DURABILITY TESTING OF BARRIER TREATED HIGH - DENSITY POLYETHYLENE SMALL OFF-ROAD ENGINE FUEL TANKS (March 2003)

Stationary Source Testing Branch
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Introduction

During the spring of 2002, the California Air Resources Board (CARB) conducted tests to determine the possible abrasive effects of fuel slosh on barrier treated High-Density Polyethylene (HDPE) fuel tanks. Staff selected and tested six identical barrier treated one-quart small off-road engine fuel tanks. Permeation rates were measured before and after subjecting each tank to 1.2 million 'slosh' cycles. Subsequent to that testing, it was determined that a Hindered Light Amine Stabilizer (HALS) UV inhibitor used in the molding process interfered with the barrier treatment and biased the test results. Since the results were biased, ARB decided to perform a retest with tanks that did not contain a HALS inhibitor or any other substance that may interfere with the barrier treatment process. Staff worked with American Honda to procure nine two-quart fuel tanks for testing.

The CARB staff measured the average permeation rates of three fluorinated, three sulfonated, and three untreated fuel tanks. As in the earlier testing, the rates were measured gravimetrically before and after subjecting each tank to 1.2 million slosh cycles over a 7-day period.

Test Protocol

In September of 2002, CARB staff selected nine identical two-quart small off-road engine fuel tanks for testing. Staff chose these tanks based on their material composition, volume, and uniform geometry. The internal surface area of each tank, 0.115 square meters, was calculated from CAD drawings by American Honda. The tanks were molded from an HDPE resin that contained a 2% mixture of carbon black. Three tanks were fluorinated to a SL-5 level by Fluoro-Seal at their Houston, Texas plant. Three tanks were sulfonated by Sulfo Technologies LLC at their plant in Michigan until a surface concentration of 550 micro grams of sulfur trioxide per square inch was reached. The remaining three tanks were left untreated to serve as a control group.

In October of 2002, the tanks began preconditioning at CARB's test facility in Sacramento, California. The preconditioning process began by subjecting each tank to 1000 pressure/vacuum cycled (+5.0 PSIG to -1.0 PSIG). Upon completion, the tanks were transferred to CARB's test facility located in El Monte, California. There the tanks were filled with commercial pump fuel containing MTBE and soaked at ambient temperature and pressure for ninety days. After soaking, the tanks were emptied, and immediately refilled to 50% capacity with

Phase II California Reformulated Certification (CERT) fuel. Each tank was then sealed using a hand-held fusion welder and a 1/4” thick HDPE coupon and visually inspected for leaks.

After preconditioning, an initial permeation test was performed on the fuel tanks. Weight loss was used to determine average permeation rates. All tanks were weighed using a 6,200-gram balance with sensitivity of $\pm$ 0.01 grams. After an initial weighing, the tanks were placed in a Sealed Housing for Evaporative Determination (SHED) and exposed to multiple 1-day/24-hour/1440-minute variable temperature profiles (see Attachment 1). The tanks were then post weighed after each 24-hour cycle and the weight loss calculated.

Data were collected until the daily weight loss data met our acceptance criteria (standard deviation of less than 0.05 grams). The daily weight loss data were then used to determine average permeation rates. After the initial permeation test, the tanks were transported to Sacramento and ‘sloshed’ using an orbital shaker table (orbital diameter 30-mm). The frequency was set to two cycles per second. The orbital shaker subjected the fuel tanks to 1.2 million ‘slosh’ cycles over a seven-day period. During sloshing, the fuel inside the tanks was subjected to a centripetal acceleration of 0.24 g.

After exposure to fuel ‘sloshing’, the sealed tanks were transported back to El Monte to measure any change in average permeation rates. As before, the tanks were exposed to multiple 1-day/24-hour/1440-minute variable temperature profiles. The tanks were then post weighed after each 24-hour cycle and the weight losses calculated.

Results

Permeation rates for each tank were calculated by dividing the average daily weight loss by the tank’s internal surface area. Although each tank underwent multiple diurnal cycles, results are calculated using only the average of the last five 24-hour cycles. The initial cycles of test data were not used in determining individual per container permeation rates due to variability. Figure 1 and Table 1 summarize the permeation results both before and after sloshing.

Figure 1

Barrier Treated Fuel Tank Durability Test Results

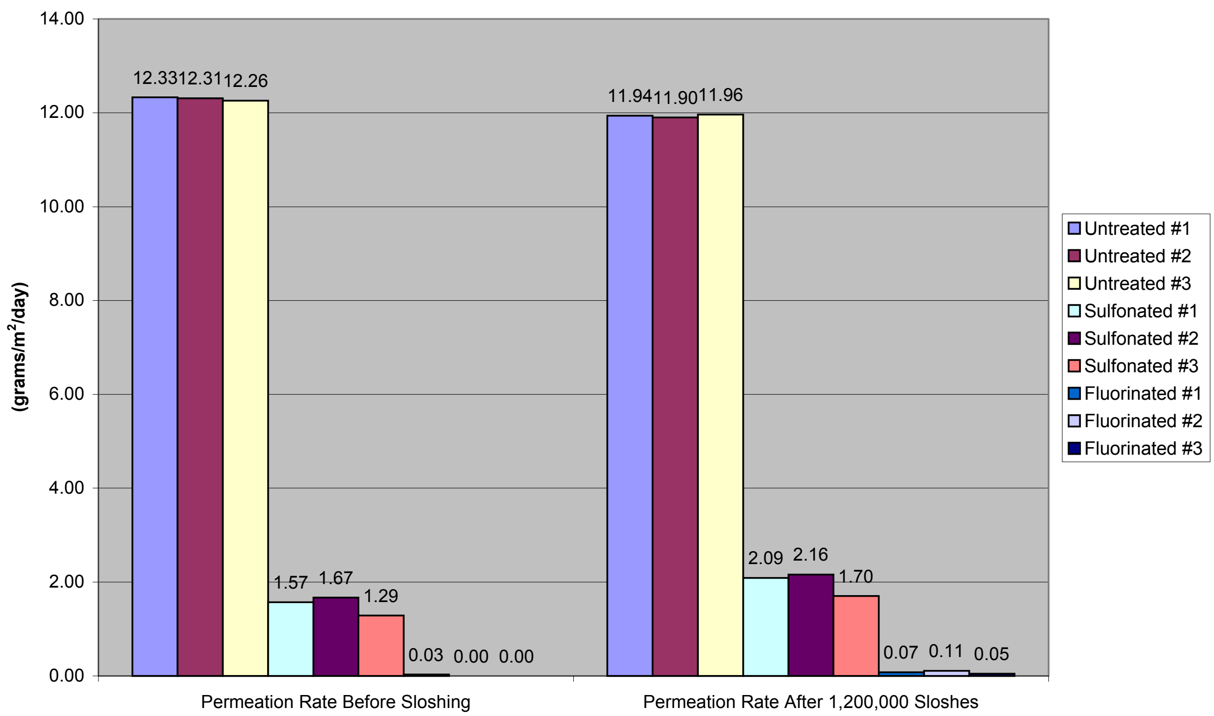

Table 1

	Perm. Rate Before Sloshing (grams/m^2/day)	% Reduction from Average Untreated	Perm. Rate After Sloshing (grams/m^2/day)	% Reduction from Average Untreated
Untreated #1	12.33		11.94	
Untreated #2	12.31		11.90	
Untreated #3	12.26		11.96	
Average	12.30		11.93	
Sulfonated #1	1.57	87.2%	2.09	82.5%
Sulfonated #2	1.67	86.4%	2.16	81.9%
Sulfonated #3	1.29	89.5%	1.70	85.7%
Average	1.51	87.7%	1.98	83.4%
Fluorinated #1	0.03	99.8%	0.07	99.4%
Fluorinated #2	0.00	100%	0.11	99.1%
Fluorinated #3	0.00	100%	0.05	99.6%
Average	0.01	99.9%	0.08	99.3%

Conclusion

The test results indicate a clear benefit of barrier treating equipment fuel tanks using fluorination and sulfonation. Both types of surface treatments initially provide an effective barrier against permeation (> 80%) when compared to untreated tanks. The test results indicate that fluorination provides a superior permeation barrier (> 99%). Additionally, the data indicate slight to marginal reductions in barrier effectiveness (0.7% to 6.6%) for both fluorination and sulfonation, respectively, when subjected to excessive fuel sloshing. In spite of the reduction in barrier effectiveness, both processes can provide significant long-term benefits.

Attachment 1

1 Day / 24 Hour / 1440 Minute Variable Temperature Profile

HOUR	MINUTE	TIME REMAINING (MINUTES)	TEMPERATURE (°F)
0	0	1440	65.0
1	60	1380	66.6
2	120	1320	72.6
3	180	1260	80.3
4	240	1200	86.1
5	300	1140	90.6
6	360	1080	94.6
7	420	1020	98.1
8	480	960	101.2
9	540	900	103.4
10	600	840	104.9
11	660	780	105.0
12	720	720	104.2
13	780	660	101.1
14	840	600	95.3
15	900	540	88.8
16	960	480	84.4
17	1020	420	80.8
18	1080	360	77.8
19	1140	300	75.3
20	1200	240	72.0
21	1260	180	70.0
22	1320	120	68.2
23	1380	60	66.5
24	1440	0	65.0