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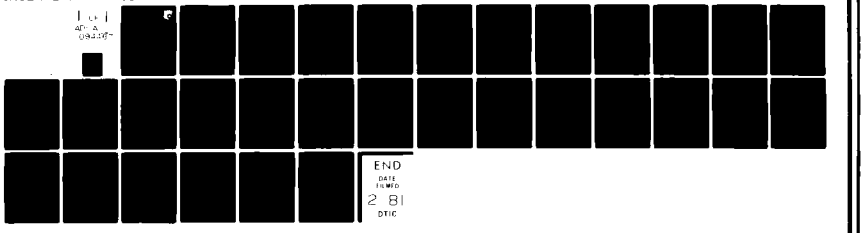

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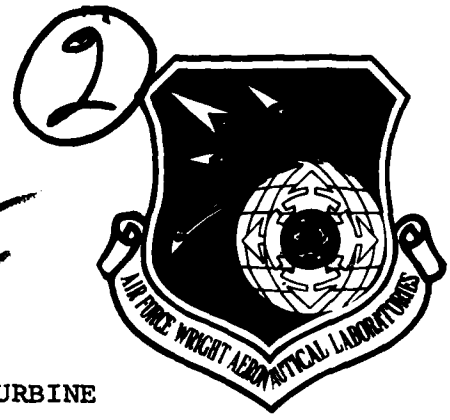

COMPATIBILITY OF RETICULATED FOAMS IN TYPICAL TURBINE FUELS WITH CURRENTLY APPROVED ADDITIVES

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Albert Olevitch

FOR THE DIRECTOR

ALBERT OLEVITCH, Acting Chief
Systems Support Division
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tensile strength	metal deactivator	
turbine fuels	fuel system icing inhibitor	

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Reticulated polyester polyurethane foams have been successfully employed by the U.S. Air Force since the late 1960's in fuel tanks and dry bay areas of certain combat aircraft. Use of reticulated foams as fire and explosion retardants was initiated in 1965 when some Indianapolis 500 race cars were retrofitted with foam-filled fuel tanks to improve the crash resistance of the tanks. As a result of tests conducted for the USAF to verify the fire and

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20. Abstract (Concluded)

explosion suppressing capability of foams, a nominal 10 pores per inch foam was produced in which all membranes in the cell structure were eliminated by thermal reticulation. The resulting material, corresponding to Military Specification MIL-B-83054, Type I, was an open-pore three-dimensional network of strands having a density of 1.8 pounds per inch cubic foot.[2,3] This foam was orange in color.

During 1970 to 1972, lighter weight polyester materials were developed. These foams, which were yellow and red in color, result in a weight reduction of approximately 25 percent. The new foams also exhibited improved hydrolytic stability over the Type I orange foam which was susceptible to the combined effects of temperature and humidity. The yellow and red foams corresponded to MIL-B-83054, Types II and III, respectively. It was estimated that the useful work life of these materials would extend from five to eight years before requiring replacement.

Development of a polyether polyurethane foam was initiated in 1974. The resulting dark blue and light blue foams, designated as MIL-B-83054B, Types IV and V, respectively, were intended to provide hydrolytic stability estimated to be five to ten times greater than that of the polyester materials.[4]

PREFACE

The work described in this report was conducted by the University of Dayton Research Institute for the Systems Support Division of the Materials Laboratory, Air Force Wright Aeronautical Laboratories. The program was conducted under Project 2421, Task 242103 as a part of Air Force Contract F33615-80-C-5002 with Mr. Albert Olevitch as the Air Force engineer. Mr. Thomas Reed of the Flight Equipment Division, Aeronautical Systems Division provided significant technical input to this work.

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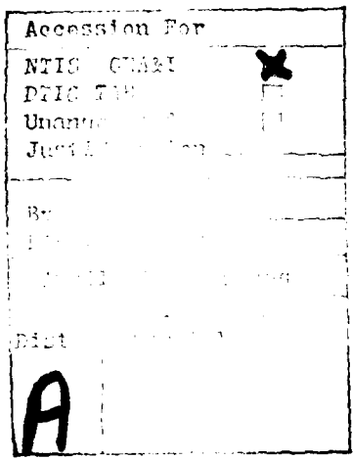

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SECTION I
INTRODUCTION

A program was undertaken by the University of Dayton Research Institute (UDRI) under the joint direction of AFWAL/MLSE and ASD/ENFEF to evaluate the compatibility of MIL-B-83054B, Type III and Type V reticulated foams in turbine fuels such as JP-4, JP-5, and JP-8 containing currently approved additives. Physical aging and testing of the foam materials was accomplished by UDRI. Foam test specimens for the program were provided by Scott Paper Company (Foam Division). Steam autoclave exposure of selected aged specimens was also accomplished by Scott Paper Company.

Foam tensile specimens were exposed to JP-4 and JP-5 type fuels with and without additives for an extended period at 160°F (71°C). The effects of this exposure were observed at specific intervals by evaluating tensile properties of the foams. The fuels contained various concentrations of additives which included Shell and DuPont antistatic additives, corrosion inhibitor, antioxidant, metal deactivator, and fuel system icing inhibitor. Emphasis was placed on foam compatibility with the antistatic additives since these are relatively new with respect to use by the USAF. Baseline fuel evaluations of all fuel/additive combinations were accomplished for ASD/ENFEF by SA-ALC/SFQLA.

The original test plan required that a small, controlled quantity of distilled water be included in each fuel sample used for foam exposure. Failures occurred for all polyester foams (Type III) specimens after exposure to the fuel/water mixture for 16 weeks. Prior experience indicated that under fuel exposure without water, the foams should not undergo a significant loss of tensile strength in 24 weeks. These failures were attributed to the presence of free water in the fuels.

Since it was felt that the effect of additives on the foam would be masked by these premature failures, a revised test plan was formulated to include the evaluation of the foams in

fuel samples containing no water. Many of the original tests (Phase I) were repeated in the revised program (Phase II) to provide comparative data.

SECTION II
TEST PROCEDURES AND RESULTS

The Phase I test plan to evaluate the effects of antistatic and other additives on the life of reticulated foams in a turbine fuel environment included two fuels, JP-4 and JP-5, per MIL-T-5624 (clay treated). Fuel additives selected were Shell ASA-3 and DuPont Stadis 450 antistatic additives, DCI-4A corrosion inhibitor (CI), Ethyl 733 antioxidant (AO), N,N-Disalicylidene-1,2-propane diamine metal deactivator (MDI), and EGME fuel system icing inhibitor (FSII).

Test fluids were made up using the two jet fuels and various combinations of additives in parts per million (ppm):

Fluid No. 1	JP-4 (no additives)
Fluid No. 2	JP-5 (no additives)
Fluid No. 3	JP-4 (5 ppm ASA-3; 5 ppm Stadis 450)
Fluid No. 4	JP-4 (2 ppm ASA-3; 2 ppm Stadis 450)
Fluid No. 5	JP-5 (2 ppm ASA-3; 2 ppm Stadis 450)
Fluid No. 6	JP-4 (2 ppm ASA-3)
Fluid No. 7	JP-4 (2 ppm Stadis 450)
Fluid No. 8	JP-5 (2 ppm ASA-3)
Fluid No. 9	JP-5 (2 ppm Stadis 450)
Fluid No. 10	JP-4 (2 ppm ASA-3; 2 ppm Stadis 450; 1 ppm CI; 1 ppm AO; 1 ppm MDI; 1 ppm FSII)
Fluid No. 11	JP-5 (2 ppm ASA-3; 2 ppm Stadis 450; 1 ppm CI; 1 ppm AO; 1 ppm MDI; 1 ppm FSII)

Two test foams were employed for the evaluation, Red Polyester Fine Pore (MIL-B-83054B, Type III) and Blue Polyether Fine Pore (MIL-B-83054B, Type V). The foams were provided by Scott Paper Company in tensile specimen configuration conforming to ASTM Method D1564-71. The red foam was identified as W258R (1-1), a foam containing a new resin in which Trimethanol propane (TMP) normally used in the polyester molecule was replaced with glycerine (non-TMP). To provide a comparison between the TMP and non-TMP resins, tensile specimens of a TMP red foam W901P (15-4) were included for testing in JP-4 fuel with all additives

(Fluid No. 10). The blue polyether foams were identified as runs W236R (19-1) and W236R (3-1).

Three special polyether foams containing 1.1 parts of PDI pigment were also included for evaluation in Fluid No. 10 at 160°F (71°C). These foams utilized standard resin used in blue polyether. These polyether foams were designated W402-2, W403-2, and W404-2. W402-2 contained 1.1 parts standard PDI blue pigment; W403-2 contained 1.6 parts experimental orange pigment No. 4602; and W404-2 contained 1.6 parts experimental red pigment No. X13623-4.

A total of 18 red polyester foam specimens and 36 blue polyether foam specimens were exposed to each respective test fluid at 160°F (71°C). The test fluids were contained in quart mason jars, each jar holding 900 ml of test fluid plus 10 ml of distilled water. Nine tensile specimens were suspended in the fuel portion of each fluid. Three red specimens and six blue specimens were removed from each fluid at four-week intervals for 24 weeks. Test fluids for the remaining samples were also changed at each four-week interval. Three specimens each of red and blue foams were tested for tensile strength and elongation after rinsing with petroleum ether followed by air drying for 30 minutes. The remaining three blue foam specimens were tested in a fuel-wet condition at each four-week interval. Three additional blue foam specimens aged in JP-4 with all additives were provided to Scott Paper Company for steam autoclave exposure at each six-week interval. A summary of tensile strength data for red W258R (1-1) non-TMP and W901P (15-4) TMP polyester foams in all fuel/additives combinations used in Phase I is provided in Table 1. Tensile strengths of blue W236R (19-1) polyether foam in JP-4 fuel/additives and JP-5 fuel/additives are summarized in Tables 2 and 3 for dry and wet test conditions, respectively. Wet and dry tensile strengths of the three special polyether foams, W402-2, W403-2, and W404-2, are presented in Table 4.

TABLE 1. POLYESTER FOAM SUMMARY TENSILE DATA

Exposure: 160°F (71°C) in 900 ml Fuel + 10 ml Water
Test Foam: Red W258R (1-1) Non-TMP Polyester Resin (Type III)

Test Fluid	Exposure Time in Weeks						
	Baseline psi (MPa)	4 weeks psi (MPa)	8 weeks psi (MPa)	12 weeks psi (MPa)	16 weeks psi (MPa)	20 weeks psi (MPa)	24 weeks psi (MPa)
#1 JP-4 (no additives)	34.4 (0.24)	32.7 (0.23)	29.4 (0.20)	23.7 (0.16)	2.7 (0.02)		
#3 JP-4 (5 ppm ASA-3; 5 ppm Stadis 450)	34.4 (0.24)	28.8 (0.20)	29.7 (0.20)	20.9 (0.14)	Failed		
#4 JP-4 (2 ppm ASA-3; 2 ppm Stadis 450)	34.4 (0.24)	26.8 (0.18)	4.9 (0.03)	Failed			
#6 JP-4 (2 ppm ASA-3)	34.4 (0.24)	26.8 (0.18)	23.1 (0.16)	14.4 (0.10)	2.5 (0.02)		
#7 JP-4 (2 ppm Stadis 450)	34.4 (0.24)	30.3 (0.21)	27.5 (0.19)	17.9 (0.12)	4.0 (0.03)		
#10 JP-4 (all additives)	34.4 (0.24)	28.5 (0.20)	13.9 (0.10)	7.5 (0.05)	Failed		
#2 JP-5 (no additives)	34.4 (0.24)	32.1 (0.22)	30.0 (0.21)	9.9 (0.07)	5.6 (0.04)		
#5 JP-5 (2 ppm ASA-3; 2 ppm Stadis 450)	34.4 (0.24)	31.5 (0.22)	24.5 (0.17)	25.6 (0.18)	Failed		
#8 JP-5 (2 ppm ASA-3)	34.4 (0.24)	27.2 (0.19)	7.9 (0.05)	5.6 (0.04)	Failed		
#9 JP-5 (2 ppm Stadis 450)	34.4 (0.24)	34.0 (0.23)	23.8 (0.16)	17.0 (0.12)	Failed		
#11 JP-5 (all additives)	34.4 (0.24)	31.6 (0.22)	16.3 (0.11)	7.9 (0.05)	2.4 (0.02)		

Test Foam: Red W901P (15-4) TMP Polyester Resin (Type III)

#10 JP-4 (all additives)	30.3 (0.21)	22.1 (0.15)	22.4 (0.15)	13.1 (0.09)	Failed		

NOTE: All additives include 2 ppm ASA-3; 2 ppm Stadis 450; CI; AO; MDI; FSII.
All samples were failed at 20 weeks exposure.

TABLE 3. POLYETHER FOAM SUMMARY DRY TENSILE DATA

Exposure: 160°F (71°C) in 300 ml Fuel + 15 ml Water
Test Foam: Blue W236R (1-1), W236F (3-1) Polyether Foam (Type V)

Test Fluid	Exposure Time in Weeks						
	Baseline psi (MPa)	4 weeks psi (MPa)	8 weeks psi (MPa)	12 weeks psi (MPa)	16 weeks psi (MPa)	20 weeks psi (MPa)	24 weeks psi (MPa)
#1 JP-4 (no additives)	17.8 (0.12)	15.4 (0.11)	16.9 (0.12)	14.1 (0.10)	12.8 (0.09)	14.6 (0.10)	15.4 (0.11)
#3 JP-4 (5 ppm ASA-3; 5 ppm Stadis 450)	17.8 (0.12)	18.0 (0.12)	18.1 (0.12)	15.4 (0.11)	12.8 (0.09)	14.5 (0.10)	14.9 (0.10)
#4 JP-4 (2 ppm ASA-3; 2 ppm Stadis 450)	17.8 (0.12)	17.2 (0.12)	16.2 (0.11)	14.7 (0.10)	13.2 (0.09)	17.3 (0.12)	15.2 (0.10)
#6 JP-4 (2 ppm ASA-3)	17.8 (0.12)	16.8 (0.11)	17.4 (0.12)	16.0 (0.11)	13.9 (0.10)	14.7 (0.10)	13.6 (0.09)
#7 JP-4 (2 ppm Stadis 450)	17.8 (0.12)	15.8 (0.11)	15.7 (0.11)	17.4 (0.12)	13.3 (0.09)	15.4 (0.11)	17.1 (0.12)
#10 JP-4 (all additives)[1]	17.8 (0.12)	15.7 (0.11)	16.8 (0.12)	16.9 (0.12)	12.7 (0.09)	15.8 (0.11)	14.5 (0.10)
#10 JP-4 (Steam autoclave)[2]	17.8 (0.12)	11.8 (0.08)	11.7 (0.08)	no data	10.2 (0.07)	11.6 (0.08)	11.2 (0.08)
#2 JP-5 (no additives)	17.8 (0.12)	15.8 (0.11)	14.3 (0.10)	11.7 (0.08)	14.1 (0.10)	15.3 (0.11)	15.5 (0.11)
#5 JP-5 (2 ppm ASA-3; 2 ppm Stadis 450)	17.8 (0.12)	15.7 (0.11)	16.9 (0.12)	16.2 (0.11)	13.5 (0.09)	17.3 (0.12)	15.6 (0.11)
#8 JP-5 (2 ppm ASA-3)	17.8 (0.12)	15.3 (0.11)	14.4 (0.10)	11.4 (0.08)	16.6 (0.11)	14.7 (0.10)	14.9 (0.10)
#9 JP-5 (2 ppm Stadis 450)	17.8 (0.12)	14.7 (0.10)	15.7 (0.11)	14.7 (0.10)	15.1 (0.10)	15.3 (0.11)	16.1 (0.11)
#11 JP-5 (all additives)	17.8 (0.12)	15.0 (0.10)	14.1 (0.10)	14.1 (0.10)	14.5 (0.10)	15.7 (0.11)	14.6 (0.10)

NOTES: [1]All additives include 2 ppm ASA-3; 2 ppm Stadis 450; CI; AO; MDI; FSII.

[2]Steam Autoclave exposure for 15 hours per MIL-B-83054B.

TABLE 3. POLYETHER FOAM SUMMARY WET TENSILE DATA

Exposure: 160°F (71°C) in 900 ml Fuel + 10 ml Water
Test Foam: Blue W236R (19-1), W236R (3-1) Polyether Foam (Type V)

Test Fluid	Exposure Time in Weeks						
	Baseline psi (MPa)	4 weeks psi (MPa)	8 weeks psi (MPa)	12 weeks psi (MPa)	16 weeks psi (MPa)	20 weeks psi (MPa)	24 weeks psi (MPa)
#1 JP-4 (no additives)	9.8 (0.07)	8.8 (0.06)	8.9 (0.06)	8.7 (0.06)	7.5 (0.05)	8.2 (0.06)	7.0 (0.05)
#3 JP-4 (5 ppm ASA-3; 5 ppm Stadis 450)	9.8 (0.07)	9.1 (0.06)	9.5 (0.06)	7.8 (0.05)	8.3 (0.06)	8.7 (0.06)	6.8 (0.05)
#4 JP-4 (2 ppm ASA-3; 2 ppm Stadis 450)	9.8 (0.07)	8.8 (0.06)	8.7 (0.06)	7.7 (0.05)	8.0 (0.06)	8.1 (0.06)	6.9 (0.05)
#6 JP-4 (2 ppm ASA-3)	9.8 (0.07)	9.2 (0.06)	8.7 (0.06)	8.9 (0.06)	8.2 (0.06)	8.5 (0.06)	7.8 (0.05)
#7 JP-4 (2 ppm Stadis 450)	9.8 (0.07)	10.1(0.07)	9.8 (0.07)	8.4 (0.06)	8.0 (0.06)	7.9 (0.05)	7.8 (0.05)
#10 JP-4 (all additives)	9.8 (0.07)	9.6 (0.07)	9.4 (0.06)	8.5 (0.06)	7.6 (0.05)	7.7 (0.05)	7.5 (0.05)
#2 JP-5 (no additives)	9.8 (0.07)	9.1 (0.06)	9.4 (0.06)	8.5 (0.06)	8.4 (0.06)	8.0 (0.06)	7.8 (0.05)
#5 JP-5 (2 ppm ASA-3; 2 ppm Stadis 450)	9.8 (0.07)	8.7 (0.06)	10.3(0.07)	8.4 (0.06)	8.1 (0.06)	8.6 (0.06)	9.2 (0.06)
#8 JP-5 (2 ppm ASA-3)	9.8 (0.07)	10.6(0.07)	8.8 (0.06)	8.7 (0.06)	8.5 (0.06)	9.2 (0.06)	9.1 (0.06)
#9 JP-5 (2 ppm Stadis 450)	9.8 (0.07)	9.1 (0.06)	8.7 (0.06)	9.6 (0.07)	9.2 (0.06)	7.6 (0.05)	7.8 (0.05)
#11 JP-5 (all additives)	9.8 (0.07)	8.4 (0.06)	9.8 (0.07)	8.7 (0.06)	7.9 (0.05)	7.3 (0.05)	7.1 (0.05)

NOTE: All additives include 2 ppm ASA-3; 2 ppm Stadis 450; CI; AO; MDI; FSII

TABLE 4. SPECIAL POLYETHER SUMMARY TENSILE DATA (DRY AND WET)

Exposure: 160°F (71°C) in 900 ml Fuel + 10 ml Water
Test Foam: W402-2 Standard PDI Blue Pigment Polyether Foam

Test Fluid	Exposure Time in Weeks						
	Baseline psi (MPa)	4 weeks psi (MPa)	8 weeks psi (MPa)	12 weeks psi (MPa)	16 weeks psi (MPa)	20 weeks psi (MPa)	24 weeks psi (MPa)
#10 JP-4 (all additives)[1]							
(Dry)	16.8 (0.12)	15.4 (0.11)	11.6 (0.08)	13.1 (0.09)	13.8 (0.10)	15.6 (0.11)	13.8 (0.10)
(Wet)	9.6 (0.07)	8.8 (0.06)	7.9 (0.05)	8.6 (0.06)	7.6 (0.05)	8.0 (0.06)	7.2 (0.05)
#10 JP-4 (Steam Autoclave)[2]	12.1 (0.08)	10.9 (0.08)	11.9 (0.08)	12.6 (0.07)	11.4 (0.08)	11.6 (0.08)	10.9 (0.08)

Test Foam: W403-2 Experimental No. 4602 Orange Pigment Polyether Foam

#10 JP-4 (all additives)[1]							
(Dry)	17.9 (0.12)	17.5 (0.12)	14.7 (0.10)	18.2 (0.13)	17.2 (0.12)	16.7 (0.12)	16.9 (0.12)
(Wet)	10.1 (0.07)	11.3 (0.08)	10.0 (0.07)	10.6 (0.07)	9.5 (0.07)	9.6 (0.07)	7.9 (0.05)
#10 JP-4 (Steam Autoclave)[2]	13.5 (0.09)	11.9 (0.08)	13.9 (0.10)	14.0 (0.10)	14.0 (0.10)	12.7 (0.09)	11.9 (0.08)

Test Foam: W404-2 Experimental No. X13623-4 Red Pigment Polyether Foam

#10 JP-4 (all additives)[1]							
(Dry)	16.1 (0.11)	15.7 (0.11)	9.8 (0.07)	12.8 (0.09)	13.1 (0.09)	15.5 (0.11)	13.6 (0.09)
(Wet)	9.5 (0.07)	8.5 (0.06)	8.9 (0.06)	8.5 (0.06)	9.9 (0.07)	7.4 (0.05)	7.2 (0.05)
#10 JP-4 (Steam Autoclave)[2]	11.7 (0.08)	9.9 (0.07)	11.4 (0.08)	11.9 (0.08)	10.3 (0.07)	10.5 (0.07)	9.7 (0.07)

NOTES: [1]All additives include 2 ppm ASA-3; 2 ppm Stadis 450; CI; AO; MDI; FSII.
[2]Steam Autoclave exposure for 15 hours per MIL-B-83054B.

Phase II was initiated when premature failures of the red polyester foams in all fuel/additives combinations were attributed to the presence of the 10 ml quantity of water in the test fluids. The test program was revised to evaluate current production orange foam (MIL-B-83054B, Type I) made with both TMP and non-TMP polyester resins.

Test fluids were again made up of JP-4 and JP-5 fuels with additives. Concentrations of antistatic additives were reduced from two to one part per million (ppm). The test fluids contained no distilled water except for Fluid No. 10 in which water was retained to provide comparative polyester foam data to the Phase I results. The fluid designations were:

Fluid No. 10	JP-4 w/10 ml. dist. water (1 ppm ASA-3; 1 ppm Stadis 450; 1 ppm CI; 1 ppm AO; 1 ppm MDI; 1 ppm FSII)
Fluid No. 21	JP-4 (no additives)
Fluid No. 22	JP-5 (no additives)
Fluid No. 23	JP-4 (5 ppm ASA-3; 5 ppm Stadis 450)
Fluid No. 24	JP-4 (1 ppm ASA-3; 1 ppm Stadis 450)
Fluid No. 30	JP-4 (1 ppm ASA-3; 1 ppm Stadis 450; 1 ppm CI; 1 ppm AO; 1 ppm MDI; 1 ppm FSII)
Fluid No. 31	JP-5 (1 ppm ASA-3; 1 ppm Stadis 450; 1 ppm CI; 1 ppm AO; 1 ppm MDI; 1 ppm FSII)
Fluid No. 32	JP-5 (1 ppm ASA-3; 1 ppm Stadis 450; 1 ppm CI; 1 ppm FSII)
Fluid No. 33	JP-4 (1 ppm ASA-3; 1 ppm Stadis 450; 1 ppm CI; 1 ppm FSII)
Fluid No. 34	JP-4 (1 ppm CI; 1 ppm FSII)

Samples from each drum of jet fuel supplied for this evaluation were provided to SA-ALC/SFQLA for chemical analyses. The results for the baseline JP-4 and JP-5 fuels are summarized in Table 5.[5] Table 5 also indicates which foams were used in conjunction with each type of fuel.

Orange polyester foams designated W593R (31-1) TMP and W547R (26-1) non-TMP were provided in tensile specimen form by Scott Paper Company for 24 weeks exposure to the Phase II

TABLE . . BASELINE TEST FUELS

	JP-4 (FP 20F) Blue; Orange	JP-5 Blue; Red
Gravity, (°API)	54.3	42.7
E. Gum (mg/100 ml)	1.6	2.4
Mercaptan Sulfur (% Weight)	0.0003	0.0002
Total Sulfur (% Weight)	0.05	0.05
Vapor Pressure (psig)	1.5	---
Anomatics (% Volume)	12.3	17.4
Flash Point)	---	125°F
SFQLA[1] Test Report Test Date	79-F-2324 20 Nov 1979	79-F-994 9 May 1979

NOTE: [1]Detachment 13, SA-ALC/SFQLA, WPAFB, Ohio 45433, T. J. O'Shaughnessy

test fluids. Sufficient orange foam specimens were provided for a 12-week exposure to Fluid No. 1 to verify Phase I results. Blue polyether W236R (3-1) foam specimens were also provided for comparative evaluations between Fluid Nos. 21 and 30 containing no water and the previous tests conducted in Fluid Nos. 1 and 10 with water.

Quart mason jars containing 900 ml of test fluid only were again used in which nine tensile specimens of each foam were suspended. The foams were exposed to the various test fluids for 24 weeks at 160°F (71°C). Test fluids were changed at four-week intervals. Three tensile specimens of each orange polyester foam (TMP and non-TMP) were removed for testing at each interval. Three tensile specimens of blue polyether foam were removed from Fluid No. 21 for testing. Nine specimens of blue polyether foam were removed from Fluid No. 30 at each four-week interval and were tested in dry, wet and extended dry (two weeks air dry after petroleum ether rinse) conditions.

Data summaries for orange W593R (31-1) TMP and W547R (26-1) non-TMP polyester foams are presented in Tables 6 and 7 for JP-4 and JP-5 test fluids, respectively. Orange foam tensile strengths for Test Fluid Nos. 1 and 10 are tabulated in Table 8. Tensile data for W236R (3-1) blue polyether foam in Test Fluid Nos. 21 and 30 are also shown in Table 8. The results for the special pigment polyether foams are presented in Table 4.

TABLE [illegible] POLYESTER RESIN FOAM TENSILE DATA

Exposure: 160°F (71°C) in [illegible] Fuel
Test Foam: Orange W593R (31-1) TMP Polyester Resin (Type I)

Test Fluid	Exposure Time in Weeks						
	Baseline psi (MPa)	4 weeks psi (MPa)	8 weeks psi (MPa)	12 weeks psi (MPa)	16 weeks psi (MPa)	20 weeks psi (MPa)	24 weeks psi (MPa)
#21 JP-4 (no additives)	22.2 (0.15)	25.1 (0.17)	24.6 (0.17)	19.8 (0.14)	23.7 (0.16)	25.8 (0.18)	23.7 (0.16)
#23 JP-4 (5 ppm ASA-3; 5 ppm Stadis 450)	22.2 (0.15)	25.2 (0.17)	18.4 (0.13)	23.1 (0.16)	24.0 (0.17)	20.4 (0.14)	23.3 (0.16)
#24 JP-4 (1 ppm ASA-3; 1 ppm Stadis 450)	22.2 (0.15)	21.3 (0.15)	21.8 (0.15)	18.9 (0.13)	22.0 (0.15)	20.8 (0.14)	22.1 (0.15)
#30 JP-4 (all additives)	22.2 (0.15)	22.1 (0.15)	21.9 (0.15)	16.6 (0.11)	20.6 (0.14)	19.6 (0.14)	19.5 (0.13)
#33 JP-4 (1 ppm ASA-3; 1 ppm Stadis 450; CI; FSII)	22.2 (0.15)	23.7 (0.16)	22.1 (0.15)	19.9 (0.14)	21.4 (0.15)	20.7 (0.14)	21.7 (0.15)
#34 JP-4 (CI; FSII)	22.2 (0.15)	24.4 (0.17)	22.6 (0.16)	19.5 (0.13)	20.4 (0.14)	19.6 (0.14)	19.1 (0.13)

Test Foam: Orange W547R (26-1) Non-TMP POLYESTER RESIN (Type I)

#21 JP-4 (no additives)	17.0 (0.12)	17.8 (0.12)	18.3 (0.13)	17.1 (0.12)	17.9 (0.12)	16.9 (0.12)	16.6 (0.11)
#23 JP-4 (5 ppm ASA-3; 5 ppm Stadis 450)	17.0 (0.12)	17.7 (0.12)	24.7 (0.17)	16.5 (0.11)	17.3 (0.12)	19.7 (0.14)	18.8 (0.13)
#24 JP-4 (1 ppm ASA-3; 1 ppm Stadis 450)	17.0 (0.12)	16.8 (0.12)	17.3 (0.12)	18.7 (0.13)	18.3 (0.13)	19.3 (0.13)	18.1 (0.12)
#30 JP-4 (all additives)	17.0 (0.12)	18.5 (0.13)	15.8 (0.11)	14.6 (0.10)	19.6 (0.14)	18.1 (0.12)	18.7 (0.13)
#33 JP-4 (1 ppm ASA-3; 1 ppm Stadis 450; CI; FSII)	17.0 (0.12)	17.3 (0.12)	17.1 (0.12)	16.4 (0.11)	16.7 (0.12)	18.1 (0.12)	18.4 (0.13)
#34 JP-4 (CI; FSII)	17.0 (0.12)	18.9 (0.13)	18.3 (0.13)	17.4 (0.12)	17.1 (0.12)	18.5 (0.13)	18.0 (0.12)

TABLE 7. POLYESTER FOAM SUMMARY TENSILE DATA

Exposure: 160°F (71°C) in 900 ml Fuel
Test Foam: Orange W593R (31-1) TMP Polyester Resin (Type I)

Test Fluid	Exposure Time in Weeks						
	Baseline psi (MPa)	4 weeks psi (MPa)	8 weeks psi (MPa)	12 weeks psi (MPa)	16 weeks psi (MPa)	20 weeks psi (MPa)	24 weeks psi (MPa)
#22 JP-5 (no additives)	22.2 (0.15)	22.3 (0.15)	22.1 (0.15)	21.6 (0.15)	21.8 (0.15)	22.3 (0.15)	22.5 (0.16)
#31 JP-5 (1 ppm ASA-3; 1 ppm Stadis 450; CI;AO;MDI;FSII)	22.2 (0.15)	19.0 (0.13)	18.8 (0.13)	15.8 (0.11)	17.5 (0.12)	19.5 (0.13)	17.6 (0.12)
#32 JP-5 (1 ppm ASA-3; 1 ppm Stadis 450; CI; FSII)	22.2 (0.15)	21.3 (0.15)	19.4 (0.13)	19.1 (0.13)	16.3 (0.11)	18.4 (0.13)	15.4 (0.11)

Test Foam: Orange W547R (26-1) Non-TMP Polyester Resin (Type I)

#22 JP-5 (no additives)	17.0 (0.12)	16.2 (0.11)	17.8 (0.12)	14.9 (0.10)	17.3 (0.12)	18.6 (0.13)	16.9 (0.12)
#31 JP-5 (1 ppm ASA-3; 1 ppm Stadis 450; CI;AO;MDI;FSII)	17.0 (0.12)	16.5 (0.11)	18.1 (0.12)	14.5 (0.10)	16.0 (0.11)	15.8 (0.11)	15.6 (0.11)
#32 JP-5 (1 ppm ASA-3; 1 ppm Stadis 450; CI; FSII)	17.0 (0.12)	17.5 (0.12)	17.8 (0.12)	17.3 (0.12)	16.9 (0.12)	15.3 (0.11)	15.5 (0.11)

TABLE 8. ADDITIONAL FOAM SUMMARY TENSILE DATA

Exposure: 160°F (71°C) in 900 ml Fuel + 10 ml Water
Test Foam: Orange W593R (31-1) TMP, W547R (26-1) Non-TMP Polyester Resins (Type I)

Test Fluid	Exposure Time in Weeks						
	Baseline psi (MPa)	4 weeks psi (MPa)	8 weeks psi (MPa)	12 weeks psi (MPa)	16 weeks psi (MPa)	20 weeks psi (MPa)	24 weeks psi (MPa)
#1 JP-4 (no additives) TMP	22.2 (0.15)	17.5 (0.12)	12.9 (0.09)	0.9 (0.01)	No		
Non-TMP	17.0 (0.12)	15.0 (0.10)	15.2 (0.11)	3.5 (0.02)	Specimens		
#10 JP-4(all additives)[1] TMP	22.2 (0.15)	18.6 (0.13)	9.5 (0.07)	Failed			
Non-TMP	17.0 (0.12)	10.0 (0.07)	3.3 (0.02)	Failed			

Exposure: 160°F (71°C) in 900 ml Fuel
Test Foam: Blue W236R (3-1) Polyether Foam (Type V)

#21 JP-4(no additives) Dry	18.6 (0.13)	19.0 (0.13)	18.1 (0.12)	16.6 (0.11)	18.9 (0.13)	17.2 (0.12)	16.8 (0.12)
Wet	9.2 (0.06)	9.7 (0.07)	10.0 (0.07)	9.0 (0.06)	9.2 (0.06)	8.9 (0.06)	8.4 (0.06)
#21 JP-4(Steam Autoclave)[2]	18.6 (0.13)	12.7 (0.09)	12.0 (0.08)	12.5 (0.09)	11.8 (0.08)	10.9 (0.07)	11.4 (0.08)
#30 JP-4(all additives)[1] Dry	18.6 (0.13)	18.4 (0.13)	17.7 (0.12)	16.1 (0.11)	16.2 (0.11)	18.1 (0.12)	13.2 (0.09)
Wet	9.2 (0.06)	9.8 (0.07)	9.1 (0.06)	7.8 (0.05)	9.1 (0.06)	8.4 (0.06)	8.2 (0.06)
#30 JP-4 (Steam Autoclave)[2]	18.6 (0.13)	12.6 (0.09)	12.0 (0.08)	11.6 (0.08)	11.3 (0.08)	11.2 (0.08)	10.5 (0.07)

NOTES: [1]All additives include 1 ppm ASA-3; 1 ppm Stadis 450; CI; AO; MDI; FSII.
[2]Steam Autoclave exposure for 15 hours per MIL-B-83054B.

SECTION III
DISCUSSION

Premature failures occurred for red and orange polyester polyurethane foams in all fuel/additives combinations in which water was present. These failures in JP-4 fuel without additives and containing all additives are illustrated in Figures 1 and 2, respectively. Table 1 also verifies these failures for all other test fluids containing water. Figures 1 and 2 also show that both Trimethanol propane (TMP) and glycerine (non-TMP) polyester resins have poor hydrolytic stability. Red Fine Pore (MIL-B-83054B, Type III) foams do, however, exhibit somewhat greater hydrolytic stability than Orange Polyester (MIL-B-83054, Type I) foam as Figures 1 and 2 graphically illustrate.

A marked change in compatibility of both TMP and non-TMP polyester foams in JP-4 fuel containing no water is evident in Figure 3. This improved compatibility occurs in all test fluids. Figures 4 and 5 illustrate the improved compatibility in JP-4.

Blue Fine Pore (MIL-B-83054B, Type V) foam is virtually unaffected by the presence of water or additives in fuel. Figure 1 shows a comparison of the hydrolytic stability of the blue polyether polyurethane with both red and orange polyester foams in fuel containing water. Figures 4 and 5 compare the compatibility of blue W236R polyether foam with TMP and non-TMP polyester foams in JP-4 fuel without and with additives, respectively. Figures 6 and 7 illustrate the compatibility of blue foam with JP-4 with and without additives and the presence of water. The special pigment polyether polyurethane foams were also compatible with fuel additives and water. This is to be expected since these foams are identical to W236R blue polyether foam except for types and concentrations of pigment.

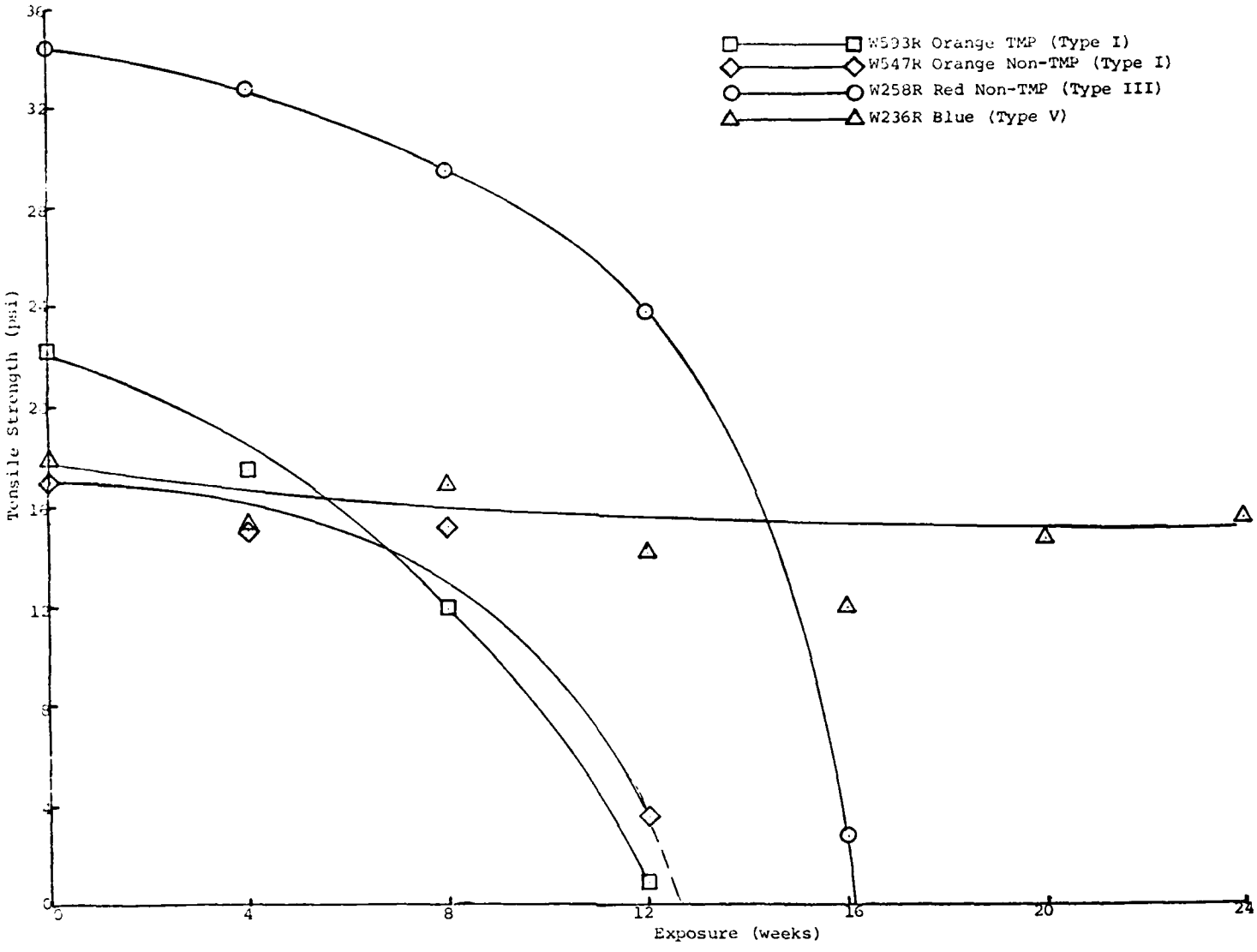

Figure 1. Comparative Tensile Properties of Foams Exposed to 900 ml Fuel + 10 ml Water (JP-4, no additives).

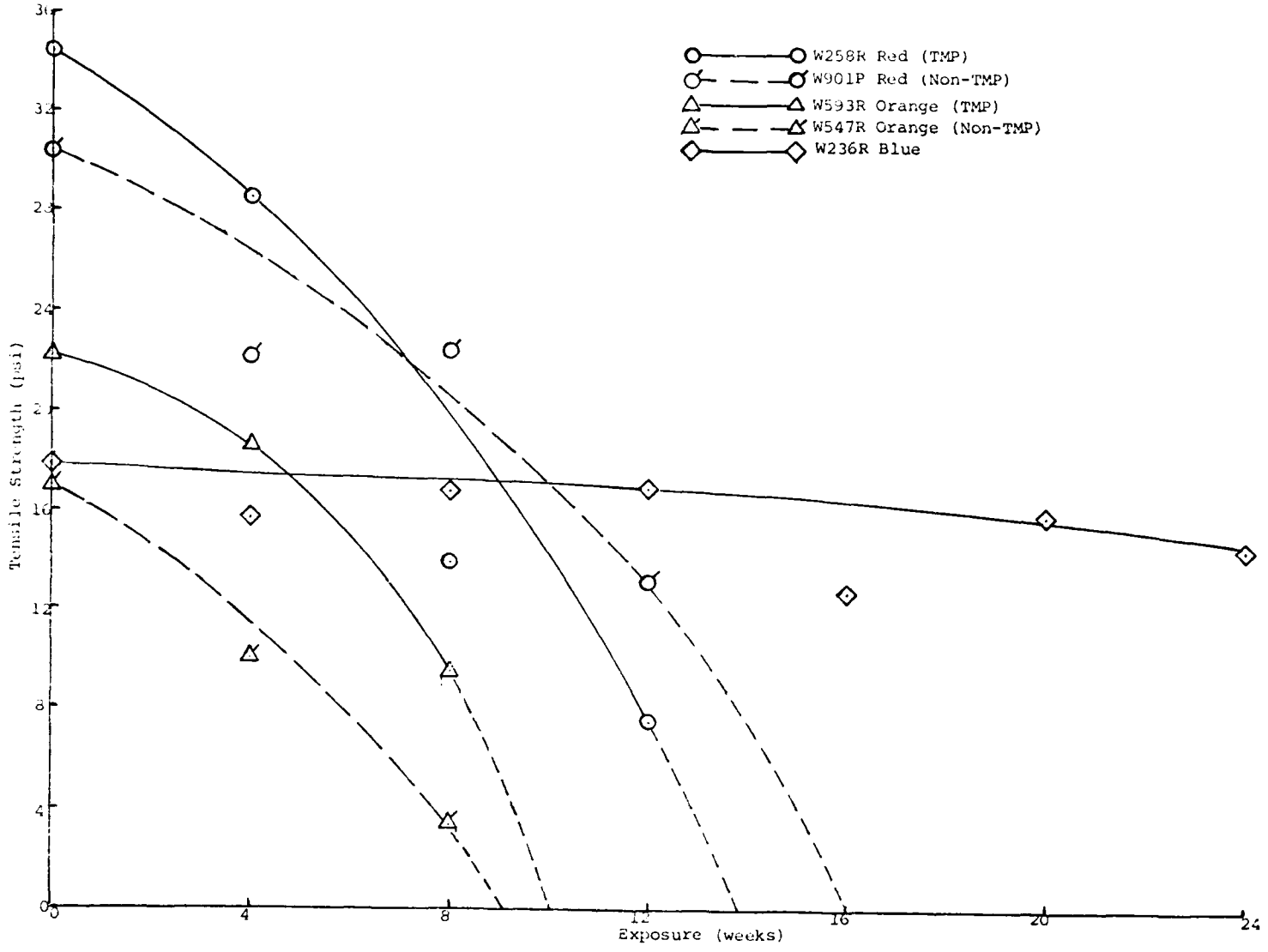

Figure 2. Comparative Tensile Properties of Polyester Foams Exposed to 900 ml Fuel + 10 ml Water (JP-4, all additives).

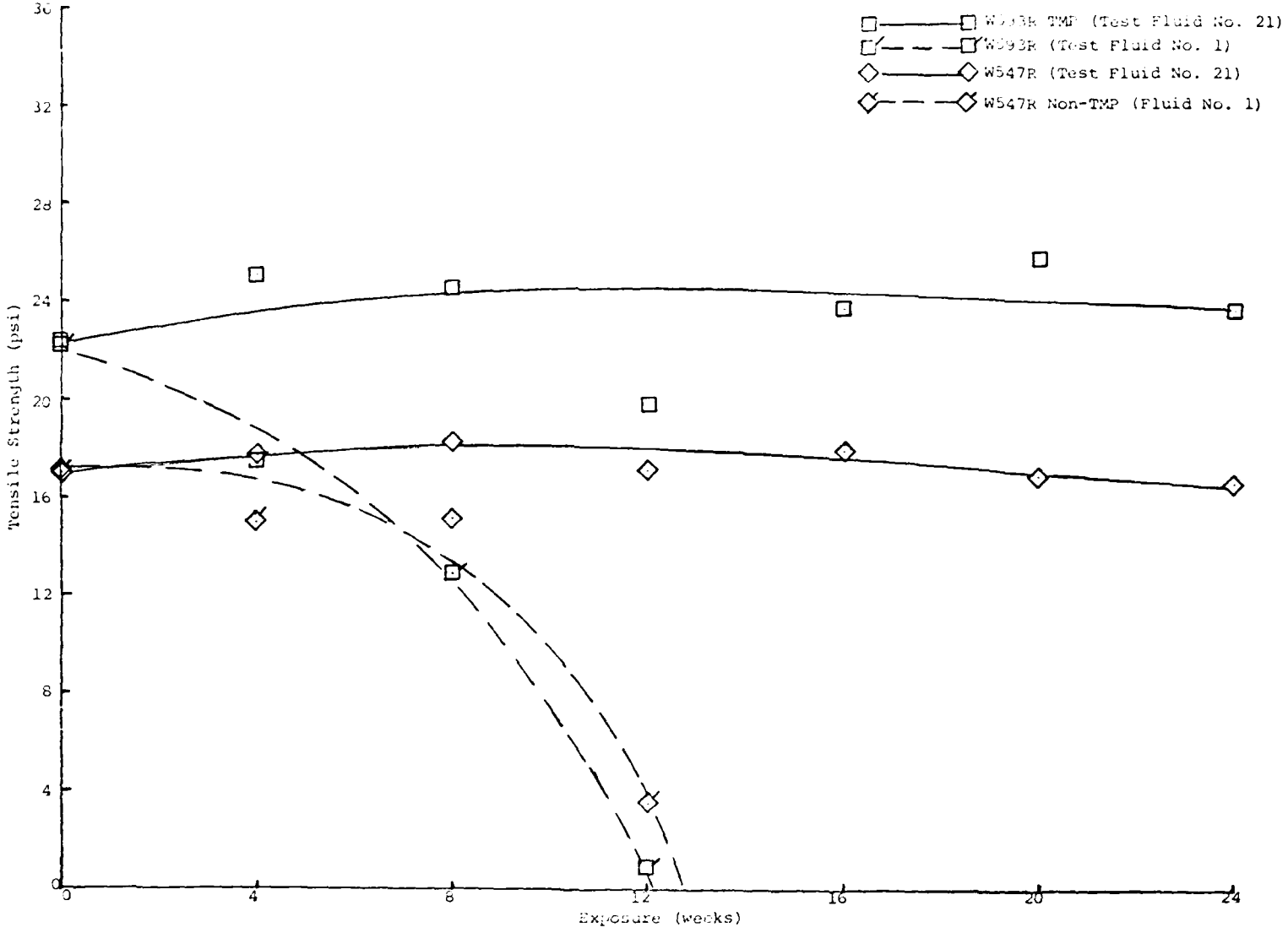

Figure 3. Comparative Tensile Properties of Orange Polyester (TMP and Non-TMP) Foams Exposed to Fuel With and Without Water (JP-4, No additives).

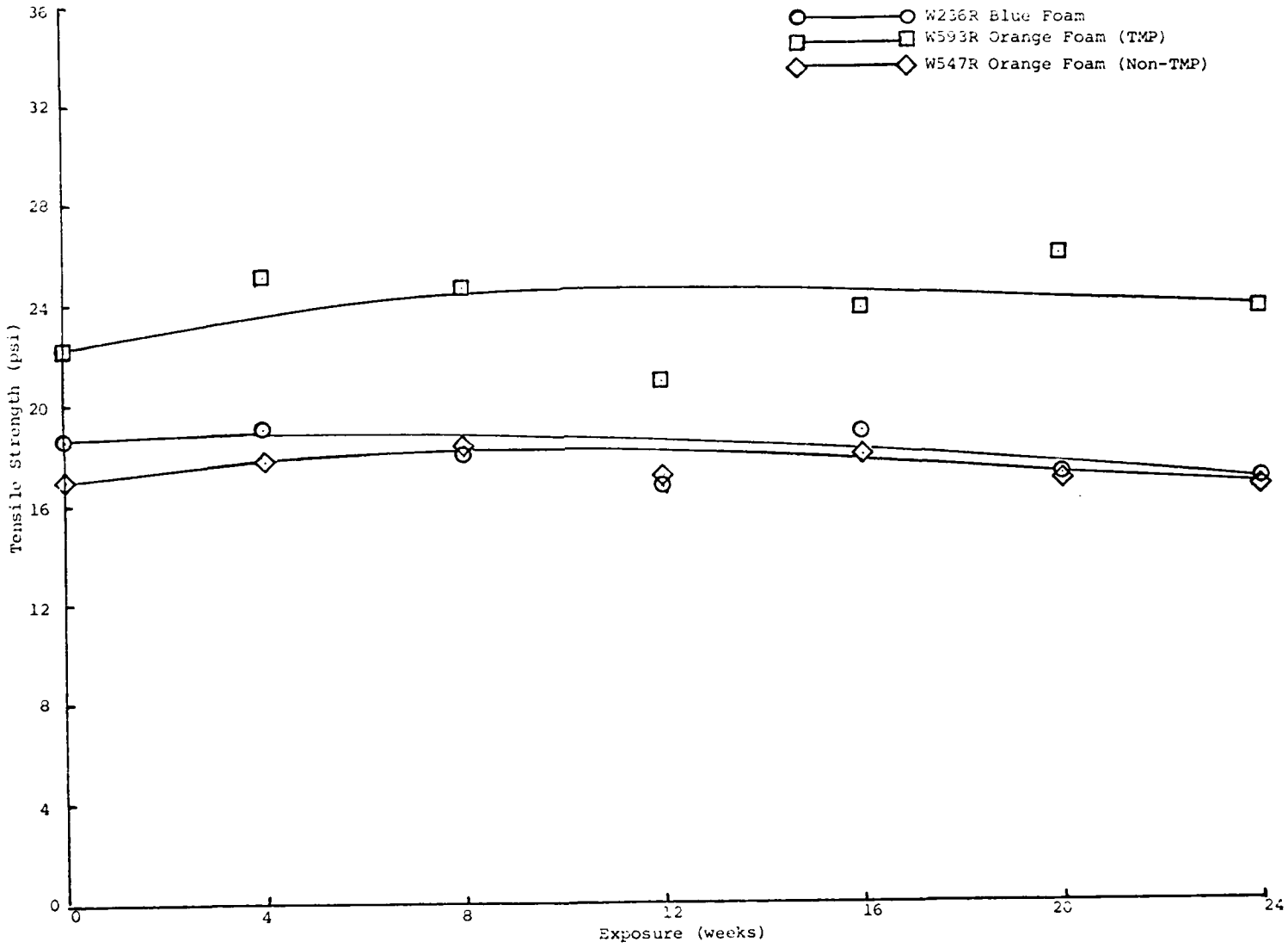

Figure 4. Comparative Tensile Properties of Foams Exposed to Fuel Only (JP-4, No additives).

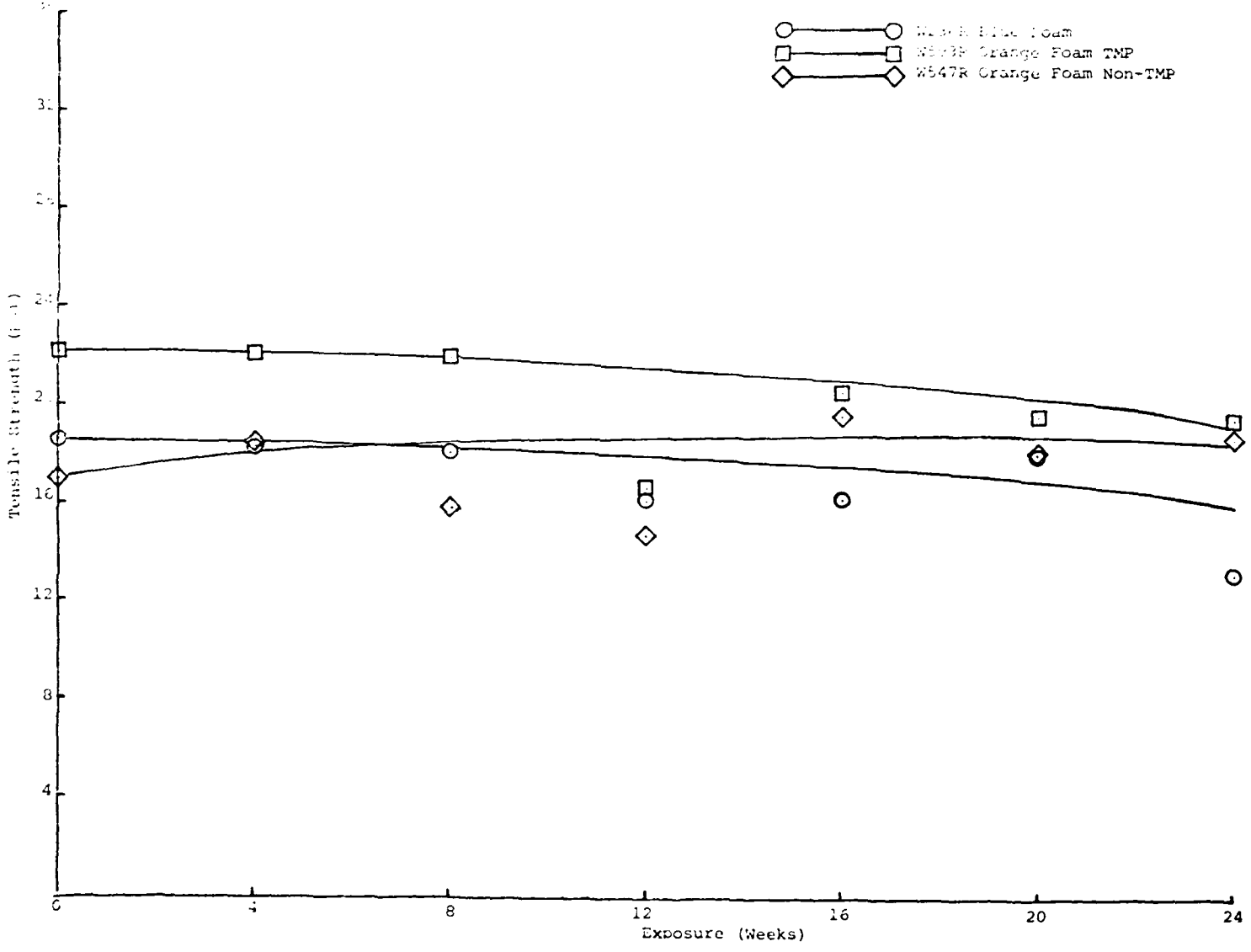

Figure 5. Comparative Tensile Properties of Foams Exposed to Fuel Only (JP-4, All additives).

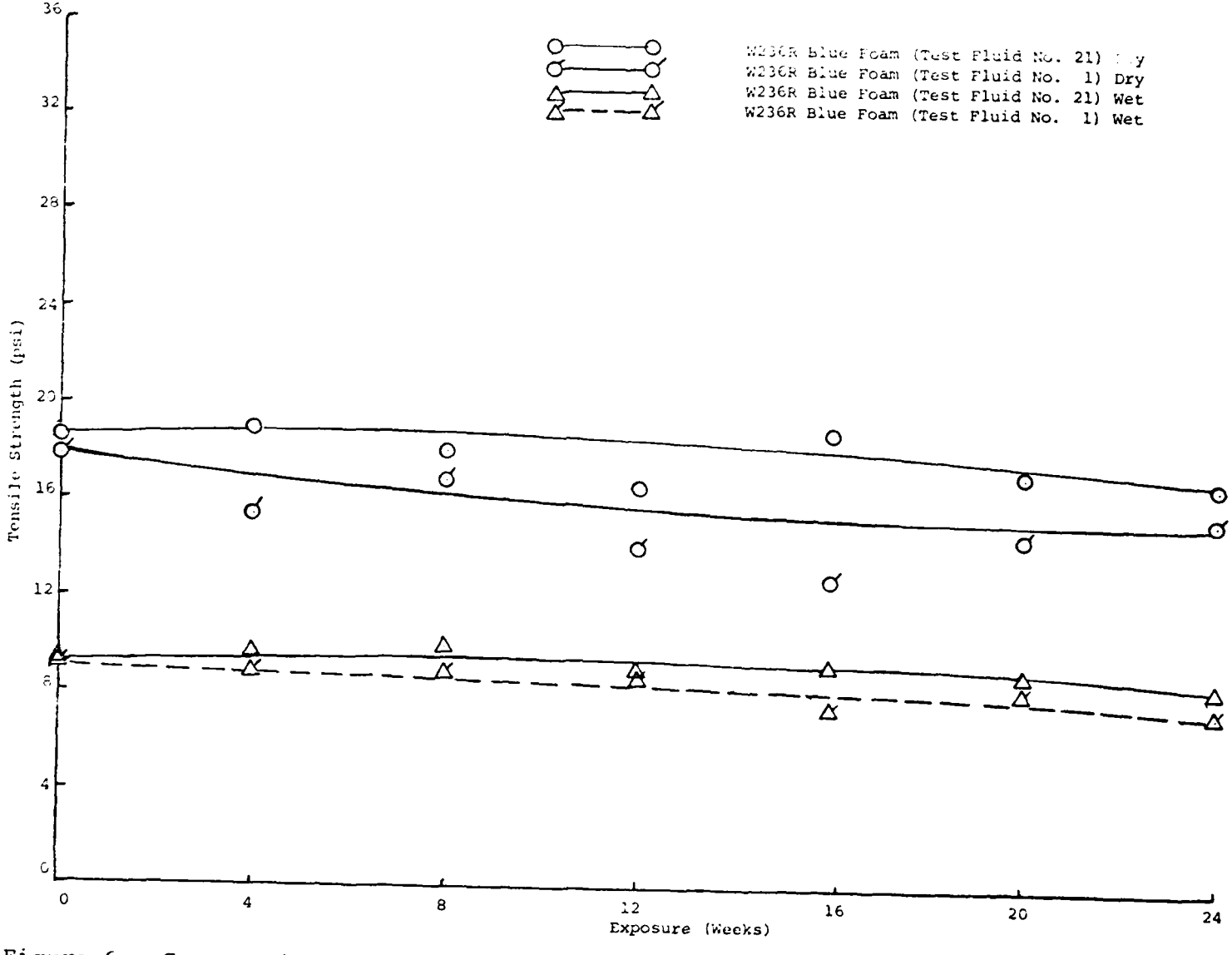

Figure 6. Comparative Tensile Properties (Dry and Wet) of Polyether Foam Exposed to Fuel With and Without Water (JP-4, No additives).

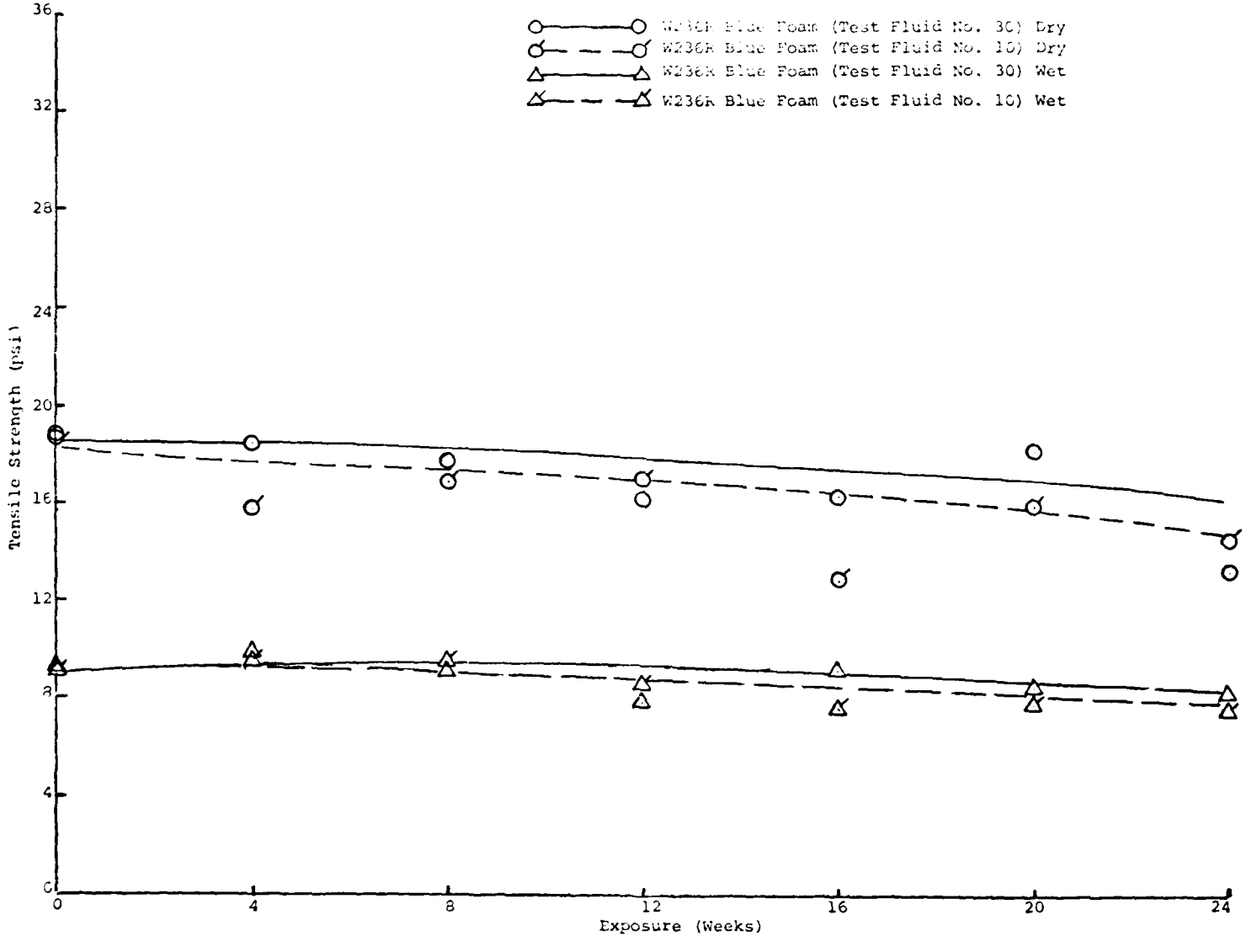

Figure 7. Comparative Tensile Properties (Dry and Wet) of Polyether Foam Exposed to Fuel With and Without Water (JP-4, All additives).

SECTION IV
CONCLUSIONS

The results of the program to evaluate the compatibility of reticulated foams in typical turbine fuels containing currently approved additives indicates that:

- Polyester polyurethane foams exhibit poor hydrolytic stability. Premature failures occurred for all fluid/additive combinations due to the presence of water in the Phase I fuel samples. These failures occurred for both TMP and non-TMP polyester resins.

- Polyether polyurethane foams are hydrolytically stable. The presence of water in the test fluids has virtually no effect on the foam tensile properties.

- Typical fuel additives have no apparent effect on fuel compatibility of both polyester and polyether foams.

- Red polyester foam appears to have greater hydrolytic stability than orange polyester foam.

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4. Reed, T. O. and Vahle, Lt. W. D., "Qualification Test Results for Scott Paper Co., Blue Hybrid Polyether Foam," Technical Memorandum ENFEF-TM-79-08, December 1979.

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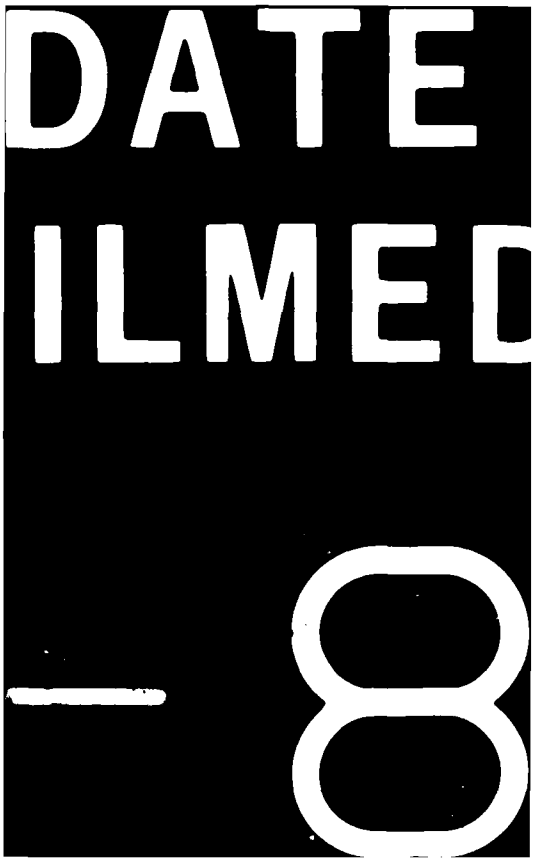
*U.S.Government Printing Office: 1980 — 757-002/285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