Image Cover Sheet

TITLE

Chemical resistance of candidate accelerometer cable sheathings to fluids used on CF ships

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JAN 2000**	2. REPORT TYPE	3. DATES COVERED
4. TITLE AND SUBTITLE **Chemical Resistance of Candidate Accelerometer Cable Sheathings to Fluids Used on CF Ships**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defence R&D Canada - Atlantic,9 Grove Street, PO Box 1012,Dartmouth, Nova Scotia B2Y 3Z7 Canada, ,**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Ship Noise Group DREA is studying ships vibrations radiated into the ocean. This study is part of the "Ship Noise Management System" project whose goal is to predict a ship's signature from within the ship. To monitor the vibrations, accelerometers are to be mounted m the bilge spaces of CF Ships. There was concern that the fluids in the bilge space might degrade the accelerometer cable sheathing and affect the accelerometer output. The Materials Chemistry Group DREA was asked to aid in the selection of an accelerometer cable sheathing with the required resistance to bilge fluids. The sheathmgs, taken from Vibra Metncs, PCB Piezotronics and Wilcoxon Research accelerometers, were immersed in six flmds and their chem1cal resistance evaluated by momtonng weight gain. The six flmds were 3-GP-24 aviation turbme fuel, MIL-H-5606 hydrauhc fluid, MIL-L-23699 synthetic lubricating ml, MIL-L-9000 diesel lubricating ml 6% AFFF in water, and ethlyene glycol/water (1: 1). The urethane based sheathings had good to exce1lent resistance to all fluids except the synthetic lubricating oiL The copolymer sheathmg exhibited only fair resistance to the aviation turbine fuel and the hydraulic fluid. As the major organic constituents of bilge flmds are fuels and hydrocarbon based lubricants, polyurethane cable sheathing is suitable for use m bilge spaces.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**35**	

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CHEMICAL RESISTANCE OF CANDIDATE ACCELEROMETER CABLE SHEATHINGS TO FLUIDS USED ON CF SHIPS

R.D. Haggett – J.A. Hiltz

DEFENCE RESEARCH ESTABLISHMENT ATLANTIC

Technical Memorandum

DREA TM 2000-011

January 2000

National Defence Défense nationale

Canada

National Defence
Research and Development Branch

Défense nationale
Bureau de recherche et développement

DREA TM 2000-011

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TECHNICAL MEMORANDUM

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Abstract

The Ship Noise Group DREA is studying ships vibrations radiated into the ocean. This study is part of the "Ship Noise Management System" project whose goal is to predict a ship's signature from within the ship. To monitor the vibrations, accelerometers are to be mounted in the bilge spaces of CF Ships. There was concern that the fluids in the bilge space might degrade the accelerometer cable sheathing and affect the accelerometer output. The Materials Chemistry Group DREA was asked to aid in the selection of an accelerometer cable sheathing with the required resistance to bilge fluids.

The sheathings, taken from Vibra Metrics, PCB Piezotronics and Wilcoxon Research accelerometers, were immersed in six fluids and their chemical resistance evaluated by monitoring weight gain. The six fluids were 3-GP-24 aviation turbine fuel, MIL-H-5606 hydraulic fluid, MIL-L-23699 synthetic lubricating oil, MIL-L-9000 diesel lubricating oil, 6% AFFF in water, and ethlyene glycol/water (1:1).

The urethane based sheathings had good to excellent resistance to all fluids except the synthetic lubricating oil. The copolymer sheathing exhibited only fair resistance to the aviation turbine fuel and the hydraulic fluid. As the major organic constituents of bilge fluids are fuels and hydrocarbon based lubricants, polyurethane cable sheathing is suitable for use in bilge spaces.

Résumé

Le Groupe des bruits des navires du CRDA étudie présentement les vibrations émises dans l'océan par les navires. Cette étude est réalisée dans le cadre du projet sur le "Système de gestion des bruits des navires" dont l'objectif est de prévoir la signature acoustique à partir d'un point situé dans le navire. L'installation d'accéléromètres dans la cale de navires des FC permettra de mesurer les vibrations. Nous nous demandions s'il n'y aurait pas dégradation de la gaine des câbles des accéléromètres par les eaux de cale et, partant, modification du signal de sortie des accéléromètres. Nous avons demandé l'aide du Groupe de la chimie des matériaux du CRDA pour sélectionner une gaine de câble possédant la résistance voulue aux eaux de cale.

Nous avons plongé dans six liquides des gaines de câble provenant d'accéléromètres *Vibra Metrics*, *PCB Piezotronics* et *Wilcoxon Research*, puis nous avons évalué leur résistance chimique en déterminant les gains de poids. Les six liquides en question étaient le carburéacteur 3-GP-24, le liquide hydraulique MIL-H-5606, l'huile de graissage synthétique MIL-L-23699, l'huile de graissage pour diesel MIL-L-9000, une solution aqueuse à 6 % d'une mousse de type A.F.F.F. et un mélange (1/1) d'éthylèneglycol/eau.

Les gaines à base d'uréthane présentaient une résistance allant de bonne à excellente à tous les liquides, sauf à l'huile de graissage synthétique. Les gaines en copolymère ne présentaient qu'une résistance moyenne au carburéacteur et au liquide hydraulique. Comme les principaux constituants organiques des eaux de cale sont des carburants et des lubrifiants à base d'hydrocarbure, les gaines de câble en polyuréthane conviennent dans ces endroits.

DREA TM 2000-011

Chemical Resistance of Candidate Accelerometer Cable Sheathings to Fluids Used on CF Ships

Randall D. Haggett and John A. Hiltz

EXECUTIVE SUMMARY

Introduction

The Ship Noise Group DREA is studying ships vibrations radiated into the ocean. This study is part of the "Ship Noise Management System" project whose goal is to predict a ship's signature from within the ship. To monitor the vibrations, accelerometers are to be mounted in the bilge spaces of CF Ships. There was concern that the fluids in the bilge space might degrade the accelerometer cable sheathing and affect the accelerometer output. The Materials Chemistry Group DREA was asked to aid in the selection of an accelerometer cable sheathing with the required resistance to bilge fluids.

This report describes the evaluation of the resistance of three commercial accelerometer cable sheathings to six fluids commonly found in the bilge spaces of CF Ships. The sheathings were from Vibra Metrics, PCB Piezotronics and Wilcoxon Research accelerometers. The six fluids were 3-GP-24 aviation turbine fuel, MIL-H-5606 hydraulic fluid, MIL-L-23699 synthetic lubricating oil, MIL-L-9000 diesel lubricating oil, 6% AFFF in water, and ethylene glycol/water (1:1).

Principal Results

Analysis of the three sheathings samples indicated that the Vibra Metrics sheathing is a cross-linked copolymer similar to poly(tetrafluoroethylene-propylene), and that the PCB Piezotronics and Wilcoxon Research sheathings are poly(ether)urethanes. The chemical resistance of the sheathings to the fluids was evaluated by monitoring weight gain of the sheathings while immersed in the fluids.

The Vibra Metrics cable sheathing exhibited good resistance to petroleum based and synthetic lubricating oils but poor resistance to the lighter hydrocarbons found in hydraulic fluids and fuels. The PCB Piezotronics and Wilcoxon Research cable sheathings (polyurethane) exhibited good resistance to all the test fluids except synthetic based lubricating oil.

On the basis of the immersion testing and data on the major organic constituents of bilge fluids, the polyurethane based cable sheathings were determined to be suitable for use in the bilge spaces of CF Ships.

Significance of the Results

Installation of accelerometers with cable sheathing that has the required resistance to bilge fluids eliminates failures related to chemical attack on the sheathing. This will ensure that the accelerometers will work as planned and that the vibration information is collected in a timely manner.

CRDA TM 2000-011

Résistance chimique de gaines de câble d'accéléromètre d'intérêt potentiel aux liquides utilisés à bord des navires des FC

Randall D. Haggett et John A. Hiltz

RÉSUMÉ À L'INTENTION DE LA DIRECTION

Introduction

Le Groupe des bruits des navires du CRDA étudie présentement les vibrations émises dans l'océan par les navires. Cette étude est réalisée dans le cadre du projet sur le "Système de gestion des bruits des navires" dont l'objectif est de prévoir la signature acoustique à partir d'un point situé dans le navire. L'installation d'accéléromètres dans la cale de navires des FC permettra de mesurer les vibrations. Nous nous demandions s'il n'y aurait pas dégradation de la gaine des câbles des accéléromètres par les eaux de cale et, partant, modification du signal de sortie des accéléromètres. Nous avons demandé l'aide du Groupe de la chimie des matériaux du CRDA pour sélectionner une gaine de câble possédant la résistance voulue aux eaux de cale.

Dans le présent rapport, nous décrivons l'évaluation de la résistance de la gaine de câbles provenant de trois accéléromètres commerciaux, soit *Vibra Metrics*, *PCB Piezotronics* et *Wilcoxon Research*, à six liquides couramment présents dans la cale des navires des FC. Les six liquides étaient le carburéacteur 3-GP-24, le liquide hydraulique MIL-H-5606, l'huile de graissage synthétique MIL-L-23699, l'huile de graissage pour diesel MIL-L-9000, une solution aqueuse à 6 % d'une mousse de type A.F.F.F. et un mélange (1/1) d'éthylèneglycol/eau.

Principaux résultats

L'analyse des trois échantillons a révélé que la gaine *Vibra Metrics* est constituée d'un copolymère réticulé semblable au poly(tétrafluoroéthylène-propylène), tandis que les gaines *PCB Piezotronics* et *Wilcoxon Research* étaient constituées de poly(éther)uréthanes. Nous avons évalué la résistance chimique des gaines en déterminant leur gain de poids pendant qu'elles étaient plongées dans les liquides.

La gaine *Vibra Metrics* présentait une bonne résistance aux huiles de graissage à base de pétrole et aux huiles de graissage synthétiques, mais une résistance médiocre aux hydrocarbures plus légers présents dans les liquides hydrauliques et les carburants. Les gaines *PCB Piezotronics* et *Wilcoxon Research* (en polyuréthane) présentaient une bonne résistance à tous les liquides d'essai, sauf à l'huile de graissage synthétique.

Selon les résultats des essais d'immersion et les données sur les principaux constituants organiques des eaux de cale, il a été déterminé que les gaines en polyuréthane étaient suffisamment résistantes pour être utilisées dans la cale des navires des FC.

Importance des résultats

L'installation d'accéléromètres dont les câbles sont protégés par une gaine possédant une résistance suffisante aux eaux de cale permet d'éliminer les pannes provoquées par la dégradation chimique du matériau de la gaine. Ainsi, les accéléromètres fonctionneront de la manière prévue et permettront d'obtenir en temps utile des données sur les vibrations.

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Introduction

As part of the development of the "Ship Noise Management System", accelerometers will be mounted in the bilge spaces of CF Ships to monitor ship vibrations that may be radiated from the ship into the ocean. The cable connecting the accelerometers to the monitoring system will run through the bilge and will be exposed to any fluids that are present in the bilge. If the bilge fluid degrades the sheathing this can result in variations in the conductance of the cabling and may affect the accuracy of the accelerometer readings.

There are a number of fluids that are found in the bilge spaces of CF Ships [1]. These include aviation turbine fuel, naval distillate fuel, ethylene glycol based coolants, synthetic and hydrocarbon based lubricating oils, hydraulic fluids, and aqueous film forming foam (AFFF) used for fire fighting. The effects of fluids on cable sheathing will depend on the composition of the cable sheathing and the fluid. Exposure of a polymer material, such as a cable sheathing, to a fluid can result in diffusion of the fluid into the polymer. Absorbed fluid will cause the polymer to swell and have adverse effects on the properties of the polymer. In the worst case the fluid can cause total dissolution of the polymer.

In this memorandum the results of immersion testing of three cable sheathings in six fluids are reported. The cable sheathings were removed from three commercial accelerometers proposed for use in the ship vibration study. The six fluids were selected as being representative fluids in a bilge space that could degrade polymeric cable sheathing.

Experimental

Accelerometers

The cable sheathing from three accelerometers were evaluated. The accelerometer manufacturer and model number are listed in Table 1.

Table 1

Manufacturer, accelerometer model number and cable sheathing composition (supplied by the manufacturers) of accelerometers used in this study.

Manufacturer	Model	Sheathing
Vibra Metrics Hamden, Connecticut	8002	**TUFKEM** cross linked copolymer
PCB Piezotronics Depew, New York	625A12	polyurethane
Wilcoxon Research Gettysburg, Maryland	748	Poly(vinylchloride)

Cable Sheathing

Cable sheathing compositions, as indicated by the manufacturer, are listed in Table 1. The weight per unit length was determined for each of the sheathings. There were Vibra Metrics - 0.1593 gm/cm, Wilcoxon Research - 0.1047 gm/cm and PCB Piezotronics – 0.2679 gm/cm.

Immersion Fluids

The sheathing of each accelerometer was immersed in six fluids commonly used on CF ships. These fluids were MIL-L-23699 Synthetic lubricating oil [2], MIL-H-5606 Petroleum based hydraulic fluid [3], MIL-L-9000 Diesel Lubricating oil [4], 3-GP-24 High Flash Type Aviation Turbine Fuel (NATO F-44) [4], 1:1 Ethylene glycol/water mixture [6], and 6% (by volume) Aqueous Film Forming Foam [7] in seawater.

MIL-L-23699 is a 5 centistoke (cSt) synthetic gas turbine lubricating oil manufactured using neopentyl polyol ester base stocks.

MIL-H-5606 is a petroleum based hydraulic fluid commonly used in aircraft hydraulic systems and in the hydraulic systems of some shipboard weapons systems.

MIL-L-9000 diesel lubricating oil is a mineral oil based lubrication oil used in propulsion and auxiliary diesel engines on all CF Ships.

3-GP-24 aviation turbine fuel is a minimum 60^0C flash point fuel used onboard CF and NATO Ships to fuel helicopters and fixed wing aircraft.

Ethylene glycol/water mixture (1:1) is used in the cooling systems of most shipboard diesel engines.

Aqueous Film Forming Foam (AFFF) is a fluorinated surfactant normally used onboard ship in a 3 or 6 percent dilution (by volume) of a concentrate, in fresh or seawater, to fight fuel related fire. An AFFF solution is sometimes poured into a bilge space to prevent a fire if hot work or welding is being carried out.

The fluids were selected as being representative of the range of fluids that could be found in a bilge. For instance, both a synthetic ester based (MIL-L-23699) and a hydrocarbon based (MIL-L-9000) lubricating oil were used as immersion fluids as their compositions are very different. 3-GP-11 naval distillate fuel was not used because aviation turbine fuel (3-GP-24), which contains lighter (lower boiling) but structurally similar hydrocarbons, is more aggressive towards polymers with poor resistance to hydrocarbons. MIL-H-5606 hydraulic fluid was included as it is a lighter hydrocarbon based fluid than 3-GP-36 hydraulic fluids and therefore should be more aggressive. Ethylene glycol and AFFF are water soluble chemicals found on CF ships that may end up in the bilge spaces.

Instrumentation

Gas chromatography/mass spectrometry (GC/MS) analysis was carried out on a Fisons Platform II quadrupole MS with a Fisons Model 8000 GC. A 30m long X 0.25 mm inside diameter ARX-5 capillary column with a 0.25 μm thick stationary phase (5% phenyl-95%dimethylpolysiloxane) was used for all separations.

For GC/MS analysis, the temperature program for the GC oven consisted of holding the temperature at 40°C for 5 min, ramping the temperature to 150°C at a rate of 8°C/min, and then ramping the temperature to 300°C at a rate of 10°C/min. The temperature was then held at 300°C for 15 min. The GC was operated in the constant flow (0.7mL/min) mode using Helium as the carrier gas. Samples were dissolved in hexane (1 in 100 dilution) and 1 microliter of the resulting solution analysed. The GC injector temperature was set at 275°C.

All pyrolyses were performed using a CDS Model 2000 pyroprobe controller and a platinum coil pyroprobe (Chemical Data Systems, Oxford, PA). The sheathing sample (0.1 mg to 0.2 mg) was centered with glass wool in a 25 mm quartz tube and heated with the ramp off (maximum heating rate) to the final temperature (700°C). The hold time at the final temperature was 20 seconds. The pyroprobe/GC interface was held at 300°C.

For pyrolysis GC/MS analysis, the temperature program for the GC oven consisted of holding the temperature at 40°C for 5 min, then ramping the temperature to 300°C at a rate of 10°C/min, and finally holding at 300°C for 10 minutes. The GC was operated in the constant pressure mode (10 psi) using Helium as the carrier gas.

Immersion Testing - Procedure

Seven equal sized lengths of the cable sheathings were stripped from each of the accelerometer cables. Each section of sheathing was cut lengthwise and the inner protective coating was removed. Cutting the sections lengthwise in effect doubled the surface area of the sheathing, i.e., both inner and outer surfaces of the sheathing were exposed to the immersion fluid. This facilitated drying the sheathing section after removal from the fluid and prior to weighing. The sections were weighed and a section was immersed in each of the six fluids. One section of each cable was set aside as a blank sample. Following immersion for 2, 4, 6 and 24 hour the cable sheathing was removed, patted dry to remove excess fluid, weighed and replaced in the fluid. After the first 24 hours the sections were weighed at 24 hour intervals for for the duration of the test.

Plots of weight gain versus the square root of time ($t^{1/2}$) can be used to calculate diffusion coefficients for fluids in a polymeric material. In many instances the weight gain of a polymer in contact with a fluid correlates with the chemical resistance of the polymer to the fluid. That is, the larger the weight gain of the polymer in contact with the fluid, the lower its chemical resistance to that fluid. This has been used to comment on the chemical resistance of the three cable sheathing samples to the immersion fluids.

Weight change of the immersed sheathing section was calculated as the difference in the weight of the sheathing section at immersion time t and the weight of the sheathing section prior to immersion. Percent weight change was calculated by dividing weight change by the weight of the sheathing prior to immersion and multiplying by 100.

Immersion tests were carried out at approximately 23°C.

Results

Gas Chromatography/Mass Spectrometry Analysis of Fluids

Chromatograms of MIL-L-23699 synthetic lubricating oil, MIL-H-5606 hydraulic fluid, MIL-L-9000 diesel lubricating oil and 3-GP-24 aviation turbine fuel are shown in Figures 1a through 1d respectively. The chromatograms are plots of intensity (y-axis), that is, the amount of a particular constituent in the sample, versus the time it takes for the constituents to elute from the chromatographic column. The GC/MS also stores a mass spectrum for each of the peaks in the chromatograph that can be used to identify the constituents of the mixtures.

Comparison of the chromatograms indicates that the four fluids are very different in composition. For instance, the chromatogram for MIL-L-23669 has a number of distinct peaks at 34.07 min, 34.77 min, 35.54 min, 36.48 min, 37.53 min, and 38.73 min while the chromatogram for MIL-L-9000 has a very broad envelope of poorly separated peaks between 26 min and 45 min. Mass spectral analysis of MIL-L-23996 indicates that its major constituents are neopentyl polyol esters while mass spectral analysis of the constituents of MIL-L-9000 indicates that it is composed a mixture straight and branched chain saturated and unsaturated hydrocarbons. Mass spectral analysis indicated that MIL-H-5606 is a mixture of cyclic and unsaturated aliphatic hydrocarbons containing between eleven and sixteen carbons and that 3-GP-24 is a mixture of straight and branched aliphatic hydrocarbons containing between eight and sixteen carbons and alkyl substituted aromatic hydrocarbons. The shorter retention times of the constituents of aviation turbine fuel are indicative of their lower molecular weights and boiling points compared to the constituents of MIL-L-9000 and MIL-H-5606.

The properties of the constituents of the fluids, that is, their boiling points, molecular weights, polarity, and structure, are important in determining how they will interact with a particular polymer. A polymer may have good resistance to aliphatic hydrocarbons but be degraded when in contact with esters or aromatic hydrocarbons.

Pyrolysis GC/MS Analysis of Cable Sheathings

The cable sheathings were analysed using pyrolysis GC/MS. In this technique the polymer is heated rapidly to a predetermined temperature in an inert atmosphere. The resulting thermal degradation products are separated and identified on a GC/MS. As the degradation products are related to the structure of the polymer, this technique is commonly used to identify polymeric materials.

Pyrograms of the Vibra Metrics, PCB Piezotronics, and Wilcoxon Research cable sheathings are shown in Figures 2a through 2c respectively.

Mass spectral analysis of the degradation products of Vibra Metrics cable sheathing, reported to be TUFKEM, indicated that it was a copolymer of tetrafluoroethylene and propylene.

Mass spectral analysis of the degradation products of the PCB Piezotronics and Wilcoxon Research cable sheathings indicated they were poly(ether)urethane based polymers. The polyether portions of these polyurethanes were based on polytetramethylene ether glycol. The presence of methylenediphenyldiisocyanate (MDI) (25.52 min) and 1,4-butanediol (10.00 min) in the degradation products of the Wilcoxon Research cable sheathing indicated that the sheathing was a MDI/ polytetramethylene ether glycol/1,4-butanediol poly(ether)urethane.

It should be noted that information received with the Wilcoxon Research accelerometer indicated that the sheathing was poly(vinylchloride). The Wilcoxon Research cable sheathing analysed at DREA/DL was polyurethane, not poly(vinylchloride).

Plots of weight gain versus the square root of time ($t^{1/2}$) can be used to calculate diffusion coefficients for fluids in a polymeric material. In many instances the weight gain of a polymer in contact with a fluid correlates with the chemical resistance of the polymer to the fluid. That is, the larger the weight gain of the polymer in contact with the fluid, the lower its chemical resistance to that fluid. This has been used to comment on the chemical resistance of the three cable sheathing samples to the immersion fluids.

<u>Weight Gain of Sheathings in Individual Immersion Fluids</u>

MIL-L-23699 Synthetic Lubricating Oil

The percent weight change of the three cable sheathings immersed in MIL-L-23699 is plotted against $t^{1/2}$ in Figure 3. On the basis of the percent weight change of the sheathing samples, the synthetic lubricant is more aggressive towards the polyurethane (Wilcoxon Research and PCB Piezotronics) cable sheathings than the Vibra Metrics cable sheathing.

MIL-H-5606 Hydraulic Fluid

The percent weight change of the three cable sheathings immersed in MIL-H-5606 is plotted against $t^{1/2}$ in Figure 4. It can be seen from the slope of the percent weight change versus $t^{1/2}$ plots that the diffusion of the hydraulic fluid into the cable sheathing sections was rapid during the first week of immersion. The rate of diffusion of the hydraulic fluid and the weight percent hydraulic fluid absorbed was greatest for the Vibra Metrics cable sheathing.

MIL-L-9000 Diesel Lubricating Oil

The percent weight change of the three cable sheathings immersed in MIL-L-9000 is plotted against $t^{1/2}$ in Figure 5. The Vibra Metrics cable sheathing absorbed approximately 11% by weight MIL-L-9000, while the PCB Piezotronics and Wilcoxon Research polyurethane cable sheathings absorbed approximately 7% and 4.5% MIL-L-9000 respectively.

3-GP-24 Aviation Turbine Fuel

The percent weight change of the three cable sheathings immersed in 3-GP-24 aviation turbine fuel is plotted against $t^{1/2}$ in Figure 6. The rate of diffusion of 3-GP-24, as indicated by the plot of percent weight change versus immersion time, was fastest for the Vibra Metrics sheathing. This sheathing sample absorbed 30% 3-GP-24 by weight. The polyurethane samples absorbed approximately 12.5% 3-GP-24.

Ethylene Glycol/Water Mixture (1:1)

The percent weight change of the three cable sheathings immersed in ethylene glycol/water mixture (1:1) is plotted against $t^{1/2}$ in Figure 7. The Vibra Metrics cable sheathing showed the greatest weight gain in the test period (less than 6%) while the Wilcoxon Research and PCB Piezotronics polyurethane cable sheathings gained less than 5% and 4% by weight respectively.

Aqueous Film Forming Foam in water (6% solution)

The AFFF solution used in the immersion study was approximately 94% water. The percent weight change of the three cable sheathings immersed in 6% AFFF solution is plotted against $t^{1/2}$ in Figure 8. The PCB Piezotronics cable sheathing showed the greatest weight gain (~4%) in the test period.

Weight Gain of Sheathing in All Immersion Fluids

Vibra Metrics Cable Sheathing

The percent weight changes of the Vibra Metrics cable sheathing samples after immersion in the five test fluids are plotted against $t^{1/2}$ in Figure 9. On the basis of the weight change of the sheathing in contact with the fluids, this sheathing shows reasonable resistance to MIL-L-9000 diesel lubricating oil, MIL-L- 23699 synthetic lubricating oil and ethylene glycol/water mixture (1:1). However, the results indicate that this sheathing will absorb considerable weights of the lighter hydrocarbons present in MIL-H-5606 hydraulic fluid and 3-GP-24 aviation turbine fuel.

PCB Piezotronics Accelerometer Cable Sheathing

The percent weight changes of the PCB Piezotronics cable sheathing samples after immersion in the five test fluids are plotted against $t^{1/2}$ in Figure 10. The PCB Piezotronics polyurethane cable sheathing showed good resistance to all the fluids except MIL-L-23699 synthetic lubricating oil.

Wilcoxon Research Accelerometer Cable Sheathing

The percent weight changes of the Wilcoxon Research cable sheathing samples after immersion in the five test fluids are plotted against $t^{1/2}$ in Figure 11. The immersion testing results for the Wilcoxon Research polyurethane cable sheathing were similar to those for the PCB Piezotronics cable sheathing, i.e., this sheathing exhibited good resistance to all of the fluids except MIL-L-23699. During the immersion testing period, the sheathing sample immersed in MIL-L-23699 synthetic lubricating oil absorbed greater than 25 percent of its weight in MIL-L-23699.

Discussion

Tetrafluoroethylene-propylene copolymer elastomers, such as the Vibra Metrics cable sheathing, are reported to have good chemical resistance to a broad range of chemicals [8]. More specific chemical resistance information indicates that these elastomers swell moderately in contact with diesel fuel and MIL-H-5606, with good retention of properties, and have excellent resistance to SAE 40 motor oils and ethylene glycol [9]. Chemical resistance data for lighter hydrocarbons, i.e., hexane and isooctane, indicate that they are more aggressive towards tetrafluoroethylene-propylene copolymer elastomers. The results for the Vibra Metrics TUFKEM cable sheathing are consistent with this data. The fluids that cause the greatest weight change are hydrocarbon based fluids containing lower molecular weight hydrocarbons.

Poly(ether)urethanes are reported to have good resistance to diesel fuels, ethylene glycol, SAE 40 lubricating oils, and moderate resistance to gasoline [9]. The results for the PCB Piezotronics and Wilcoxon Research polyurethane cable sheathing are consistent with this data. These sheathing exhibit good resistance to ethylene glycol and hydrocarbon based fluids. However, as the molecular weight of the constituents of the hydrocarbon based fluids decrease, the amount of the constituents absorbed by these sheathings increased.

Conclusions

In general the weight gain of a polymer immersed in a fluid correlates with its chemical resistance to the fluid. That is the larger the weight gain the lower its chemical resistance. Experimentation has shown that the Vibra Metrics cable sheathing (tetrafluoroethylene-propylene copolymer elastomer) exhibited reasonable resistance to petroleum and synthetic base lubricating oils but poor resistance to the lighter hydrocarbons found in hydraulic fluids and fuels. Experimentation has also shown that both the PCB Piezotronics and Wilcoxon Research cable sheathings (polyurethane) exhibited good resistance to all the test fluids except synthetic based lubricating oil. These experimental finding are consistent with published data [8,9].

A recent survey [1] of 40 bilge spaces in CF Ships found that, on average, the major constituent of bilge fluid was water (83% by volume). Analysis of the organic portion of the bilge indicated that distillate fuel and diesel lubricating oils were the major organic constituents.

Based on the major constituents of the organic portion of the bilge and the immersion testing results in this report, accelerometer cables with polyurethane sheathings are suitable for use in bilge spaces.

It should be noted that the Wilcoxon Research accelerometer was claimed to have a cable sheathing composed of poly(vinylchloride), but in fact was supplied with polyurethane sheathing. Poyl(vinylchloride) sheathing was not evaluated to determine its chemical resistance to the 6 candidate fluids.

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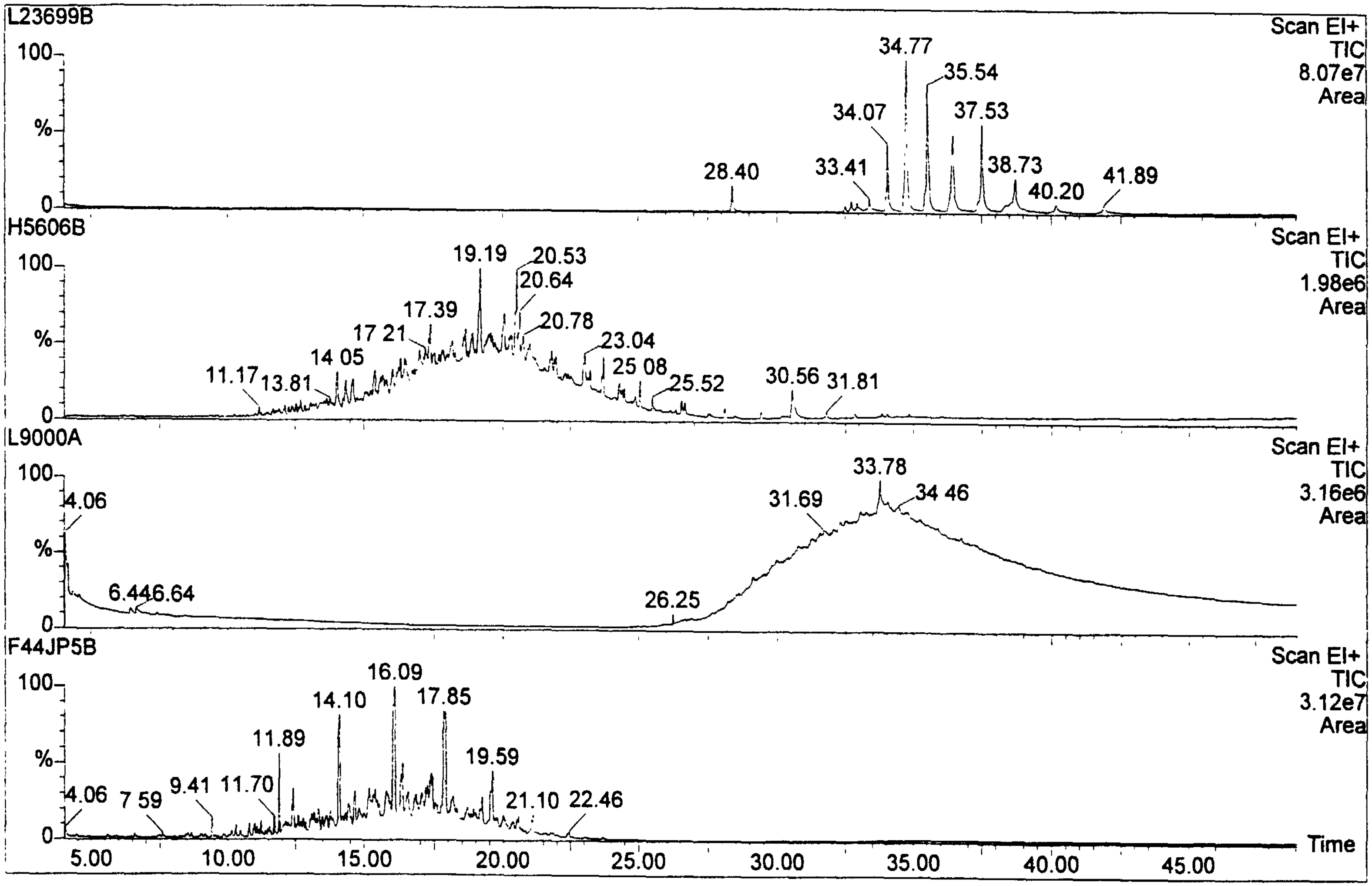


Figure 1 – Chromatograms of a) MIL-L-23699 synthetic lubricating oil, b) MIL-H-5606 hydraulic fluid, c)MIL-L-9000 diesel lubricating oil, and d) NATO F44 aviation turbine fuel.

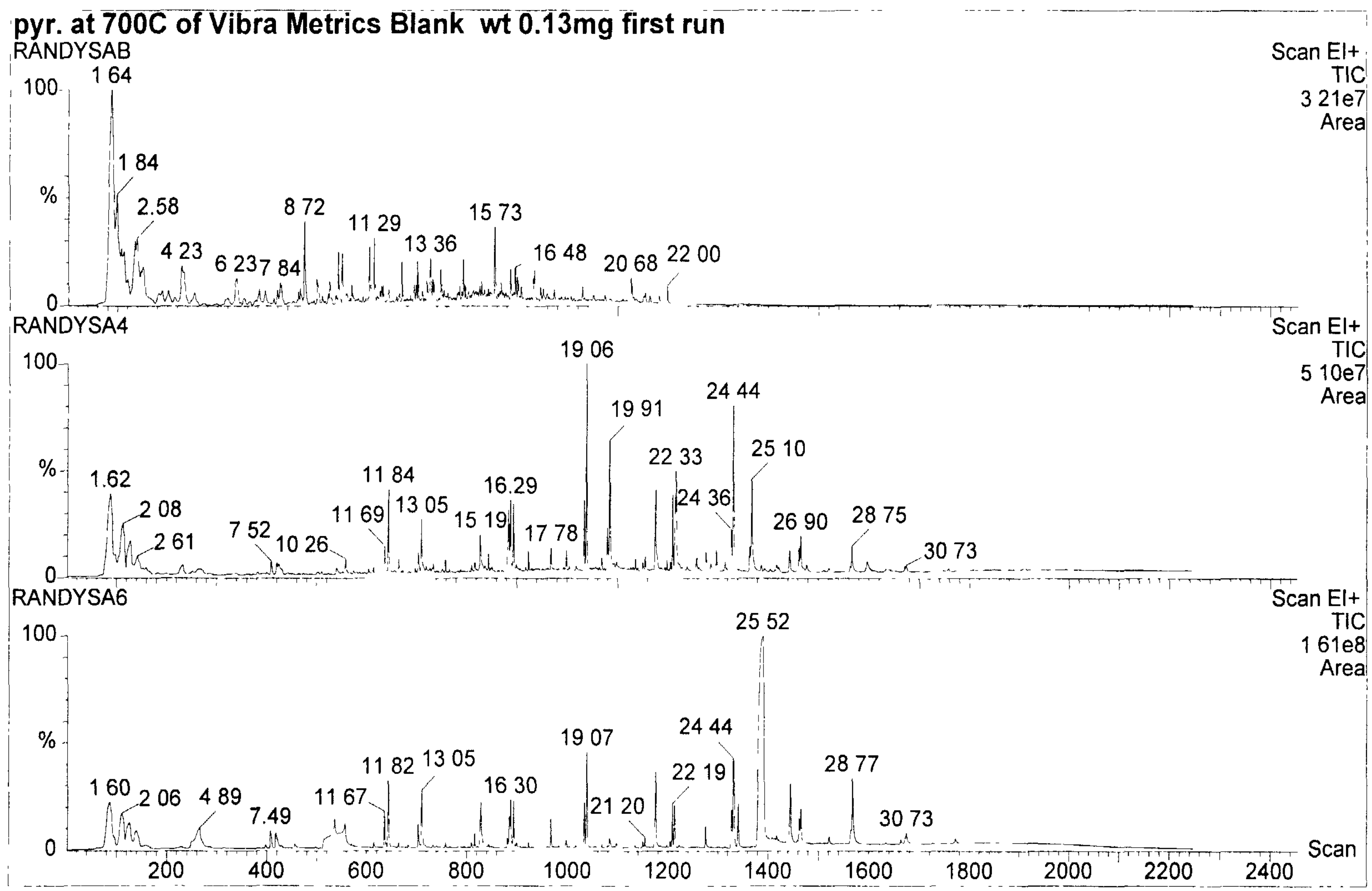


Figure 2 – Pyrograms of samples of a) Vibra Metrics TUFKEM cable sheathing, b) PCB Piezotronics cable sheathing and c) Wilcoxon Research cable sheathing.

Figure 3: - Percent Weight Change of Cable Sheathings in MIL-L-2369 Synthetic Lubricant.

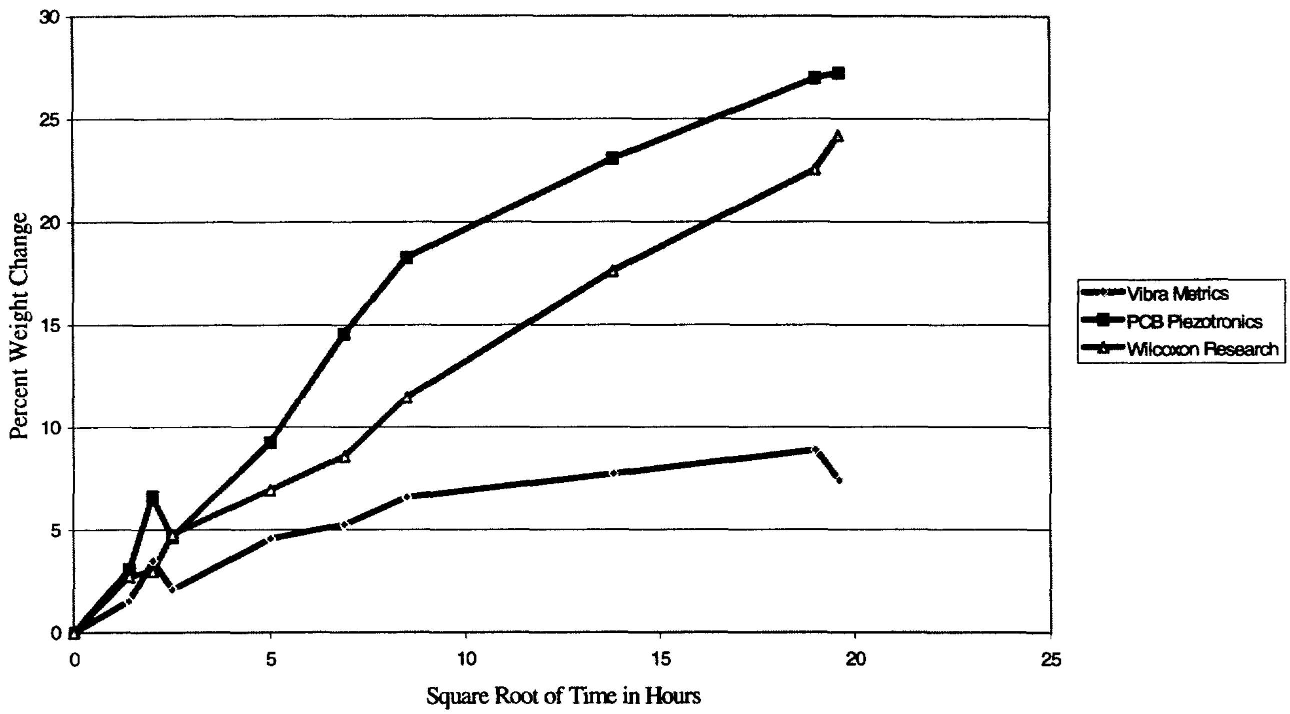


Figure 4: - Percent Weight Change of Cable Sheathings in MIL-H-5606 Hydraulic Fluid

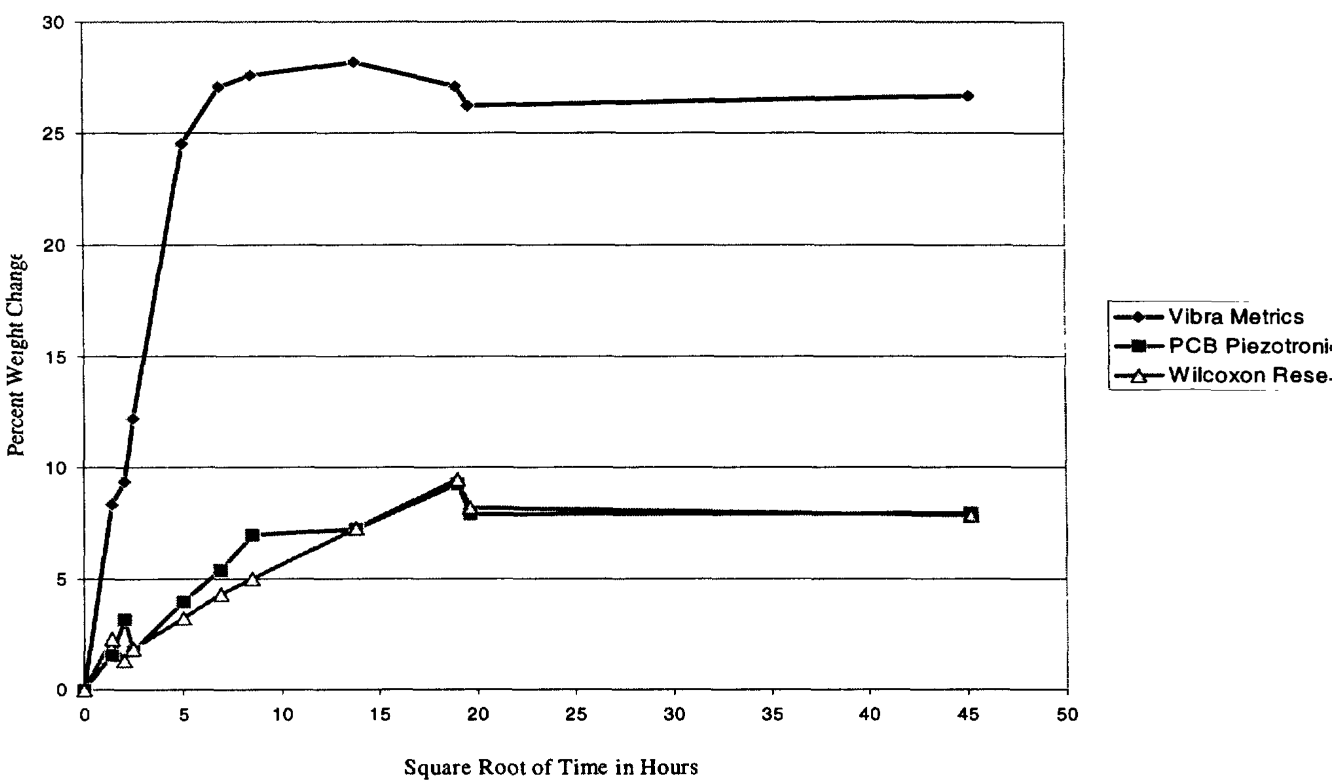


Figure 5 - Percent Weight Change of Cable Sheathings in MIL-L-9000 Diesel Lubricating Oil

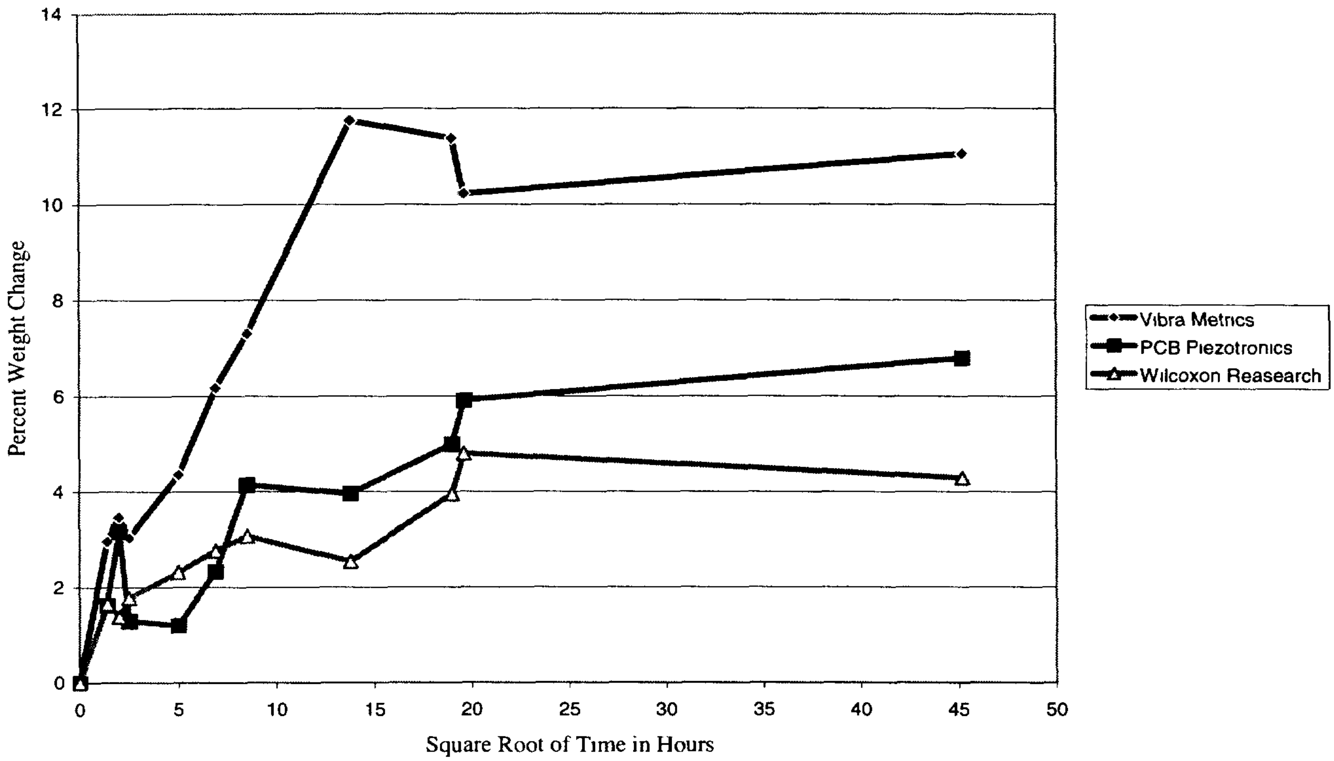


Figure 6. - Percent Weight Change of Cable Sheathings in F44 Aviation Turbine Fuel

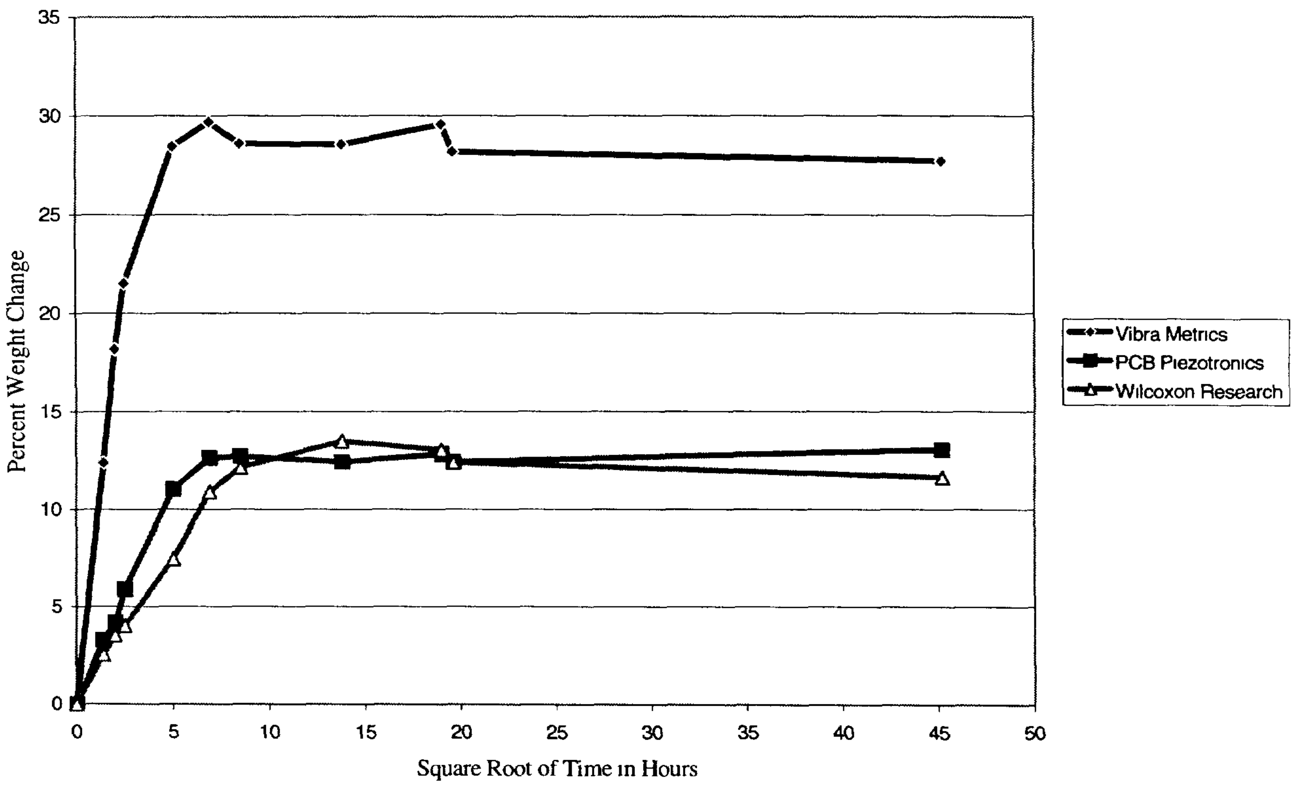


Figure 7: - Percent Weight Change of Cable Sheathings in 50/50 Glycol and Water

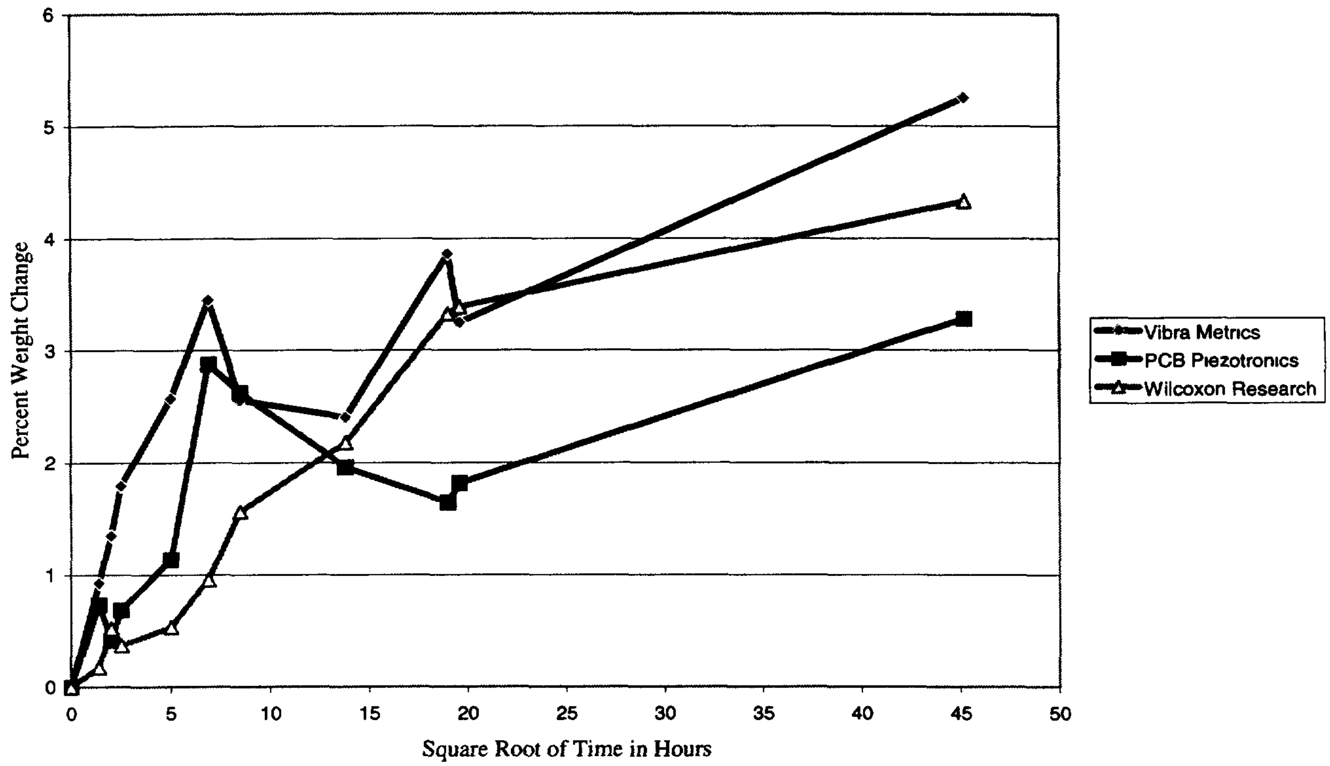


Figure 8: - Percent Weight Change of Cable Sheathings in 6% AFFF in Seawater

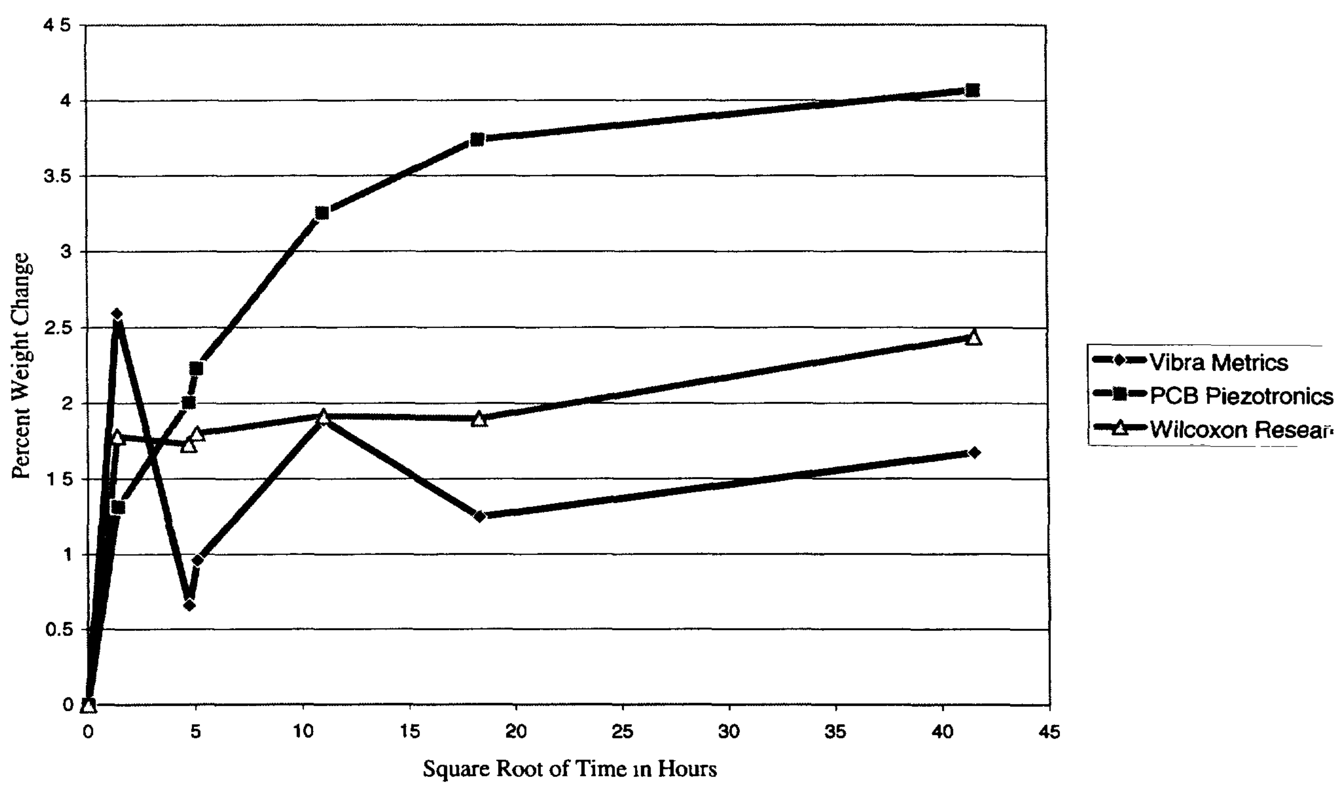


Figure 9. - Percent Weight Change of Vibrametrics Cable Sheathing in Test Fluids

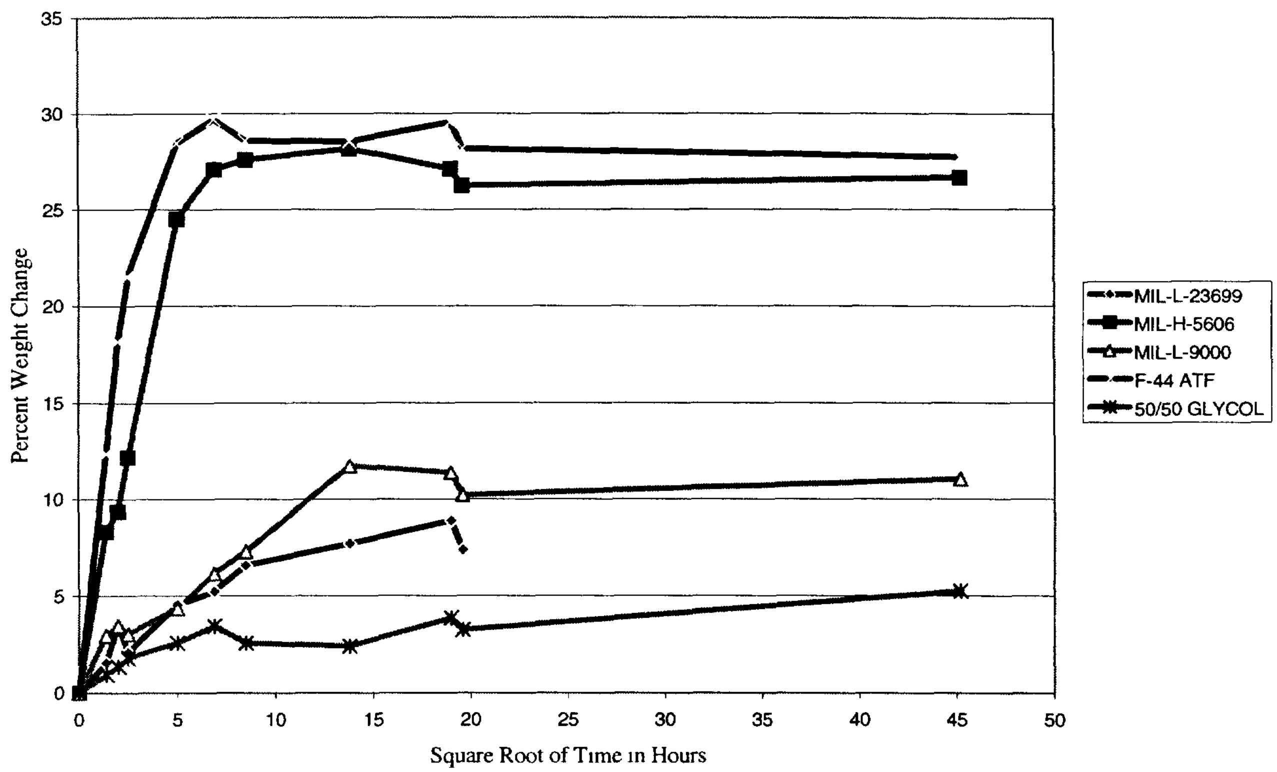


Figure 10. - Percent Weight Change of PCB Piezotronics Cable Sheathing in Test Fluids

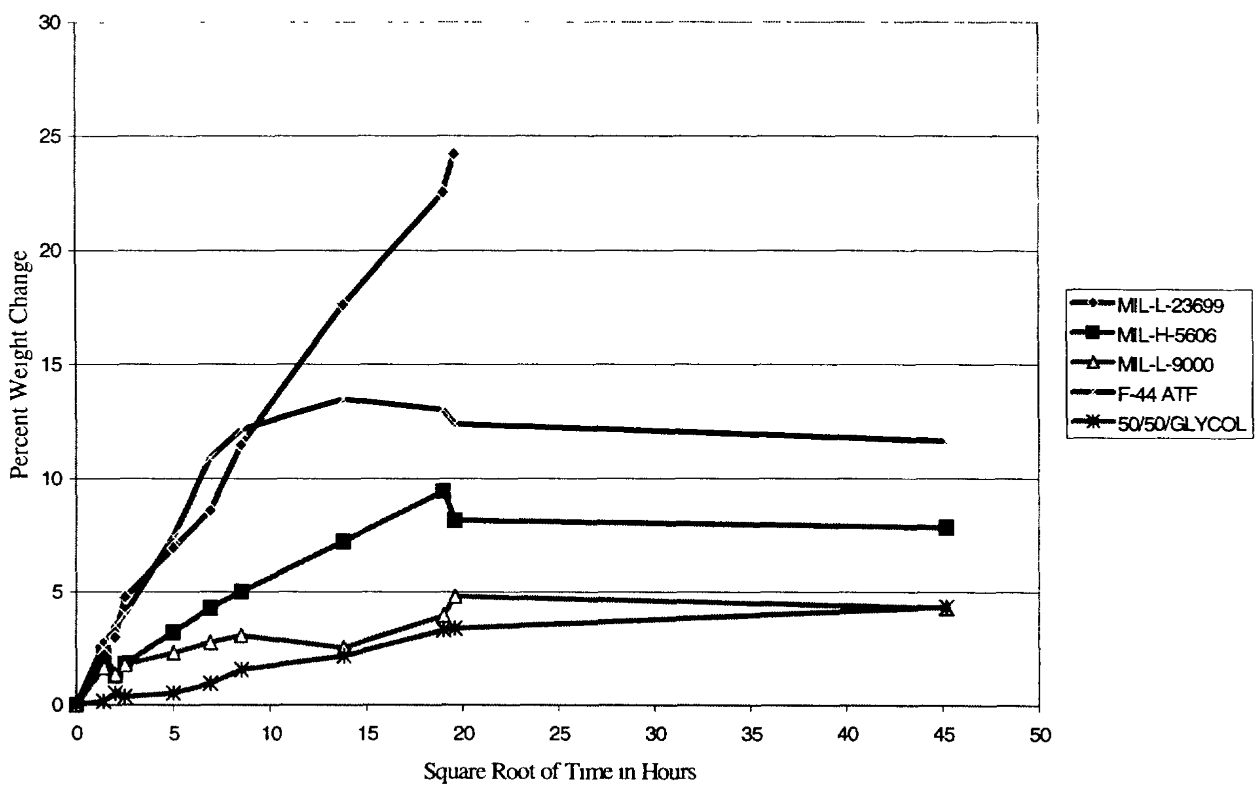
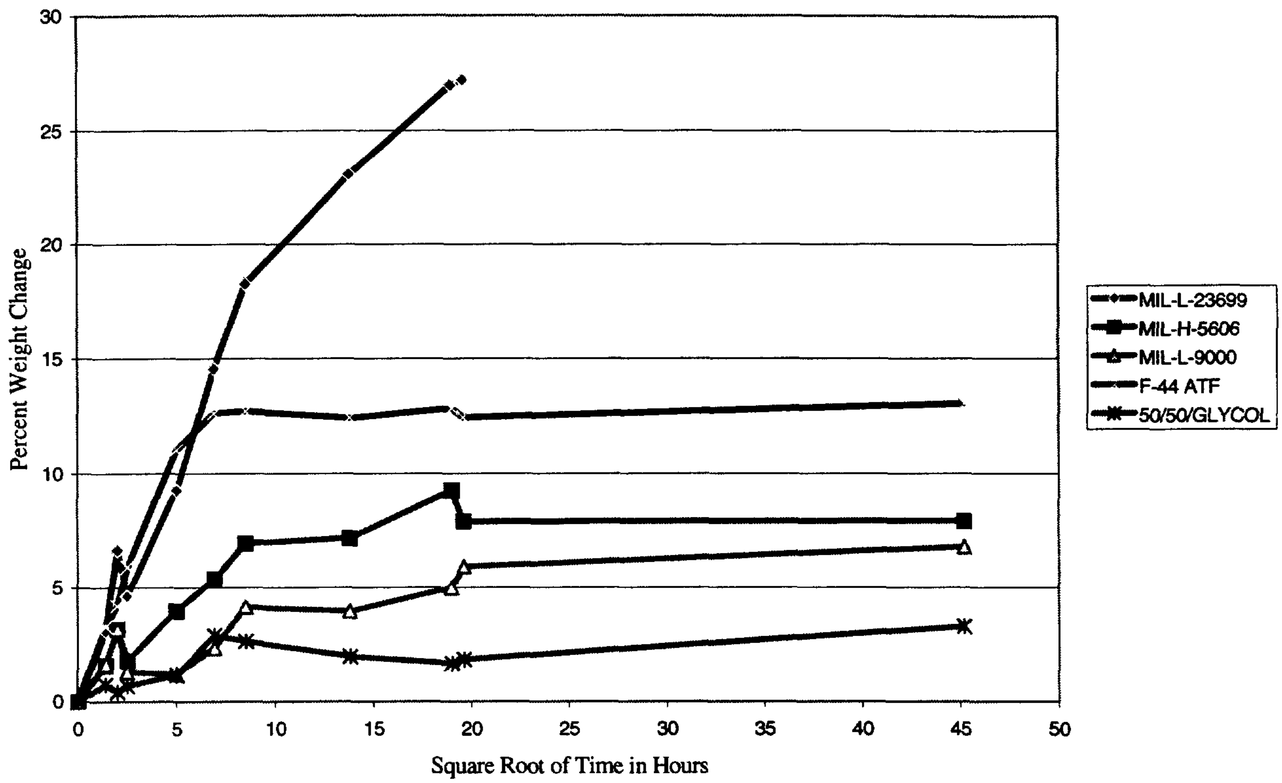


Figure 11: - Percent Weight Change of Wilcoxon Research Cable Sheathing in Test Fluids



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2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)

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3. TITLE (the complete document title as indicated on the title page Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title)

Chemical Resistance of Candidate Accelerometer Cable Sheathings to Fluids Used on CF Ships

4 AUTHORS (Last name, first name, middle initial If military, show rank, e g Doe, Maj John E)

Randall D. Haggett and John A. Hiltz

5 DATE OF PUBLICATION (month and year of publication of document)

January 2000

6a NO OF PAGES (total containing information Include Annexes, Appendices, etc)

24 (approx.)

6b NO OF REFS (total cited in document)

9

7 DESCRIPTIVE NOTES (the category of the document, e g technical report, technical note or memorandum If appropriate, enter the type of report, e g interim, progress, summary, annual or final Give the inclusive dates when a specific reporting period is covered)

TECHNICAL MEMORANDUM

8 SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development Include address)

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9a PROJECT OR GRANT NO (if appropriate, the applicable research and development project or grant number under which the document was written Please specify whether project or grant)

1gi11

9b CONTRACT NO (if appropriate, the applicable number under which the document was written)

10a ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity This number must be unique to this document)

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The Ship Noise Group DREA is studying ships vibrations radiated into the ocean. This study is part of the "Ship Noise Management System" project whose goal is to predict a ship's signature from within the ship. To monitor the vibrations, accelerometers are to be mounted in the bilge spaces of CF Ships. There was concern that the fluids in the bilge space might degrade the accelerometer cable sheathing and affect the accelerometer output. The Materials Chemistry Group DREA was asked to aid in the selection of an accelerometer cable sheathing with the required resistance to bilge fluids.

The sheathings, taken from Vibra Metrics, PCB Piezotronics and Wilcoxon Research accelerometers, were immersed in six fluids and their chemical resistance evaluated by monitoring weight gain. The six fluids were 3-GP-24 aviation turbine fuel, MIL-H-5606 hydraulic fluid, MIL-L-23699 synthetic lubricating oil, MIL-L-9000 diesel lubricating oil, 6% AFFF in water, and ethlyene glycol/water (1:1).

The urethane based sheathings had good to excellent resistance to all fluids except the synthetic lubricating oil. The copolymer sheathing exhibited only fair resistance to the aviation turbine fuel and the hydraulic fluid. As the major organic constituents of bilge fluids are fuels and hydrocarbon based lubricants, polyurethane cable sheathing is suitable for use in bilge spaces.

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Cable sheathing
Accelerometers
Chemical resistance
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MIL-PRF-9000
MIL-H-5606
3-GP-24
AFFF
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