvement Program (STRIP) is sponsored by NAVSEA 63X-T.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Transducers	Connectors	Water Permeation
Corona	Noise and Vibration	Environmental Tests
Transducer Fluids	Pressure Release	
Encapsulation	Noise	
Cables	Material Evaluation	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Progress accomplished during the third quarter of FY79 in the Sonar Transducer Reliability Improvement Program is reported. Each of the nine program tasks is discussed in some detail. The most significant aspects are failure modes in the TR-316 transducer design and the testing techniques used to discover them, the quantification of corona levels on ceramic and in wet and dry SF_6, accelerated reactions of polymers in water, and the discrimination of transducer self-noise and spurious system noise.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

CONTENTS

		Page
1.	INTRODUCTION	1
	1.1 PROGRAM OVERVIEW	1
	1.2 SUMMARY OF PROGRESS	2
	1.3 PLANS	3
	1.4 REPORT ORGANIZATION	3
2.	TASK A-1 - TRANSDUCER FLUIDS AND SPECIFICATIONS	4
	2.1 BACKGROUND	4
	2.2 OBJECTIVES	4
	2.3 PROGRESS	4
	2.4 PLANS	10
3.	TASK B-1 - CORONA ABATEMENT	11
	3.1 BACKGROUND	11
	3.2 OBJECTIVES	11
	3.3 PROGRESS	11
	3.4 PLANS	16
4.	TASK C-1 - CABLES AND CONNECTORS	17
	4.1 BACKGROUND	17
	4.2 OBJECTIVES	17
	4.3 PROGRESS	17
	4.4 PLANS	20
5.	TASK D-1 - MATERIALS EVALUATION	21
	5.1 BACKGROUND	21
	5.2 OBJECTIVES	21
	5.3 PROGRESS	22
	5.4 PLANS	26
6.	TASK E-1 - STANDARDIZED TEST PROCEDURES	27
	6.1 BACKGROUND	27
	6.2 OBJECTIVES	27
	6.3 PROGRESS	27
	6.4 PLANS	33
7.	TASK F-1 - NOISE AND VIBRATION	34
	7.1 BACKGROUND	34
	7.2 OBJECTIVES	34
	7.3 PROGRESS	34
	7.4 PLANS	37

Page

8. TASK G-1 - SLEEVE-SPRING PRESSURE RELEASE MECHANISM . . 39

8.1 BACKGROUND 39
8.2 OBJECTIVES 39
8.3 PROGRESS 39
8.4 PLANS. 39

9. TASK G-2 - TEST AND EVALUATION. 40

9.1 BACKGROUND 40
9.2 OBJECTIVES 40
9.3 PROGRESS 40
9.4 PLANS. 42

10. TASK G-3 - ENGINEERING DOCUMENTATION. 43

10.1 BACKGROUND 43
10.2 OBJECTIVES 43
10.3 PROGRESS. 43
10.4 PLANS 44

Distribution List 45

Accession For
NTIS GRA&I ☑
DDC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or special
A

Sonar Transducer Reliability Improvement Program

NRL Problem 82 S02-43

FY79 Third Quarter Report

1. INTRODUCTION

1.1. PROGRAM OVERVIEW

The general objective of this program is to perform relevant engineering development which addresses the operational requirements for fleet transducers for active sonar, passive sonar, surveillance, counter-measures and deception devices, navigation, and acoustic communications. The approach is to develop, test, and evaluate improved transducer design, materials, components, and piece parts that will meet specified requirements in the operational environment during the entire useful life of the transducer. Standards will be prepared to ensure that results obtained during preliminary testing will be obtained consistently in production. This program should result in improved performance and reliability and reduced costs through better utilization and a more comprehensive characterization of materials and design data. The program goals are as follows:

- Reduction in transducer replacement costs

  Goal - less than 9% of population replaced each year with no automatic replacements at overhaul

  Threshold - less than 18% of population replaced each year

- Improvement in transducer reliability

  Goal - less than 1% of population failures each year

  Threshold - less than 3% of population failures each year

- Improvement in transducer receiving sensitivity

  Goal - less than ±1 dB variation from the specified value over operational frequency band

  Threshold - less than ±2 dB variation from the specified value over operational frequency band

- Reduction in transducer radiated self-noise

  Goal - 30 dB reduction
  Threshold - 20 dB reduction

The Sonar Transducer Reliability Improvement Program (STRIP) is a part of Program Element 64503N. Major task areas with specific objectives to achieve the program goals have been described in the Program Plan and include:

Task Area A.	Encapsulation Methods
Task Area B.	High Voltage Engineering
Task Area C.	Cables and Connectors
Task Area D.	Transducer Material Standards
Task Area E.	Environmental Test Methods
Task Area F.	Noise and Vibration
Task Area G.	Transducer Tests and Evaluation

The FY79 Program Plan for STRIP has been funded at the $495 K level. The specific tasks and their Principal Investigators for FY79 are listed below:

	TASK	PRINCIPAL	INVESTIGATOR
A-1	Fluids and Specifications	NRL	C.M. Thompson
B-1	Corona Abatement	NRL	L.P. Browder
C-1	Cables and Connectors	TRI	J.S. Thornton (D. Barrett)
D-1	Materials Evaluation	NUSC	C.L. LeBlanc
E-1	Standard Test Procedures	NOSC	G.L. Kinnison (J. Wong)
F-1	Noise and Vibration	NOSC	C. Bohman
G-1	Sleeve-Spring Pressure Release	TRI	J.S. Thornton (L. Smith)
G-2	Test and Evaluation	NRL	A.M. Young
G-3	Engineering Documentation	NWSC	D.J. Steele (D. Moore)

1.2. SUMMARY OF PROGRESS

During the third quarter of FY79, efforts in the various tasks of STRIP have resulted in progress toward the program goals as summarized below:

- The application of the concept of accelerated life testing of sonar transducers continues on the TR-316 and DT-605 transducers (AN/BQS-8/10/14/20). Important failure modes have been discovered in the laboratory with the result that the TR-316 has failed first article testing. Identification of the failure modes is in progress. See Section 6.3.1.

- A report entitled "Interim Report on Composite Unit Accelerated Life Testing of Sonar Transducers" has been issued. See Section 6.3.2.
- The compatibility of several polymers with water has been shown to be simply accelerated by temperature. See Section 2.3.2.
- Polyalkylene glycol has been shown to be sufficiently unstable as to make it unusable for any sonar transducer. RDT&E of this fluid is thus terminated. See Section 2.3.4.
- Corona inception voltage (CIV) in dry and wet SF_6 gas has been evaluated. These data together with similar data for air allows an evaluation of CIV in mixtures of these gases. See Section 3.3.1.
- A test method and results are described that provides a useful means of comparing various corona abatement techniques and materials used in sonar transducers, and to evaluate the corona resistance lifetime function. See Section 3.3.2.
- A Working Group for Cables and Connectors has been established by NAVSEA 63XT to address long-standing problems with cable and connector subsystems. Two meetings have been held. See Section 4.3.2.
- A cooperative effort between NOSC and NWSC has been established to improve the discrimination between transducer self-noise and extraneous noise. See Section 7.3.2.

1.3. PLANS

The program plan for STRIP was prepared for FY80 and presented to NAVSEA for approval in May 1979. The plan defined a $900 K engineering development effort directed toward the solution of real-life problems of the fleet transducers. A total of 33 proposals asking for $1900 K was received from the various Navy laboratories and contractors and considered for inclusion in the FY80 plan.

The FY80 Program Plan will be distributed to interested parties in the FY79 fourth quarter, after the NAVSEA funding level is established and appropriate fine tuning is accomplished. Preparations will be made for an early start in FY80.

1.4. REPORT ORGANIZATION

The remaining sections of this quarterly report will discuss the objectives, progress, and plans for the specific tasks included in the STRIP.

2. TASK A-1 - TRANSDUCER FLUIDS AND SPECIFICATIONS

2.1. BACKGROUND

A material to be used for filling a sonar transducer must meet a wide variety of specifications. The requirements imposed by the electrical nature of the device include high resistivity, high dielectric constant, as well as resistance to corona and arc discharges. The water environment of the transducer necessitates low water solubility and other attractive solution properties. In addition, the fluid must maintain its electrical and other properties in the presence of any water which permeates the covering. The acoustic requirements are a close acoustic impedance match with sea water and resistance to cavitation at high-drive levels. Other obvious properties include compatibility with other components, stability to degradation, suitable surface tension, and viscosity.

With such a wide variety of requirements, it is not surprising that compromises have to be made. The most commonly used fluid for many years has been castor oil. This use is in spite of its high viscosity. Each of the fluids proposed, so far, as a replacement has serious drawbacks. Silicone oils tend to creep onto and wet all of the surfaces of the transducer. This greatly complicates bonding the components together. Polyalkylene glycol (PAG) has the disadvantages of a high water solubility and low electrical resistivity. The various hydrocarbon liquids have too low an acoustic impedance and are frequently incompatible with the various plastics and rubbers in the transducer. Further research is necessary to find and qualify fill-fluids which represent the best match to all the requirements imposed upon it.

2.2. OBJECTIVES

The objectives of this task are:

- To find plausible new transducer fill-fluids which combine all the best properties. Candidates include: hydrophobic-polyethers, sterically protected esters, chlorine - or fluorine - containing hydrocarbons, methyl alkyl silicones, and possibly aromatic hydrocarbons.
- To apply the criteria developed during the PAG and castor oil testing to the most promising candidate fluids.

2.3. PROGRESS

2.3.1. Polytetramethylene glycol (PTMG) is a commercially available polyether compound. Commercial PTMG contains two hydroxyl functional groups which greatly influence its properties and reduce its usefulness as a transducer fluid. The modification of PTMG should provide a material with the advantages of polyalkylene glycol (such as viscosity, sound speed, PVT relations, compatibility), but without some of the critical disadvantages. The proposed modified PTMG has a lower proportion of ether-type oxygens than PAG. This will reduce the polarity of the molecule and result in decreased water solubility parameters. The increased separation between oxygen atoms eliminates the problem of chelation of metal ions discovered in PAG.

Research on PTMG has been carried out this quarter under an in-house 6.1 program. After the details of the synthesis are worked out, the research will transition back to STRIP. The modification of PTMG has been accomplished by "capping" the hydroxyl end groups with hydrocarbon groups. Di-methoxy, di-tertiarybutoxy, and di-phenoxy derivatives have all been made and all have some attractive transducer-related properties (such as densities and water solubilities). Unfortunately, all also have too high freezing points (or pour points) for universal use. Further research in this area will be directed at (1) use of a slightly lower molecular weight PTMG and (2) introduction of branches in the polymer backbone.

2.3.2. The interactions between sea water and elastomers, encapsulants, and plastics are a potential source of failure in any sonar transducer. The rapid degradation of the polyester types of polyurethanes provides a glaring example of this mode of failure. A preliminary study has begun with several compounds of each type exposed to both salt and fresh water with some studies also performed at elevated temperatures. Weight change, swell, and hardness change are being monitored. From data collected thus far, it is apparent that sea water has a definite effect on elastomers and plastics. This is evidenced by changes in all the physical properties being measured. Weight change is not an absolute measure of degradation of a material, but it gives an accurately measured, relative indication of changes. A log-log plot of the fractional weight change versus time can provide an indication whether the changes occurring are diffusion controlled. Such a process would yield a plot with a slope of 0.5. As seen in Figs. 2.1 and 2.2, the attack of both salt water and fresh water upon Neoprene W (USRD formulation) is diffusion controlled. However, polycarbonate plastic (Lexan) in Figs. 2.3 and 2.4 shows more complex curve shapes, indicating a process other than simple Fickian diffusion.

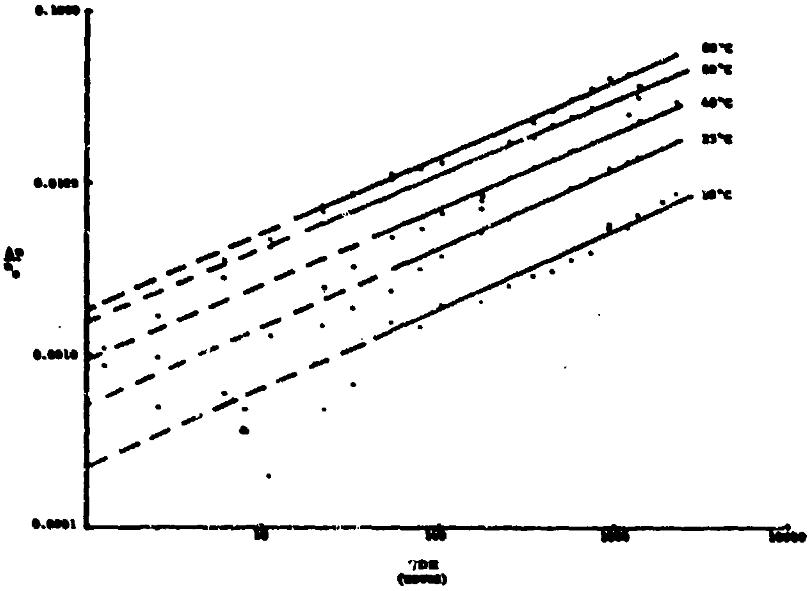

Fig. 2.1. Neoprene W in Salt Water

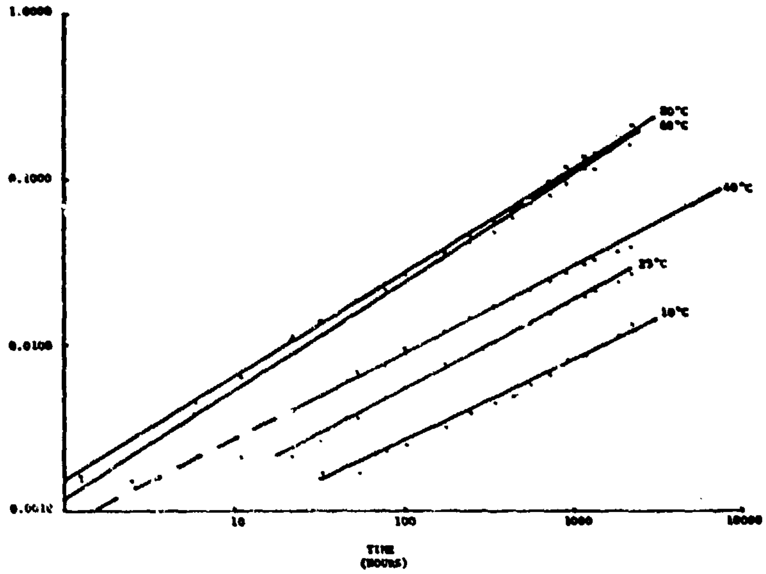

Fig. 2.2. Neoprene W in Fresh Water

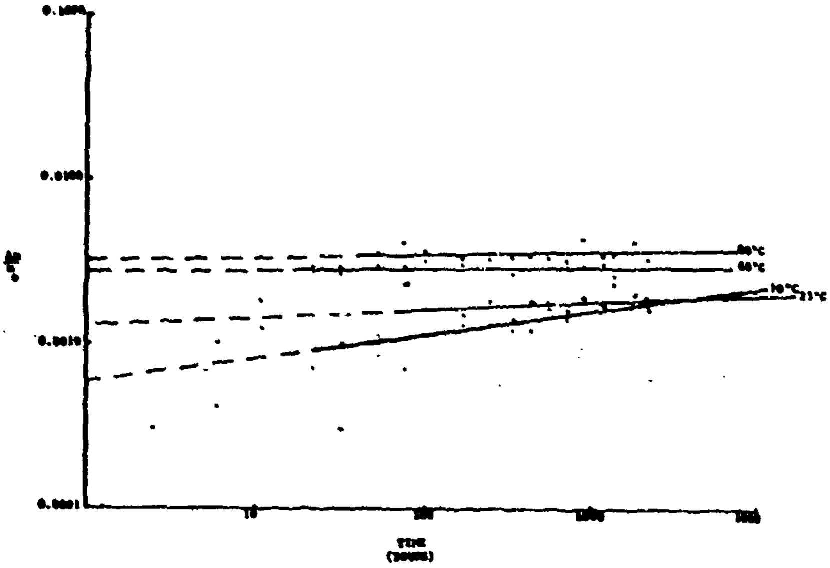

Fig. 2.3. Polycarbonate in Salt Water

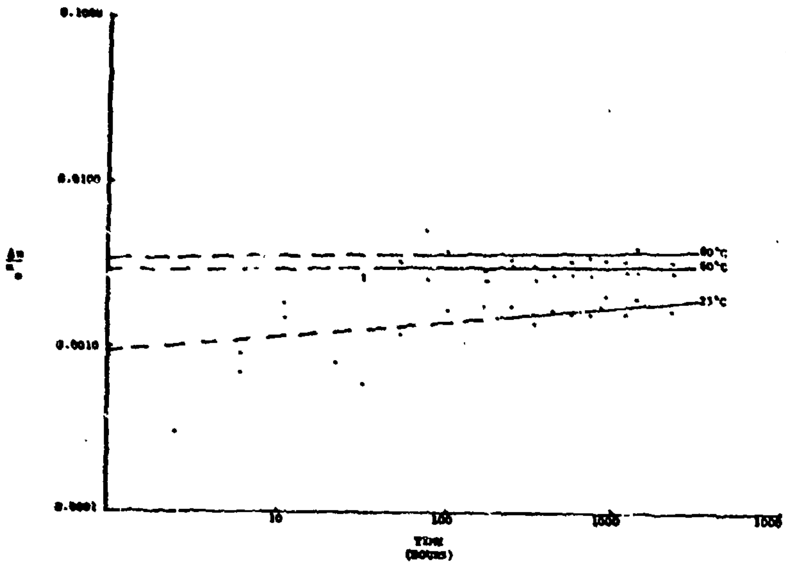

Fig. 2.4. Polycarbonate in Fresh Water

The rate of the process at each temperature can be determined by extrapolating these log-log plots to t = 1 hr. A plot of the log of the rate versus the reciprocal absolute temperature will yield a line whose slope is related to the energy of activation of the process. This process is illustrated for the data from Fig. 2.1, Neoprene W in Salt Water. The plot is shown in Fig. 2.5.

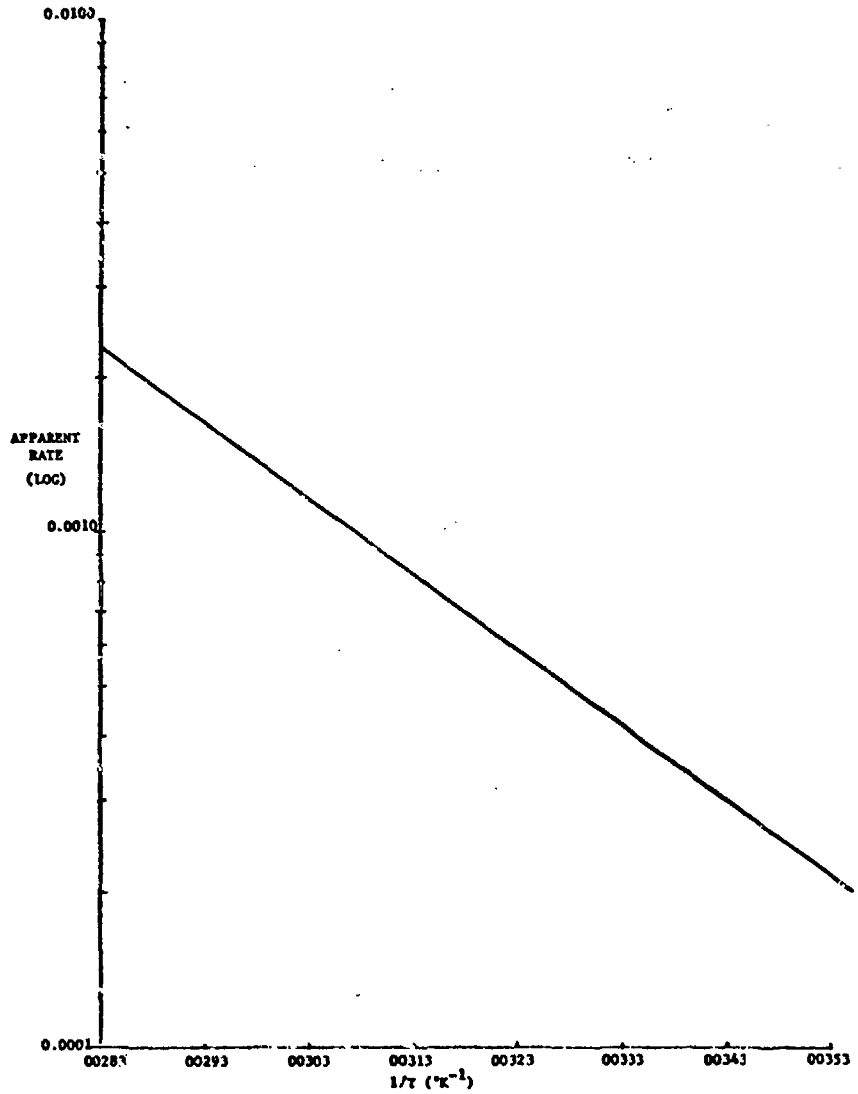

Fig. 2.5. Neoprene W (Salt Water)

A least-squares fit of the data yields the following equation for the fractional weight change:

$$\frac{\Delta m}{m_o} = 18.0\ t^{\frac{1}{2}}\ \exp(-1511/RT) \qquad (2.1)$$

where $\frac{\Delta m}{m_o}$ is the fractional weight change,

t is the time in hours,

R is the gas law constant (= 0.4749 Joules/mole °K), and

T is the temperature in °K (= °C + 273.1).

Again, weight change is not an absolute indication of degradation of the material, but this analysis clearly indicates that the degradation of at least some of the materials is simply accelerated by an increase in temperature. This holds great promise for the more practical research planned for FY80 on the degradation of polymers by water exposure.

2.3.3. The tests on methyl alkyl silicone (MAS) has continued during the third quarter of FY79. Figure 2.6 is a summary of the results. As before, weight change provides only a relative indication of degradation of the elastomer. From this graph it is seen that Polyurethane (PRC 1538) is affected very little by MAS. The 2200 hours of the test at 80°C are equivalent to 12 years of exposure at ambient ocean temperatures (assuming 1450 J/mole activation energy and a diffusion mechanism as discussed in paragraph 2.3.2).

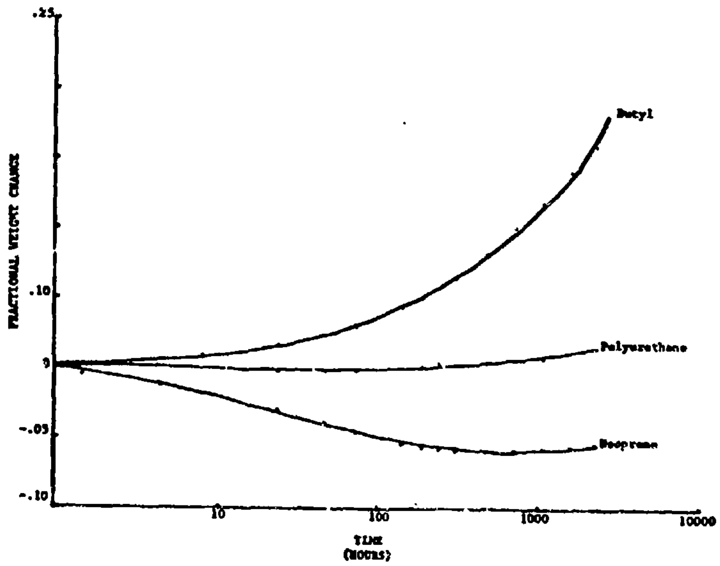

Fig. 2.6. Compatibility of Methyl Alkyl Silicone with Elastomers. Temperature = 80°C

2.3.4. Additional testing performed recently has further condemned polyalkylene glycol (PAG) as a sonar transducer fluid. During laboratory tests it became obvious that PAG undergoes air oxidation on standing at ambient temperatures. This air oxidation results in a greatly increased water solubility limit (to a value near 3.5% H_2O in our instance). This would further degrade PAG's already low electrical resistivity. Presumably, the compatibility of PAG with both rubber and metal parts will also be negatively affected by the air oxidation.

It is now thought that the many weaknesses of PAG as a transducer fill-fluid outweigh any of the advantages of its use. Further testing or reporting on PAG will be terminated.

2.4. PLANS

- Complete article on the rate of water permeation into non-ideal-oil-filled transducers.
  23 July 1979
- Complete peal tests on methyl alkyl silicone exposed metal panels.
- Perform physical, chemical, and acoustic tests on modified PTMG.
- Conclude the preliminary tests of the effect of salt and fresh water on polymers and publish the results in Memo Report form.
  15 Aug 1979
- Prepare a report on the castor oil-water phase diagram and vapor-pressure behavior.

3. TASK B-1 - CORONA ABATEMENT

3.1. BACKGROUND

A significant percentage of transducer failures is due to voltage breakdown of insulating materials developing from corona erosion mechanisms. It is not practical to test the end item (transducer) to quantify the effects of corona erosion on transducer reliability and lifetime. Corona must be studied as a failure mechanism at the component or piece-part level to quantify the protection requirements and establish reliability factors. Transducer reliability may then be achieved by control of design parameters and construction processes.

3.2. OBJECTIVES

The objectives of this task are:

- To provide consultation in selecting materials useful in corona abatement for sonar transducers.
- To reduce corona and flashover damage by quantifying voltage breakdown levels with various design parameters that may be specified and controlled.
- To study the insulating properties and corona resistance of the piezoelectric ceramic material that is an essential part of sonar transducers.
- To identify and test various thin films and coatings with high dielectric strength to establish their usefulness at reducing corona.
- To determine the quality control factors to be considered for corona abatement materials and methods selected for use in transducers.
- To provide guidance for establishing general specifications for corona abatement and high-voltage design and construction.

3.3. PROGRESS

3.3.1. Tests were made of the point-to-plane corona inception voltage (CIV) of dry and wet sulfur hexafluoride gas (SF_6) to provide a comparison with similar characteristics of air presented as Fig. 3.1 of the First Quarter Progress Report [1]. The measurements on SF_6 were made at a temperature of 25°C and at pressures of 35, 70, and 101 kPa. The dry gas had a water vapor

[1] "STRIP First Quarter Report," NRL Memorandum Report 4014, Task B-1, January 1979

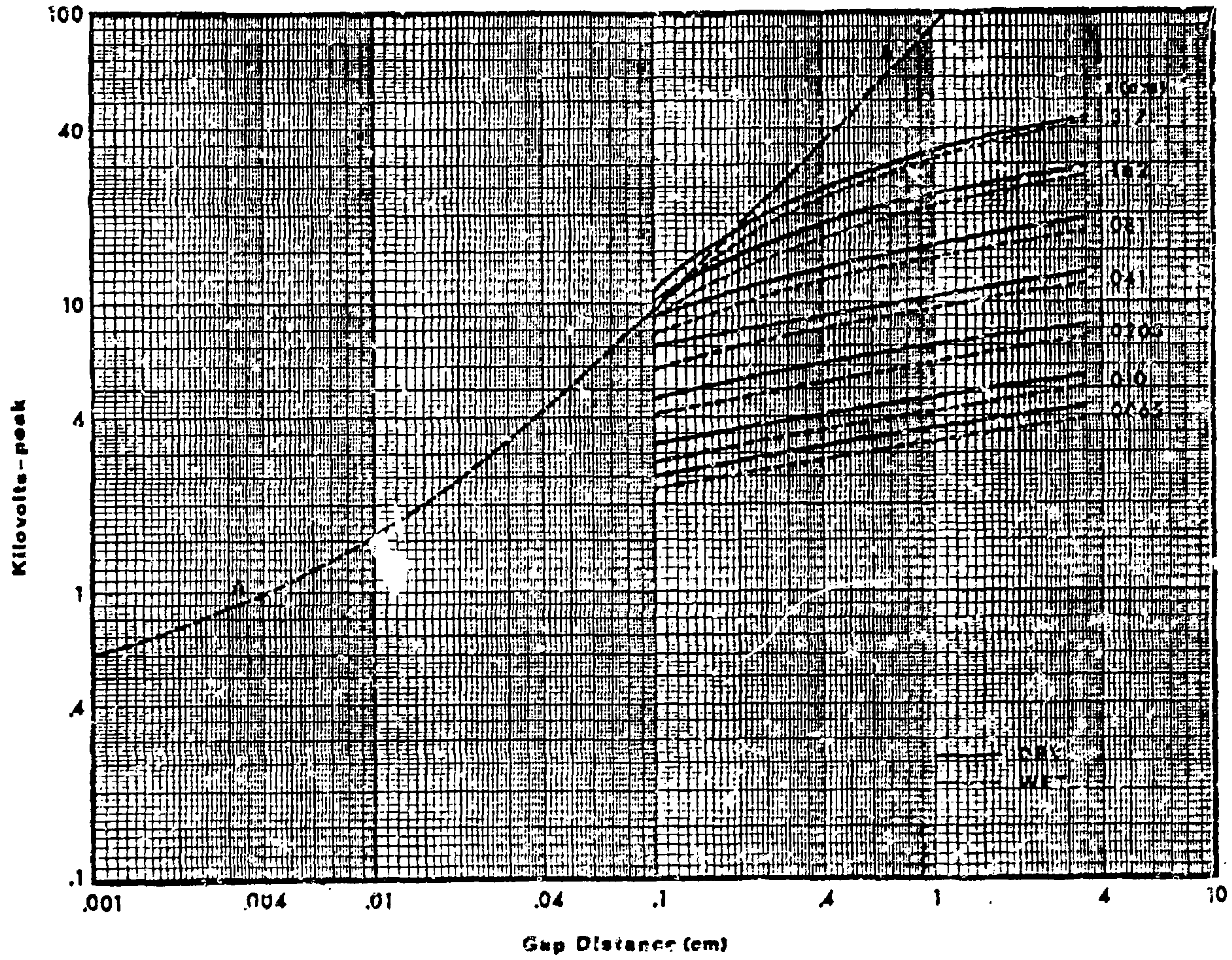

Fig. 3.1. Corona inception voltage in dry and wet SF_6

partial pressure of less than 0.24 Torr or 1% relative humidity (R.H.), and the wet gas had a water vapor partial pressure of approximately 20 Torr or 85% R.H. The procedure for obtaining the wet gas involves first introducing water vapor into the test chamber containing a high vacuum to establish the water vapor partial pressure, and then completing the test chamber fill with the dry gas. The CIV voltage level was measured using the Biddle corona detector with sensitivity sufficient to detect 3 pC discharges. The system voltmeter was calibrated using instruments with traceability to NBS.

Results of the tests with dry and wet SF_6 at atmospheric pressure are presented in Fig. 3.1. Curve A is an approximate indication of the uniform electric field breakdown characteristic of SF_6 and was obtained from the technical literature [2]. The CIV curves show variation with different point radii ranging from 0.0065 - 0.317 cm. The differences between the dry and wet gas are similar to the same effects in air and are shown in Fig. 3.2 as a function of point radii with electrode spacing of 1.0 cm. The change of CIV with SF_6 gas pressure (p) was computed from the data at different pressures and found to be proportional to $p^{.65}$.

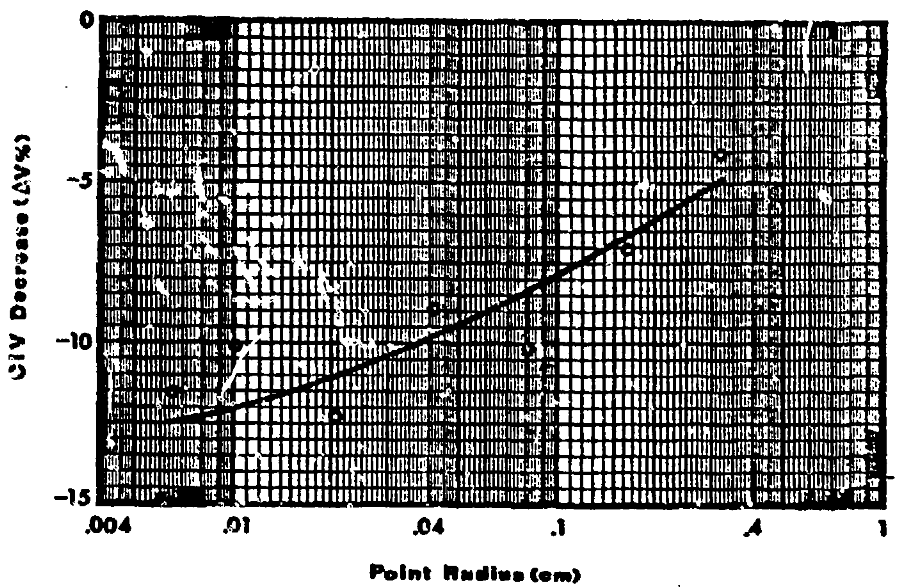

Fig. 3.2. CIV decrease in wet SF_6 compared to the dry gas as a function of point electrode radius

---

[2] J.M. Meek and J.D. Craggs, "Electrical Breakdown of Gasses," John Wiley & Sons, New York, pp 576 (1978)

These results are useful data for evaluating CIV on wires, solder tabs, and various metal electrode configurations in sonar transducers filled with SF_5 gas. These data together with that for air [1] will allow an approximate evaluation of CIV for air, SF_6, and water vapor mixtures if the relative gas concentration fractions are known.

3.3.2. The most useful results concerning PZT ceramic lifetime in the presence of corona have been obtained using a wafer of the material between the point-to-plane electrode configuration. This test allows establishing relatively high levels of corona on the ceramic surface and is stable over a fairly long period of time. Although this test does not truly measure the corona response of sonar transducers, it does provide a useful means of comparing various corona abatement techniques and materials. The test has been used by several investigators to evaluate insulating materials [3].

Figure 3.3 shows a response of this test to 1 mm thickness specimens of PZT and glass in dry and wet air atmospheres. The curves reveal that PZT allows the formation of corona discharges with levels 30-40 times greater than with glass, and that water vapor in the air reduces the corona discharge level.

The following are some interesting observations made during these tests.

- Ceramic failure due to corona (puncture through the sample) usually occurred inside microscopic cracks in the ceramic.
- The PZT ceramic endured a corona discharge level of 80,000 pC for nearly an hour before failure, and 50,000 pC for eight hours without failure.
- At corona levels greater than 120,000 pC, sustained arcing begins and ceramic failure occurs in about 3 seconds.

3.3.3. The application of ASTM D495-73, Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation, seems to be restricted to arcing applications and will have limited usefulness in evaluating corona abatement problems. It was used to observe the low-current arc breakdown of PZT. After the surface arc is initiated, track formation and material breakdown occurs within a few seconds. As the track forms, the arc intensity dims and becomes a bright glow in the conduction path

[3] L.L. Alston, "High Voltage Technology," Oxford University Press, London, pp 164-166 (1968)

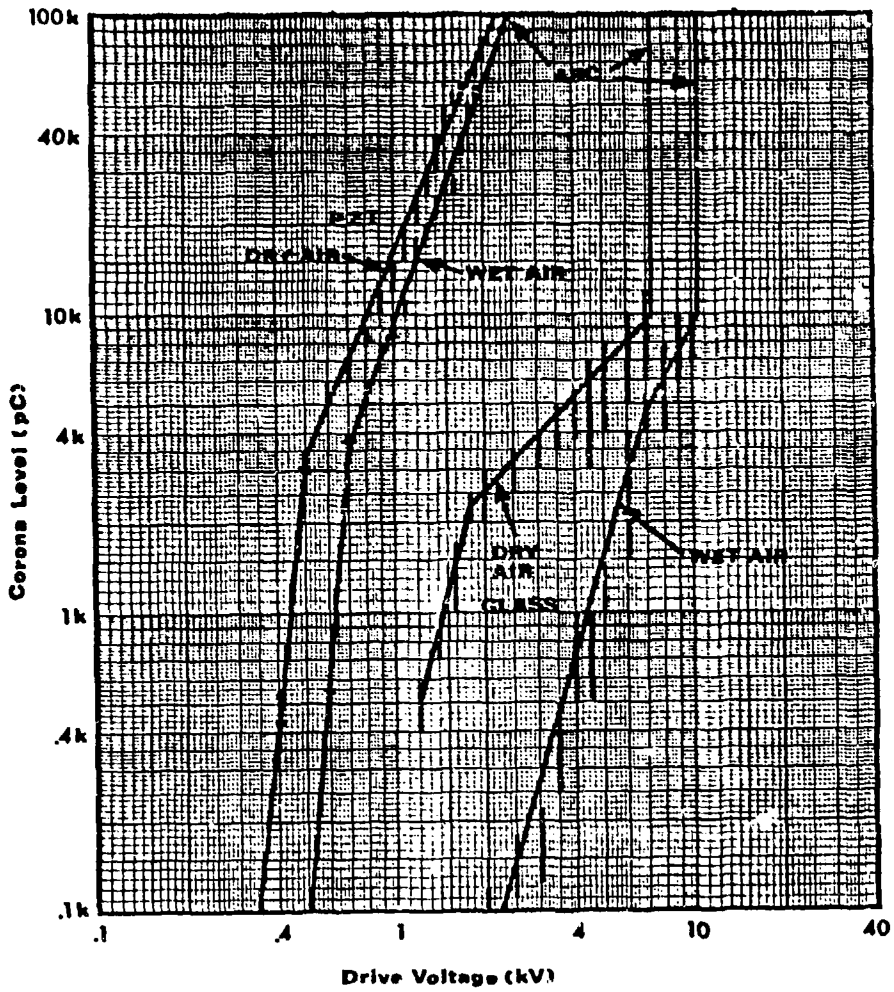

Fig. 3.3. Relative corona discharge levels on PZT ceramic and glass surfaces in dry and wet air

at the bottom of the track. Particles of PZT may crack loose on either side of the track, and a purple powder is deposited around it. When the arcing is stopped and the track allowed to cool, the ceramic regains 50 – 75% of its original electrical strength.

3.3.4. A se[illegible]es of tests were made on eight discs of Type I (PZT-4) ceramic wit[illegible] diameter of 1.27 cm (0.5 in.) and thickness of 0.635 cm (0[illegible] in.) to establish the corona and flashoever voltages of the clean [illegible]ry material. The results are summarized in Table 3.1.

	CIV (kV)		FLASHOVER (kV)	
R.H. OF AIR AT 25°C	AVERAGE	STANDARD DEVIATION	AVERAGE	STANDARD DEVIATION
<1%	5.68	1.09	7.28	.42
90%	3.87	.81	7.33	.35

Table 3.1. Ceramic corona in wet and dry air

These results indicate that with transducer designs such as the AN/SQS 56, the critical design factor in corona abatement is not the ceramic stack. Instead, use of adequate size hook-up wire (no smaller than #22) and the avoidance of sharp edges and points on solder tabs are required. Drying the ceramic and sealing in dry air helps increase the CIV.

3.3.5. Communication was maintained with the Transducer Repair Facility, Portsmouth, NH, to monitor the problems associated with the gas filling procedure for the TR-155 transducers. Information was received concerning the high-voltage test failures that occurred between 1 January and 22 June 1979. There were 1728 units processed and 17 failures, thus yielding a failure rate of 1%. This indicates that although the revised gas filling procedure is an improvement compared to the previous method with its 5.5% failure rate, it is still inadequate and should be instrumented to provide a positive indication of a complete gas fill.

3.4. PLANS

3.4.1. Continue the study of the PZT ceramic lifetime function to evaluate and identify specific ceramic defects that contribute to premature voltage breakdown.

3.4.2. Make a detail study of corona and arc formations on ceramic surfaces.

4. TASK C-1 - CABLES AND CONNECTORS

4.1. BACKGROUND

The use of cables and connectors is an area of concern for long-term sonar reliability because of a history of failures. Deficiencies can be generally categorized in the four areas of: design of cables and terminations; specification and testing; handling; and repair and maintenance. Specific problems have been identified in a recent failure modes and effects analysis of cables and connectors prepared for NAVSEA by General Dynamics/Electric Boat. They conclude, that of all the problem areas, the loss of bond of the molded boot to the connector shell or to the cable sheath is the most probable cause of failure. Cable jacket puncture in handling, at installation or in service is considered to be the second most probable cause of failure. These are the two problem areas to be addressed here.

4.2. OBJECTIVES

The general objective of the task is to provide improved reliability in the cables, connectors, and related hardware for the outboard elements of sonar transducer systems. It is occasionally necessary to also consider portions of the system interior to the ship's hull because the same cables are often used for significant distances through compartments inside the ship before terminating at their ultimate electronic package destination.

Specific objectives for the FY79 task are as follows:

- Investigate the use of cable/connector boot clamps to determine reliability and failure modes.
- Investigate the strength of unshielded cable and and shielded cable to determine reliability and failure modes.

4.3. PROGRESS

4.3.1. Work to fulfill these objectives is being performed under Contract N00173-79-C-0129 by Texas Research Institute, Inc. A task outline of this work, which began on 6 April 1979, is as follows.

The first phase of this project is to investigate the strength of unshielded and shielded cable to determine reliability and failure modes. This phase is composed of three tasks.

TASK 1: Develop Mission Profile and Test Plan

The purpose of Task 1 is to produce quantitative data about the environment and conditions which cables experience during storage, installation, ship operations and maintenance, to design a test plan to adequately simulate those experiences, and to obtain sufficient cable to evaluate the program.

TASK 2: Comparative Testing of Cables

The test plan devised in Task 1 will be carried out with the testing of several cables commonly used in the fleet. They are:

SHIELDED	UNSHIELDED
DSS-2	DSU-2
DSS-3	DSU-3
DSS-4	Trident 2-Conductor
FSS-2	Butyl 2-Conductor
	DSU-2 with reinforcement

Tensile tests of the cables and cable components have been started using a 10-cm diameter capstan grip. Components for the internal abrasion test equipment are being assembled. Two crush tests as described in ANSI/UL 44 will be used. These tests are the procedures identified thus far that will result in comparative data for crush and impact resistance in the shielded and unshielded cables. Relations of this approach to the test plan parameters and the mission profile will be discussed in the next progress report.

TASK 3: Analysis of Results

Results of the tests conducted in Task 2 will be examined to determine relative abilities of shielded and unshielded cables to survive the Mission Profile.

The second concurrent phase of this project is to investigate the use of cable/connector boot clamps to determine reliability and failure modes. This phase is composed of five tasks.

TASK 4: Develop Mission Profile and List Candidate Clamps

The purposes of this task are to produce a quantitative estimate of the Mission Profile of the connector, and a complete list of candidate clamping systems which may be selected for the tests. Continued evaluation of clamps has led to the following selections for this project:

Oetiker No. 16, $\frac{5}{8}$" dia. 316 s.s. single ear clamp with bridge
Oetiker No. 381, $1\frac{1}{2}$" dia. 316 s.s. single ear clamp with bridge
BAND-IT No. J253, 201 s.s. $\frac{1}{4}$" wide preformed clamp

The Oetiker clamps will be the primary clamps on connectors with the BAND-IT available as a back-up. All of the above clamps are preformed and as such may not be suitable for installation on existing connectors. These, however, will give uniform and controlled clamping to both connector backshell and cable, and are the most likely to result in a sealed connector.

TASK 5: Manufacture Instrumented Connectors

Under this task, TRI is manufacturing a quantity of MIL-C-24231 (Portsmouth) connectors which have been modified to permit instrumentation. The instrumentation will allow immediate determination of the presence of a leak and identification of the leakage paths. This approach will produce more useful data than using unmodified production connectors because the leakage paths can be positively identified and the leakage interface isolated. Since the leakage paths are isolated, the test of a connector can continue after one path has leaked in order to have more time for the other path to fail.

TASK 6: Conduct Factorial Experiment

In this task, a number of instrumented connectors will be pressure tested to determine if they develop leaks in either of two leakage paths between the boot and the metal backshell, and between the boot and the cable. A matrix will be constructed by assembling connectors with each of the combinations of features listed below:

Material:	Neoprene and polyurethane
Cable Type:	Shielded and unshielded
Bond:	Bonded and unbonded
Clamp:	None, Clamp 1, Clamp 2, Clamp 3

As can be seen, there are 32 combinations of the parameters of interest making up a matrix of tests. The resulting data will be manipulated using the method of Yates which is capable of revealing the sensitivity of the result to each of the constituent parameters as well as the interaction effects and internal estimates of experimental error.

TASK 7: Conduct Accelerated Life Tests on Connectors

A set of 32 instrumented control connectors manufactured under Task 5 will be subjected to accelerated life testing (ALT). The control connectors will be polyurethane, bonded onto the shielded cable with no clamps. After Task 6 is completed, the one most attractive combination of material, clamp type, etc., will be selected, and 32 identically instrumented connectors will be built of that preferred combination. Those selected connectors will then undergo accelerated life testing identical to that experienced by the controls. The accelerated life tests will include aging at elevated temperature, pressure cycling, fatigue testing, and ultimately a destructive pull test of the cable out of the connector. The concept of accelerated life testing will follow the general concept exercised in STRIP Task Area E.

TASK 8: Analysis of the Test Results

The results of the two tests (Factorial Experiment and Connector ALT) will be examined to provide answers to the questions about reliability and failure modes of boot clamps and to organize the additional data for useful presentation.

4.3.2. One result of the work done in this task area of STRIP in FY78 was the recommendation to establish administrative and logistic control of cables and connectors at the NAVSEA level, just as had been done in the past with the transducers themselves. One step in this direction has occurred with the establishment of a *Cables and Connectors Working Group* headed by C.A. Clark of NAVSEA 63XT. Two meetings of this group have been held (11, 12 April and 12, 13 Jun 1979). The initial objectives have been to quantify the specific cable and connector problems, obtain data, and lay out a plan of action to improve the situation. The approach will include R&D such as in this STRIP task as well as work in operations, quality control, and maintenance. Minutes of the meetings are available from C.A. Clark, NAVSEA 63XT.

4.4. PLANS

Work will continue on the contracted project and is scheduled for completion in six months. Another Cables and Connectors Working Group meeting will be held in August 1979 on the DT-276 cable/connector subsystem.

5. TASK D-1 - MATERIALS EVALUATION

5.1. BACKGROUND

Pressure release materials are used to mechanically and/or acoustically isolate some components of sonar transducers to improve overall acoustic performance. Normally the pressure release materials must operate effectively under bias stress anywhere from 50 psi to 3 kpsi over a discrete temperature range, e.g., 5°C to 40°C. To predict performance it is essential to know the properties of the materials under the imposed constraints. Previous measurement methods for determining the properties of some pressure release materials, such as Sonite (an asbestos - glass fiber composite), onion-skin paper, syntactic foams, Hytrel (a thermoplastic polyester elastomer), etc., have given relative results wiht a hydraulic press or bulk effects with an impedance tube. There is a strong need to correlate existing measurement data and to establish a standard measurement system to be used by the Navy for incorporation into specifications and/or acceptance tests on pressure release materials.

An additional problem is that pressure release materials absorb the transducer fill-fluids. This process increases the acoustic impedance of the pressure release material and thus reduces the effectiveness of its acoustic insulation. Degradations of from 3 dB in 3 years to 6 dB in 10 years have been reported in transducers in the field, and attributed to changes in the pressure-release material.

There are thus two phases to this task: the material characterization phase; and the fluid absorption phase.

5.2. OBJECTIVES

The objectives of this task are:

- To initiate and evaluate a standard dynamic measurement system to determining the properties of pressure release materials over the ranges of stress from 50 psi to 3 kpsi and at temperature from 5 to 40°C.
- To measure and evaluate candidate pressure release materials, such as Sonite, onion-skin, corprene, etc.
- To quantify the changes in acoustic properties of cork-rubber composites as they absorb transducer fill-fluids.

- To develop a math model that will predict changes in the acoustic properties of cork-rubber composites with time (and in turn predict changes in transducer directivity and sensitivity).
- To identify the specific problems with DC-100 which may eventually lead to its replacement with a more suitable material.

5.3. PROGRESS

5.3.1. The dynamic measurement system for the material characterization phase was described in the last quarterly progress report, and will not be repeated here. The supporting structure to freely suspend the mechanical measurement system has been built during this past quarter. The supporting structure is a movable unit so that the sample holder alone can be placed inside a temperature chamber and retracted. The complete assembly weighs approximately sixty pounds. The monitoring equipment has been assembled and the next step is to make a trial measurement run and alter the system as needed (e.g., to eliminate unwanted or spurious low-frequency resonancies in the system response, to reduce lateral clamping effects by the selection of a proper lubricant, instrumentation problems, etc.). Once the system is accepted as a viable measurement scheme, initial measurements will be made at room temperature on paraffin samples with different length-to-diameter ratios to determine possible lateral constraint effects induced by friction between the sample and loading mass surfaces. Afterwards, conventional pressure release materials such as onion-skin paper, Sonite, corprene, and Hytrel will be measured versus stress level to determine the extent of agreement with other published information on the materials. Temperature measurements are not expected to begin until FY80.

5.3.2. The phase of this task concerning the absorption of transducer fill-fluid by the pressure release materials has continued. Selections of cork-rubber composites have been soaking in castor oil, silicone oil, and polyalkylene glycol, and the permeation of the fluid has been monitored by gravimetric analysis, microscopic analysis, and by microtome sectioning.

The gravimetric analysis of oil permeation was concluded after 12 months (although 25°C tests will continue indefinitely). As an example of the collected data, Fig. 5.1 is a graph showing the temperature dependence for DC-100 immersed in castor oil (a commonly used combination). The ordinate is given as the flow of transducer fill-fluid through the exposed surface area in milligrams per square centimeter). The abscissa is the time (in hours) on a log scale. Most other combinations have similarly shaped graphs will varying degrees of curvature.

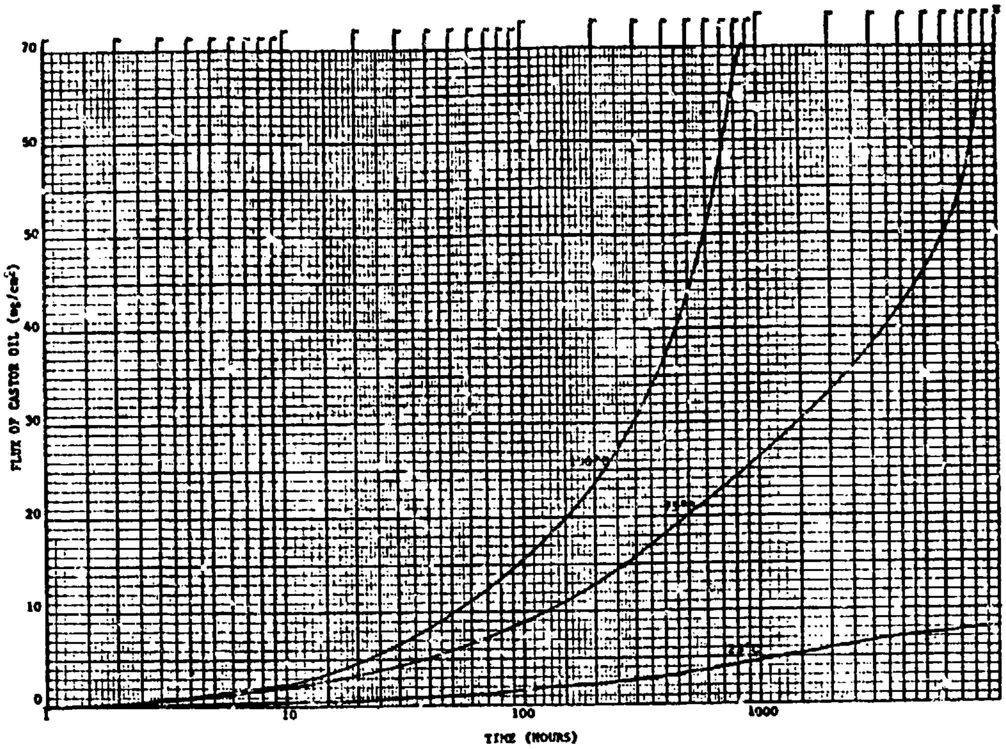

Fig. 5.1. Flow of castor oil through the surface of DC-100 as a function of time. The three curves show the temperature dependence.

Temperature dependency of oil soaking is, as usual, a complex function involving several steps with different energies of activation. It is obvious from Fig. 5.1 and the other similar graphs that the reaction is being accelerated by the increase in temperature. Calculations have been made to find the energy of activation in the region beyond the first layer of exposed cork, which would be influenced by viscous flow, and the middle of the sample, where the oil converges from the two exposed sides. It can be seen in Fig. 5.2 that the slope of the log-log plot of the flow of castor oil within this time frame is approximately 0.5 for the three temperatures tested. This, according to Fick's Second Law at diffusion, identifies a diffusion process.

$$k = k_o \, t^n \qquad (5.1)$$

where: k = rate of absorption

k_o = specific rate of absorption

t = time

or

$$\log k = n \log t + \log k_o \qquad (5.2)$$

Therefore, the slope of the log k vs log t plot gives the value of n. Also at t = 1, log k = log k_o.

Given this relationship, k_o was determined by extrapolating back to 1 hour on Fig. 5.2.

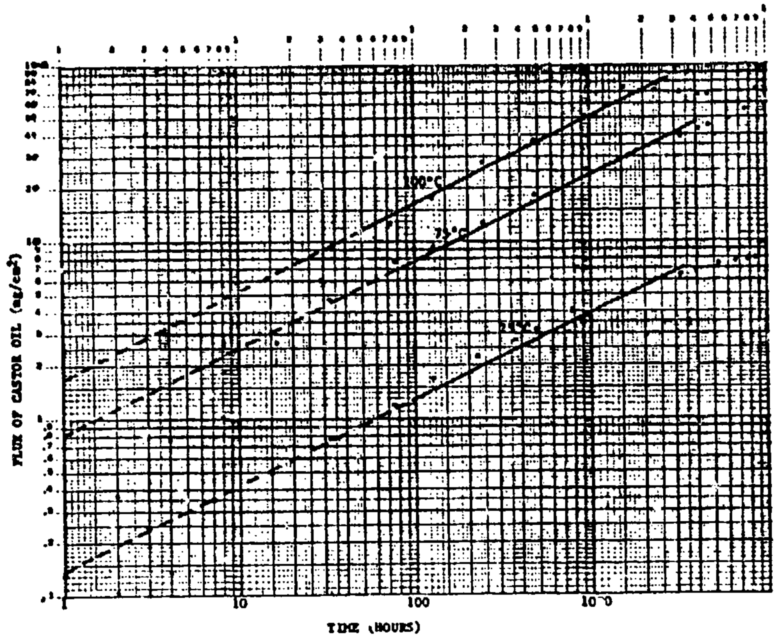

Fig. 5.2. Log-log plot of flow of castor oil through the surface of DC-100 at 25°C, 75°C, and 100°C.

In Fig. 5.3 is shown the relationship of the natural log of the extrapolated value of k_o and the reciprocal of the absolute temperature. Relating this information to the Arrhenius Equation

$$k_o = A \cdot \exp(-E_a/RT) \tag{5.3}$$

where: A = frequency factor

E_a = energy of activation

T = absolute temperature (°K)

R = gas law constant (0.4749 Joules/mole °K)

or

$$\ln k_o = \left(-E_a/_R\right)\left(\frac{1}{T}\right) + \ln A \tag{5.4}$$

Therefore, the slope of the ln k_o vs $\frac{1}{T}$ line equals $-E_a/_R$. From Fig. 5.3 the slope is -3670, therefore

$$E_a = 1745 \text{ Joules/mole}$$

An activation energy of 1745 Joules/mole is in the expected range for such a diffusion.

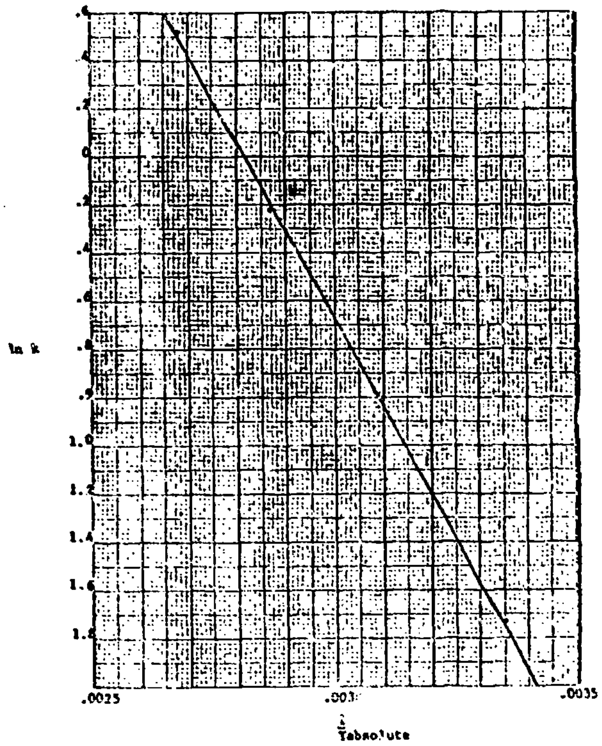

Fig. 5.3. Natural logarithm of specific rate vs reciprocal absolute temperature for DC-100 in PAG.

5.3.3. The microtome sectioning and microscopic analysis of cork-rubber composites exposed to castor oil were also concluded at the end of 12 months exposure. Samples that had been exposed to castor oil at 25°C and 75°C were sectioned at 250 μm intervals and weighed to determine the increase in weight per section (and therefore the increase in density). The sectioning was performed at 3 month intervals. Although the data have not been fully analyzed, several important factors will be found by this technique. These include the rate of advance of the fluid front as a function of time and temperature; the thickness of the fluid front; the maximum density of the composites; and whether or not the composite is dissolving along the exposed edge.

5.3.4. Impedance tube testing is underway to determine the reflection coefficient, speed of sound and attenuation for the cork-rubber composites. These tests are being conducted using samples with varying degrees of castor oil saturation. This will enable a mathematical model to be formulated that will predict acoustical changes in cork-rubber composites with time.

5.4. PLANS

- Impedance tube testing will be continued to determine the acoustic changes in cork-rubber composites with transducer fill-fluid absorption.
- With information accumulated from the above tests, a math model will be formulated and tested on a transducer element.
- Recommendations will be made about either a better pressure release material, a method to minimize changes in existing materials or a way to compensate for changes.

6. TASK E-1 - STANDARDIZED TEST PROCEDURES

6.1. BACKGROUND

It is at present not possible to subject a transducer specimen to a series of environmental stresses over a short time period and prove, if it passes certain operating parameter tests, that the specimen is a reliable transducer with a certain minimum expected life in fleet use. Of course, if we could simply use a set of transducers for the desired fleet life, we could check the failure rates against acceptable replacement or repair rates. But the approach here is to accelerate the environmental stress actions, and thereby subject the transducer specimen to seven years of life cycle stresses in a few weeks or months.

6.2. OBJECTIVES

The objective of this task is to develop a set of standardized procedures to accelerate the aging of transducers based upon environmental stress requirements.

6.3. PROGRESS

6.3.1. TR-215 and TR-316 Transducers

The Ametek-Straza TR-215 (prototype) and the TR-316 first article transducers failed to pass the high-drive accelerated life test (Tables 6.1, 6.2 and 6.3). This resulted in notification [1] to the contractor by NAVSEA 63XT of unacceptability of the Straza first article test report. Specifically, the failure was in the PD or wide beam sections of this under-ice navigation sounding transducer. The PD sections, when driven continuously at 126 volts rms and swept in frequency across the operating band initially showed satisfactory impedance measurements, well above the 50 ohms minimum required. But after a period of time ranging from a few minutes to several hours, the impedance began to drop below 50 ohms and the drive current, which may have been approximately 1.75 amperes initially, began to rise. NOSC, in testing these PD sections, stopped the testing when the current exceeded 3.0 amperes. In six of the eight PD sections (two TR-215 and two TR-316 transducers), the current was in a runaway condition when the test was terminated. The two TR-316 transducers, S/N A2 and A3 were returned to Straza. Upon disassembly of the two TR-215 units (S/N 2 and 4), the longitudinal resonators (there are five resonators wired in parallel in each PD section) showed signs of overheating (the Sylgard 184 had extruded from inside the resonator, a few of the ceramic rings had cracked and other signs at the rubber nodal grommet and acoustic window also indicated heat).

[1] NAVSEA 63XT1:CAC N00024-78-C-6090 Serial 72, 18 May 1979

CONTINUOUS DRIVE AT LOWEST OPERATING FREQUENCY. HIGH DRIVE WAS REMOVED WHEN INPUT CURRENT EXCEEDS 3 AMPS.					
TEST DATE	UNIT S/N	PD UP BEAM	NARROW BEAM	PD DOWN BEAM	TRANSDUCER POSITION & WATER DEPTH
3-21-79	4	DEFECTIVE Drew current exceeding 3 amps after 33 min with 100 V rms input.	Survived 16 hours (total test time) with 122-125 V rms input.	DEFECTIVE Drew current exceeding 3 amps after 27 min with 100 V rms input.	Transducer in horizontal position with radiating surfaces faceup. Water depth was approximately 11 meters.
3-22-79	2	May fail if driven for longer time period. Current & impedance variations follow same trend as defective units after driven with 100 V - 125 V rms for 102 min.	Survived 95 min (total test time) at 110 V rms input. However |Z| decreased from 52 Ω to 46 Ω. Out of spec when |Z| is less than 50 ohms.	DEFECTIVE Drew current exceeding 3 amps after 82 min with 125 V rms input. One week after the TRANSDEC test the rubber window was discovered punctured and leaking oil (4-2-79). This is the same window that the underside was burnt and carbonized, resulted from the ocean tower high-drive test of Nov 1978.	Same as for S/N 4 above.
5-1-79	4	DEFECTIVE Test on 3-21-79 indicate this beam drew current exceeding 3 amps after 33 min with 100 V rms input.	Tests on 3-21-79 indicate this beam survived 16 hours with 122-125 V rms input.	DEFECTIVE[1] Drew current exceeding 3 amps after 34 min with 110 V rms input.	Transducer in horizontal position, suspended on its side such that the radiating surfaces are perpendicular to the water surface. Water depth approximately 11.1 meters.

[1] Prior to high drive, castor oil was forced into the beam section to separate the rubber window from the beam resonators heads by approximately 0.190 inches.

Table 6.1. Summary of TRANSDEC high-drive tests on AMETEK-STRAZA TR-215 transducers

CONTINUOUS 2-SECOND LINEAR SWEEPS ACROSS THE OPERATING FREQUENCY BAND. INPUT VOLTAGE NOT CONSTANT ACROSS THE BAND DUE TO FREQUENCY RESPONSE OF DRIVING AMPLIFIER. HIGH DRIVE WAS REMOVED WHEN INPUT CURRENT APPROACHE 3 AMPS.					
TEST DATE	UNIT S/N	PD UP BEAM	NARROW BEAM	PD DOWN BEAM	TRANSDUCER POSITION & WATER DEPTH
4-3-79	4	DEFECTIVE Drew increasing current to 2.9 amps with 45 V rms at 1.5 kHz below highest operating frequency 132 min after start of sweep drive. Maximum voltage at the lowest operating frequency was 95 V rms. Rubber window bulged approximately 0.126 in. (measured 3 min after cessation of drive) compared to value when beam section was cold at room temperature.	Did not test	DEFECTIVE Drew increasing current to 2.9 amps with 53 V rms at highest operating frequency 27 min after start of sweep drive. Maximum voltage at the lowest operating frequency was 115 V rms.	Transducer in horizontal position with radiating surfaces faceup. Water depth was approximately 11 meters.
4-3-79	4	May fail if driven for longer time period. Approximately same drive levels as test for PD UP Beam (when transducer was in horizontal position) for 58 min (total available test time). Rubber window bulged approximately 0.070 in. (measured 3 min. after cessation of drive) compared to value when beam section was cold at room temperature	Did not test	DEFECTIVE Drew increasing current to 2.95 amps with 43 V rms at highest operating frequency 43 min. after start of sweep drive. Maximum voltage at the lowest operating frequency was 119 V rms.	Transducer in vertical position with the PD UP Beam section toward the water surface. Maximum water depth of transducer was approximately 11 meters.

Table 6.2. Summary of TRANSDEC high-drive tests on AMETEK-STRAZA TR-215 transducer suspended in two positions

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

CONTINUOUS DRIVE AT LOWEST OPERATING FREQUENCY. HIGH DRIVE WAS REMOVED WHEN INPUT CURRENT EXCEEDED 3 AMPS.					
TEST DATE	UNIT S/N	PD UP BEAM	NARROW BEAM	PD DOWN BEAM	TRANSDUCER POSITION & WATER DEPTH
3-21-79	A2 (First ARTICLE)	DEFECTIVE Draws current exceeding 3 amps after 42 min with 125 V rms input.	INOPERATIVE Input |Z| = 5 ohms, θ = 71 deg.	DEFECTIVE Draws current exceeding 3 amps after 9 min with 125 V rms input.	Transducer in horizontal position with radiating surfaces faceup. Water depth was approximately 11 meters.
3-1 & 2-79	A3 (First ARTICLE)	DEFECTIVE Draws current exceeding 3 amps after approximately 70 min with 125 V rms input. (Impedance drops rapidly from 70 ohms to 33 ohms during last 35 seconds).	Survived 81 min (total test time) with 125 V rms input.	Survived 16 hours (total test time) with 125 V rms input.	Transducer in horizontal position, suspended on its side such that the radiating surfaces are perpendicular to the water surface. Water depth was approximately 11.1 meters.

Table 6.3. Summary of TRANSDEC high-drive tests on AMETEK-STRAZA TR-316 transducers

What is the probable cause of this current runaway and consequent overheating? After much debate, experimental part testing and modeling calculations, it appears there are both design and assembly method errors. NOSC people see two basic problems to be solved. First, there is the problem of conducting the normal heat generated at the ceramic to the stainless steel case where it can be transferred to the ocean. Second, the resonator needs to behave as a resonator over a wider temperature range.

PROBLEM ONE: Heat transfer from the resonator ceramic to the ocean.

There are design errors which become apparent by considering the following aspects of Fig. 6.1. Note that the resonator is completely enclosed in very good insulative materials. The aluminum head mass, which itself is an excellent conductor of heat, is surrounded by the thick neoprene rubber acoustical window and below, by the micarta retainer block. The aluminum nodal mount is tightly encased in its neoprene grommet. The tail mass is surrounded on the side by the micarta retainer block and below by the pressure release pad. Close examination of the micarta retainer block reveals that it has a center line groove underneath, which was intended to allow the flow of air and fill-fluid during the filling process. However, this groove is deemed too small. At the top of the micarta block the neoprene window material shoulders tightly down on the retainer to cause its top surface to be approximately level with the the top of the housing flange surface. However, this shouldering design completely seals off the upper portion of the resonator cavity making it difficult to evacuate and fill with fluid, but more importantly preventing the heated fill-fluid from convecting its heat to the case.

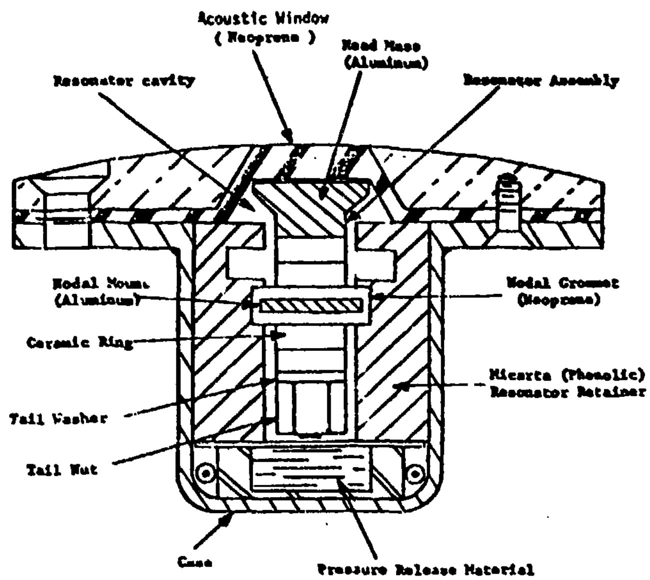

Fig. 6.1. Cross-Section of TR-316 Transducer

PROBLEM TWO: Resonator operation over a wider temperature range.

This problem was uncovered by pursuit of G. Kinnison's (NOSC) suggestion to heat the disassembled resonators in temperature increments and measure their frequency-swept impedance in air. The observation was that the heat indications appeared to be extreme only on one or two of the resonators and therefore these might show inordinate behavior with increasing temperature. They did. The impedance magnitude behavior shown in Fig. 6.2 typically showed a downward shift in frequency and a reduced amplitude difference between resonance and anti-resonance with increasing temperature. The room temperature (24°C) impedance is before the heat test and the 22°C curve is approximately 16 hours after the heat test. At the same time the phase angle of the impedance lost its typical extreme shifting at

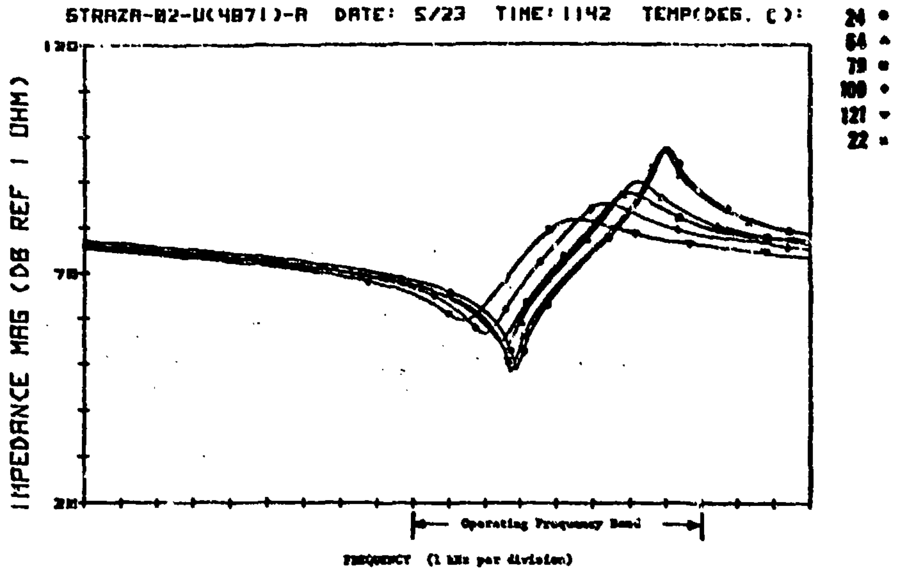

Fig. 6.2. Typical TR-215 Resonator Impedance Magnitude vs Frequency as a Function of Temperature in Air

resonance and anti-resonance as shown in Fig. 6.3. This indicates increasing loss of drive energy in the stack.

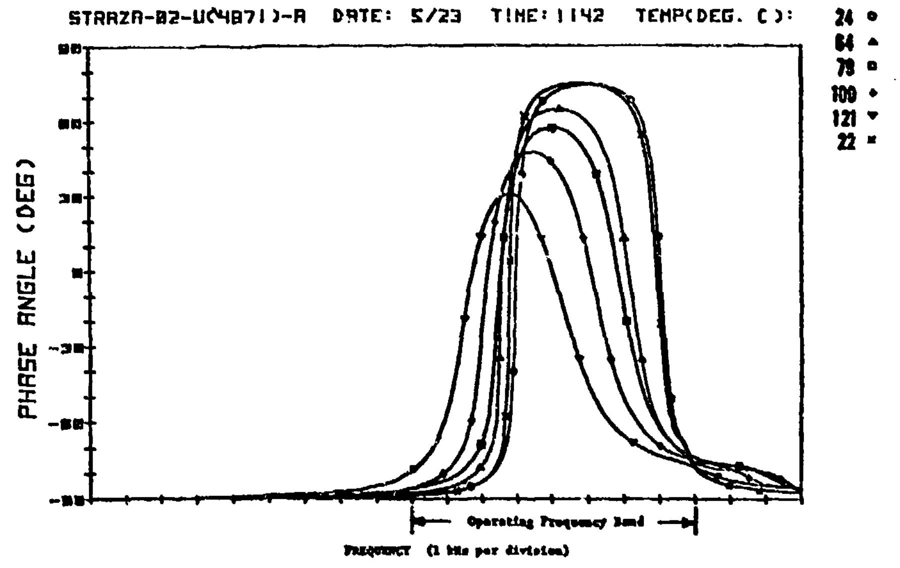

Fig. 6.3. Impedance Phase Angles of Resonator in Fig. 6.2

Because the frequency-swept impedance showed such inordinate behavior change with temperature increase it was suspected that the tail nut, which is not cemented to the ceramic, was decoupling from the stack assembly because of the greater thermal expansion coefficient of the stress rod. There was also some evidence of this, especially for those resonators with low stresses. Straza gauged the ceramic stress only by torque, which is a questionable assembly procedure. They used a stack frequency adjustment procedure which violates sound stressing principles ... one which employs a torque adjustment to achieve matched in-air resonance instead of the more responsible uniform stress approach and a more complex, with perhaps slightly lower yield, element selection and grouping procedure based on frequency and capacitance to establish specific element location in a stave.

6.3.2. A report entitled "Interim Report on Composite Unit Accelerated Life Testing of Sonar Transducers" has been issued as NOSC Technical Note 675.

6.3.3. DT-605 Transducer

Two Hazeltine Corporation DT-605 (S/N A1 and A5) transducers have completed the first exposure sequence (dry heat at 75°C) in the first year of accelerated life test agenda (Table 6.4). The acoustic test (beam patterns, receive voltage response and input impedance) following the dry heat exposure is now being conducted to obtain a before and after dry heat exposure comparisons.

EXPOSURE	TIME	PURPOSE	TIME COMPRESSION	EQUIVALENT SERVICE
Dry Heat 75°C UV Exposure*	475 hrs	Accelerate rubber degradation, reaction between fill-fluid and components, mechanical stress on boot due to expansion, degradation of rubber, simulate dockside storage	Accelerated Aging	16,300 hrs at 70°F (R = 13,000) 1-2 hrs/day of sunlight for 9 mo.
		TEST: BEAM PATTERN, TVR, OIL PRESSURE, RUBBER CHANGES, MEGGER		
Fresh Water 60°C	40 hrs	Water permeation, simulate wet operation	Accelerated Aging	375 hrs at 20°C (R = 13,000) 18,750 hrs at 20°C (R = 30,000)
		TEST: MEGGER		
Pressure Cycling	250 cycles	Mechanical stress, water instrusion, water permeation, simulate diving conditions.	Duty Cycle Increase	1 year diving
Pressure Dwell, 600 psi	2X 16 hrs ea	Mechanical stress, water instrusion, water permeation, simulate diving conditions.	Duty Cycle Increase	32 hrs at Pressure
		TEST: MEGGER, ACOUSTIC PROBE		
Thermal Shock -54° to 0°C	3 cycles	Mechanical stress due to contraction, elastomer and adhesive integrity, water intrusion, simulate, arctic conditions.	Duty Cycle Increase	One Arctic mission
Repeat Pressure Cycling & Dwells	-----	-----	-----	-----
		TEST: BEAM PATTERNS, TVR, IMPEDANCE		
High Power Drive	168 hrs	Simulate continuous operation	Duty Cycle Increase stress increase	One Arctic mission
		TEST: BEAM PATTERNS, TVR, IMPEDANCE		

* UV exposure is eliminated for the DT-605 hydrophone

Table 6.4. Revised Accelerated Life Test Proposed (July 78) for TR-215 ( ) or DT-605*

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

6.4. PLANS

6.4.1. To resolve the two problems in the TR-215 or TR-316, heat transfer from resonator ceramic to the ocean and resonator operation over a wider temperature range, the following approaches are considered.

- Use of aluminum retainer blocks for more efficient heat transfer to compare with the micarta retainer blocks that were used.
- Use type 914 high temperature adhesive in the resonators to compare with the old Epon VIII adhesive that was used.
- Higher stress on the ceramic during adhesive cure.
- New electrodes configurations for more uniform joints to provide better coupling between the ceramic and adhesive.
- No Sylgard 184 in the resonator and modify tail washer with larger grooves for better fill-fluid entry into resonator cavity.
- Thinner stress rod to allow operation at higher temperature without relieving the ceramic stress.
- Instrument with thermistors in several PD wide-beam sections using both aluminum and micarta retainer blocks to determine the heat transfer effectiveness under full power operation.

6.4.2. Continue with first year of accelerated life aging on the two DT-605 transducers.

7. TASK F-1 - NOISE AND VIBRATION

7.1. BACKGROUND

As submarine platforms become quieter and sonar systems become more sensitive, problems associated with transducer self-generated noise become more acute. The very real problem of transducer-produced noise has already been highlighted. Transducer self-noise can block out that transducer's operation as well as radiate out into the medium. Radiated noise can also interfere with other acoustic systems of a ship or submarine. Because of those problems, all new or improved transducers should be scrutinized for noise sources. At present there are no fully accepted methods for correlating the radiated noise from an installed transducer with the results of a laboratory test for noise. In addition, it is difficult to distinguish transducer noise from extraneous noise when transducers are tested in pressure tanks.

7.2. OBJECTIVES

The objectives of this task are to:

- Review and evaluate existing transducer self-noise criteria.
- Isolate and analyze sources of self-generated noise in transducers.
- Develop analytical criteria and test methods for evaluating transducer-radiated self-noise.
- Apply radiated self-noise criteria and test methods to sonar transducer standards.
- Develop test methods to discriminate between transducer self-noise and extraneous noise during acceptance tests in pressure tanks.

7.3. PROGRESS

7.3.1. Reports

A technical report (TR 397) entitled "Development and Application of a Transducer Radiated Self-Noise Criterion Based on Optimum Detection Theory" has been written and is currently being reviewed for security classification. In addition to the criterion itself, this report summarizes the application of this criterion to laboratory tests of the TR-215 transducer. A detailed description of the TR-215 tests are contained in a separate report (TN 647) entitled "Results of Radiated Self-Noise Measurements of TR-215 Transducer." Both reports will be distributed during the fourth quarter.

7.3.2. Crane Tests

Testing of transducers in large quantities and for many pressure cycles to measure pressure-induced self-noise is economical and practical only when accomplished by using pressure tanks. When measuring transducer noise in pressure tanks, however, it is difficult to differentiate between noise originating in the transducer and noise originating elsewhere. For example, the stress caused by pressure cycling not only causes the transducer to be a source of noise, but also causes the pressure tank, pressurization system, hydrophones, and anything else that is placed in the tank to be potential sources of noise. In addition, noise can be introduced into the system from outside sources through the physical structure of the tank and suspension system, or through the air. Noise transients caused by pressurizing the tank can be very similar in amplitude, time duration, and spectral content to the transients emitted by the transducer and can, therefore, make a transducer appear to be noisy when it is not. The rejection of a transducer during acceptance tests because of pressure tank or some other extraneous noise can have serious consequences in terms of costs, delays, and Navy/contractor relationships.

The pressure cycling and noise testing performed at the NWSC facilities has emphasized the need to be able to discriminate transducer self-noise from extraneous noise. This problem could be solved by using both time and amplitude differences, as analyzed at the outputs of various sensors, to distinguish the transducer's noise from other noise. A test setup for accomplishing this is shown in Fig. 7.1.

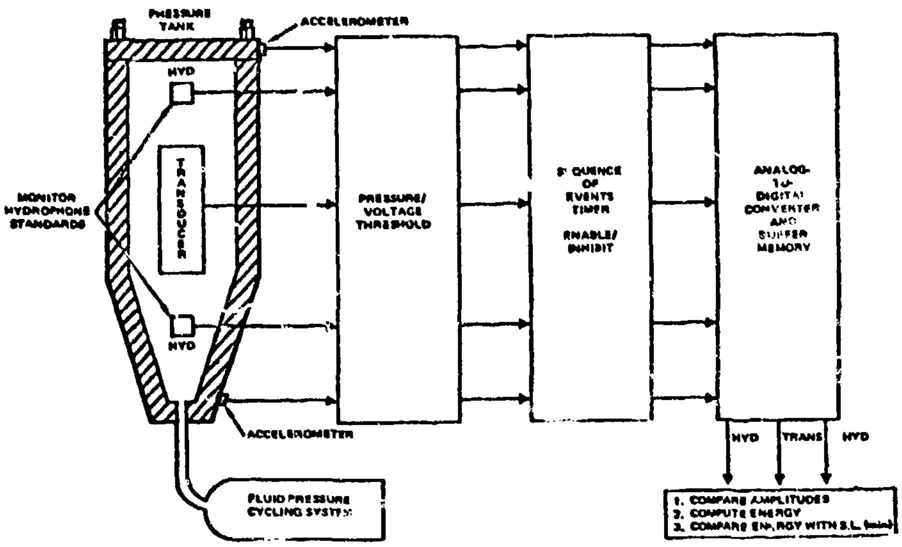

Fig. 7.1. Eliminating extraneous transients in pressure tank transducer self-noise tests

When measuring time differences, a noise transient originating in the test transducer would appear at the electrical outputs of the transducer before it would be picked up by the other sensors. Also, a noise transient originating outside the tank or from the tank itself would be detected by the accelerometer(s) before it is detected by the other sensors. Similarly, noise originating in a monitor hydrophone standard would be registered by that hydrophone before it is picked up by the other sensors. By limiting the system to respond only when the noise transient is first detected at the electrical outputs of the transducer, most of the extraneous noise could be eliminated.

Another situation could occur which is not covered by the above examples. Since the transducer has a characteristic frequency response, resonant at a specific frequency, the possibility exists that the transducer could radiate noise that is outside its frequency response range, and hence, not registered on the electrical leads. To cover this situation, amplitude and time discrimination is needed. If both monitor hydrophone standards detect a noise transient within the acoustic travel time required for a transient generated in the transducer to arrive at both standards, and if the amplitude measured is approximately (within 1 or 2 dB) the same for both standards, this transient should be accepted as being valid. The accelerometer(s) can also provide some time and amplitude discrimination. The response of the accelerometer(s) to noise generated inside the tank will be much less than noise generated on the tank structure itself. With experience, the relative amplitudes of the accelerometer(s) response as compared to the monitor hydrophone standards response, can be used to discriminate between internal, structural, and external noise.

In addition to the problem of isolating transducer self-noise and rejecting other noise, the question of how to measure and evaluate the radiated self-noise is still unresolved. Do we use the electrical transducer output only? If so, how do we obtain the transfer function between radiated and received levels in a reverberant tank? So-called "anechoic" tanks are "not," and the constraining dimension for reflections to interfere with the transfer function measurement is, typically, less than 5 feet in radius; therefore, reflections begin to interfere in less than 2 milliseconds! The safest approach (especially because the transfer function is DESIGN DEPENDENT) appears to be to measure both radiated and electrical outputs in the closed, reverberant tank, using external instrumentation hydrophones -- two in each tank. However, these instrumentation hydrophones need to be small, noiseless dur[illegible]peated pressure cyclings, and unusually sensitive so t[illegible]an be used also to isolate any pressurizing system noises which can enter the tank via plumbing.

Once a noise transient has been captured, should the detectability of that transient be evaluated by the peak pressure, total energy, energy spectral density, or by some other means? A side-by-side comparison of these different methods is needed to evaluated the potential applicability of each to pressure tank measurements.

A software program is being written to enlist the aid of a computer in the analysis and bookkeeping required for the outputs of the various pressure tank sensors. Time and amplitude comparisons will be made to develop a testing technique which will eliminate extraneous noise transients from transducer self-noise tests. The computer will also analyze the transducer self-noise transients in terms of peak pressure, total energy, energy spectral density, and time duration, and compare the results of each. The results of this comparison will help to establish a standardized test and analysis procedure for evaluating transducer self-noise in pressure tanks.

7.3.4. Pressure Release Material Tests

Parts have been received for reassembling the transducer piece-parts radiated self-noise pressure testing setup described in the STRIP Task F-1, Third Quarter Progress Report of 1978. The pressure tank has been pulsed with a known signal and the general acoustic characteristics plotted as a function of frequency. Tests will be conducted on NUSC-furnished samples of pressure release materials to measure the pressure-induced radiated self-noise.

7.3.5. Free-Field Measurements Test

The transducer-radiated self-noise free-field tests scheduled at Lake Pend Oreille, Idaho, have been rescheduled for the last week of August 1979. During this test the concept of lowering and raising transducers in a large body of water to measure pressure-induced self-noise will be investigated. Test platform flow noise, cable noise, and pressure related noise will be recorded and analyzed. Two "noisy" TR-155 elements will also be tested. The 1,200-foot cable required for this test is scheduled for delivery in July 1979.

7.4. PLANS

- The two technical reports (TR 397 and TN 647) will be distributed.
- A computer program will be written to analyze pressure tank test methods, eliminate extraneous noise during transducer acceptance tests, and compare different methods and criteria for evaluating radiated and electrical self-noise.

(This is contingent upon the receipt of funds necessary to support this task.)

- The pressure release material samples will be tested for radiated self-noise and an informal report written on the results.
- The Pend Oreille free-field tests will be conducted in August 1979.

8. TASK G-1 - SLEEVE-SPRING PRESSURE RELEASE MECHANISM

8.1 BACKGROUND

Some transducers in use by the fleet have been found to emit extraneous electrical and acoustical noise as a function of changing hydrostatic pressure. The primary source of the noise is believed to originate in the pressure release mechanism of the transducers. Interim fixes have been implemented, but final solutions require the development of new pressure release mechanisms.

8.2. OBJECTIVES

The objectives of this task are to develop, fabricate, test, and evaluate an alternative pressure release mechanism. The new pressure release mechanism will be in the form of a slotted metal sleeve spring and will be retrofitted into the TR-155 transducer for test and evaluation.

8.3 PROGRESS

The development of the sleeve-spring pressure release mechanism has been completed. The retrofitting of six TR-155 transducers with the TRI sleeve-spring pressure release mechanism has been completed. The retrofit modifications included the remounting of the transformer which is not expected to present any problem since these units will not undergo explosive shock test. In accordance with the test schedule at the NUSC/NLL Quiet Pressure Test Facility, the units were shipped to NUSC for noise testing. Before beginning the noise tests, the free-field voltage sensitivities of two of the units were measured. The measured FFVS appear to be as good as, or better than, that measured on comparable units with the conventional Belleville spring pressure release. The noise tests were scheduled to begin in the last part of May when NUSC decided to make modifications to the facility aimed at reducing electromagnetic interference. The modifications are taking longer than expected and NUSC/NLL has shipped the transducers to NWSC/Crane for the noise tests. The tests are now scheduled to begin at NWSC the second week in July and should be completed by the first week in August. The final report documenting the development, analysis, and transducer modifications is due from TRI by the end of July.

8.4. PLANS

The noise test results from NWSC and the TRI report will be combined into the final report on this task.

9. TASK G-2 - TEST AND EVALUATION

9.1. BACKGROUND

The improvements in engineering developments, the development of new test methods, and the new specifications and standards achieved must be utilized to assemble, test, and evaluate prototype transducers so that all implications of proposed changes will be known before introduction to the fleet.

9.2. OBJECTIVES

The general objectives of this task are to evaluate new engineering development transducer projects and to provide quantitative alternatives for solving problems encountered in the operation of fleet sonar systems. Specific objectives for FY79 are as follows:

- Determine the feasibility of replacing silicone fluid in operational transducers on a class-by-class basis.
- Determine the correlation between measurements of noise made in small tanks and those made in a free field.
- Evaluate the sleeve-spring pressure release mechanism for extraneous noise and pressure independence of acoustic performance.

9.3. PROGRESS

9.3.1. Further work on the replacement of silicone fluid in operational transducers is awaiting arrival of the TR-122 transducers.

9.3.2. To determine the correlation between the measurements of noise made in small tanks and free field, a transducer is being modified for use as a noise source. A small mechanical impulse source has been installed inside the transducer behind the module containing the ceramic, back mass and Belleville springs. This is shown in Fig. 9.1. The autotransformer of the transducer was removed to accomodate the installation of the noise source device. This device was built using four Type I ceramic disk elements stacked, cemented, and wired in parallel. The lower disk was used to isolate the stack from the transducer case. The stack was cemented to the 1.27 cm spacer that is between the retaining snap ring and the Belleville springs. A Faraday can was placed over the stack to isolate it electrically from the transducer leads that pass nearby. The noise source leads used are coax cables, with the shields connected to the Faraday can.

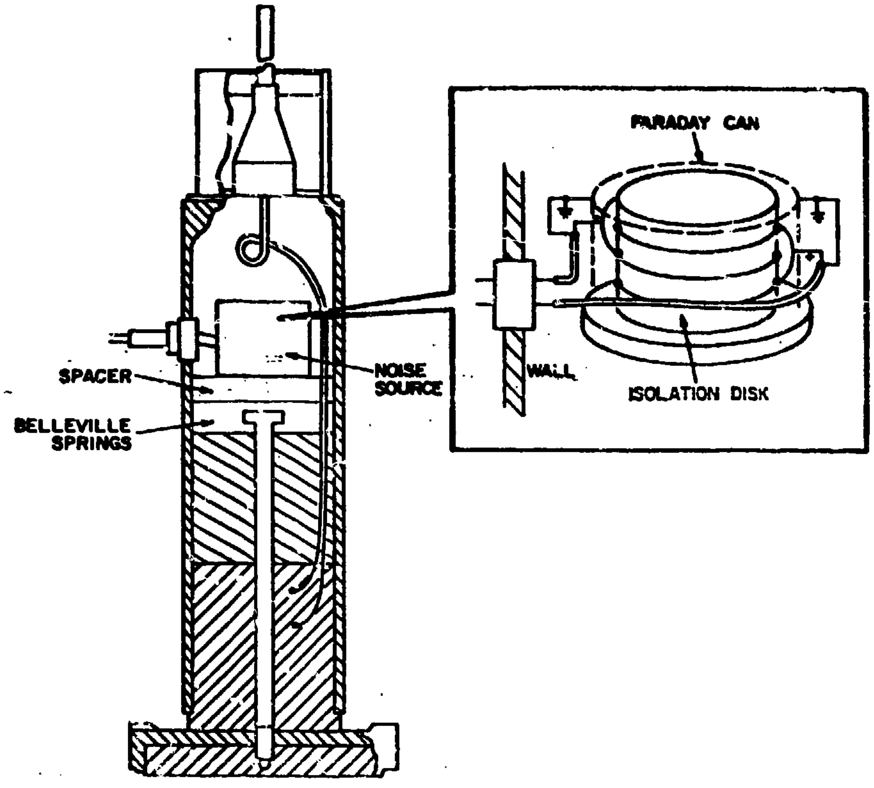

Fig. 9.1 Noise Source Transducer

The method of measurement is to excite the noise source with a sharp pulse which produces a burst of mechanical energy via the piezoelectric effect. This energy travels through the Belleville springs, the back mass and the ceramics of the transducer, through the window and into the water. A receiving hydrophone will be positioned at one meter distance from the window of the transducer and its signal will be fed into a spectrum analyzer. As the pulsed energy passes through the transducer's main ceramics an electrical signal will be generated and this signal can be analyzed and compared to the signal from the hydrophone These measurements will be done in the small tanks and in free field.

At present the modification of the transducer are complete and preliminary evaluation of its characteristics as a noise source is underway.

9.3.3. Evaluation of the sleeve-spring pressure release mechanism for extraneous noise is behind schedule because of schedule problems at NUSC.

9.4. PLANS

- The silicone oil replacement feasibility study for the TR-122 will begin contingent upon arrival of the transducers.
- Acoustic evaluation of the noise-source transducer will be completed at NRL/USRD. The transducer, power supply, and data recording systems will be transported to NOSC (Lake Pend Oreille) for participation in Task F effort (Section 7).
- A final report of the evaluation of the sleeve-spring pressure release mechanism in the TR-155 will be completed during the fourth quarter if noise measurements at NWSC are completed.

10. TASK G-3 - ENGINEERING DOCUMENTATION

10.1. BACKGROUND

It has recently become apparent to all facilities working with sonar transducers, that many problems are occurring which possibly could have been avoided. Problems with sonar transducer repair, production and/or testing have been repeated year after year simply because facilities did not see that research and development were needed. The lack of research and development can also be attributed to the fact that facilities have had very little interaction and possible solutions to problems encountered were not well documented. With the increasing numbers of sonar transducer types and acquisitions it will be necessary to know the existing and future needs for research and development. A task has been set aside for researching the severity of sonar transducer problems and establishing possible research and development projects.

10.2. OBJECTIVES

The objectives of this task are:

- To establish the existing and future needs for sonar transducer research and development.
- To produce a timetable for research and development programs that relates to sonar transducer acquisitions.

10.3. PROGRESS

Work has been completed in the literature search and notes have been compiled. An unsuccessful attempt was made to obtain a computer print-out of transducer failures that would have provided additional information.

The information obtained from the STAG and STEP reports and the acquisition schedule is being used to organize the importance of program topics.

Objectives have been written for each topic and will be used as a supplement in the program timetable.

The list of projects has been expanded somewhat and finalized. This will be used as the base for the program schedule. The list of topics is as follows:

- TR-215 extraneous noise
- TR-215 lifespan
- Transducer design parameters
- Water permeation of transducers and elastomers
- TR-155 sleeve-spring pressure release
- Pressure release materials
- Reliability of transducers

- Accelerated life test procedures for transducers
- PZT ceramic voltage breakdown
- Transducer fill-fluids
- Failure modes due to water in transducers
- BQS-8/10/14/15 transducers
- Unshielded cable strength and back shell leakage
- Ceramic lifespan
- Encapsulation materials
- Corona and reducing coatings
- Design parameters for preamplifiers
- Improved cables and connectors
- Design evaluation of UQN-1/4, BQN 17, DT-513A
- Potting compounds
- Fluids for towed arrays
- Shrink tubes for in-line splices
- Rubber specifications and accelerated life testing
- Baffle materials
- Accelerated life testing of DT-513A
- Water permeation of potted cavities
- Noise generation by fiberglass and ceramics under stress
- Identification of electrically weak transducers
- Transducer insulation aging
- Secondary noise generation by materials
- Design evaluation for TR212 (replacement)
- Design evaluation for DT-365 (replacement)
- Design evaluation for TR-155 (make it noise free)
- Handbook of insulation materials for transducers
- Handbook of transducer structural materials
- Handbook of cable and connector designs
- Optic fiber cables
- External isolation materials for transducers
- Noise reduction in the pressure release
- Determine a proper packaging procedure for storage of transducers
- Develop cable jacket specification control of ceramic variation from lot-to-lot

The factors that will be used in organizing the priorities of the timetable will be:

- Time of purchase
- Size of purchase
- Severity of transducer failures (quantity)
- Dependency of projects on actual failures

10.4. PLANS

A PERT-type chart of the program schedule will be developed along with the supplement of objectives.

DISTRIBUTION LIST FOR NRL MEMO REPORT 4009

Commanding Officer
Naval Coastal Systems Center
Panama City, FL 32407
ATTN: Code 750A, Mr. R.L. Cook (1)
ATTN: Code 753, Mr. R. Lovejoy (1)
ATTN: Code 790, Mr. D.F. Folds (1)

Officer-in-Charge
Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, CA 93043
ATTN: Code L43, Mr. J.V. Wilson (1)

Commander
Naval Ocean Systems Center
271 Catalina Blvd
San Diego, CA 92152
ATTN: Code 712, D.L. Carson (1)
ATTN: Code 712, J. Kinnison (1)
ATTN: Code 7123, C. Bohman (1)
ATTN: Code 7122, J. Wong (1)
ATTN: Code 7122, Dr. R.R. Smith (1)
ATTN: Code 724, Dr. G.E. Martin (1)

Commander
Naval Sea Systems Center
Washington, DC 20362
ATTN: SEA63XT, Mr. R.E. Heaney (1)
ATTN: SEA63XT-1, Mr. C.A. Clark (3)
ATTN: SEA63XT-2, Mr. P. Greenhaus (1)
ATTN: SEA63XT-4, Mr. T.G. Martin (1)
ATTN: SEA06H5-21, Ms. D.G. Bagley (1)
ATTN: SEA63R-12, Mr. C.C. Walker (1)

Commander
Naval Ship Engineering Center
Washington, DC 20262
ATTN: Code 6107, Mr. J. Pratchios (1)

Commander
Naval Electronic Systems Command
Washington, DC 20360
ATTN: Code 320, Ms. J. Bertrand (1)

Commanding Officer
Naval Weapons Support Center
Crane, IN 47522
ATTN: Code 70553, Mr. D.J. Steele (1)
ATTN: Code 70553, Mr. D. Moore (1)

Commanding Officer
Naval Underwater Systems Center
New London Laboratory
New London, CT 06320
ATTN: Code 316, Dr. C.H. Sherman (1)
ATTN: Code 316, Mr. R. DeAngelis (1)
ATTN: Code 316, Mr. T. Mapes (1)
ATTN: Code 316, Mr. C. LeBlanc (1)
ATTN: Code 316, Mr. R. Vogelsong (1)
ATTN: Code 316, Mr. C. Olds (1)

Commanding Officer
Naval Research Laboratory
Washington, DC 20375
ATTN: Code 2628 (20)
ATTN: Code 2628 (12 for DDC)
ATTN: Code 8000 (1)

Superintendent
Underwater Sound Reference Detachment
P.O. Box 8337
Orlando, FL 32856
ATTN: Code 8200 (1)
ATTN: Code 8270 (1)
ATTN: Code 8275 (4)
ATTN: Code 8215.2 (5)
ATTN: Code 8277 (3)
ATTN: Code 8278 (1)
ATTN: Code 8280 (1)

Transducer Repair Facility
Mare Island Naval Shipyard
Vallejo, CA 94592
ATTN: C. Porterfield (1)
ATTN: F. Peglow (1)

Transducer Repair Facility
Pearl Harbor Naval Shipyard
Pearl Harbor, HA 96860
ATTN: Code 270.3, R. Shigeta (1)

Transducer Repair Facility
Portsmouth Naval Shipyard
Portsmouth, NH 03804
ATTN: Code 216.11 Type Desk (2)
(A. Theirrien)
(E. Comeau)

Applied Physics Laboratory
University of Washington
1013 NE 40th
Seattle, WA 98105
ATTN: Dr. C.J. Sandwith (1)

General Dynamics
Electric Boat Division
Groton, CT 06340
ATTN: Mr. E.C. Hobaica (1)

Hazeltine Corporation
115 Baystate Drive
Braintree, MA 02184
ATTN: G.W. Renner

Submarine Signal Division
Raytheon Company
P.O. Box 360
Portsmouth, RI 02871
ATTN: N. Serotta, K33 Transducer Prgm
Mgr (1)
ATTN: D. Ricketts, Consultant,
Design Engr Lab (1)

Texas Research Institute
5902 W. Bee Caves Road
Austin, TX 78746
ATTN: Dr. J.S. Thornton (1)

TRACOR, Inc.
Systems Technology Division
1601 Research Blvd
Rockville, MD 20850
ATTN: Mr. P. Flannery (1)
ATTN: Mr. B. McTaggart (1)
ATTN: Mr. J. Guarnieri (1)

Man Tech Corp.
Century Bldg, Suite 103
2341 Jefferson Davis Highway
Arlington, VA 22202
ATTN: Mr. S.S. Shimomura