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Determination of the Effects of Container Wall Thickness on Average Permeation Rates from Untreated HDPE Portable Fuel Containers

Introduction

In order to determine the effect of average container wall thickness on baseline permeation rates, the Air Resources Board (ARB) staff tested several high density polyethylene (HDPE) portable fuel containers. Tests were conducted on thirty 5-gallon "jerry" cans ranging in average wall thickness from 0.225" to 0.080." All containers are monolayer HDPE, constructed of Marlex HXM 50100, and blow molded at the Phillips Plastics Technical Center using a mold provided by Chilton Metal Products. After sufficient preconditioning, containers were filled with California Phase II Certification (CERT) fuel and subjected to a variable temperature profile. Permeation rates were then determined through gravimetric analysis.

Test Protocol

Containers were received from Phillips Petroleum Company in late July and filled with commercial fuel. Fuel preconditioning for all containers began by August 2, 1999. During the preconditioning cycle containers were stored at ambient temperature and pressure in flammable storage cabinets. After 12 weeks of ambient preconditioning, the containers were emptied, blown dry with compressed zero air, and immediately refilled with CERT fuel. The containers were then sealed using a hand held fusion welder and 1/4" thick HDPE coupons and leak tested as specified in proposed ARB Test Method 513 (copy can be found at ARB web site: http://www.arb.ca.gov/regact/spillcon/spillcon.htm).

Weight loss was used as the basis for determining relative permeation rates. Sealed containers were weighed using a high capacity balance with a sensitivity of ± 0.01 grams prior to the start of each diurnal cycle. After each container was weighed and the weight recorded, they were placed in a Sealed Housing for Evaporative Determination (SHED) and exposed to a 1-day/24-hour / 1440-minute variable temperature profile (see Attachment 1). Containers were then post weighed after each 24-hour diurnal cycle and the weight loss calculated.

Cumulative weight loss data as a function of time were collected for each container tested. Two phases of testing were completed, the first consisting of 20 valid diurnal cycles, and the second consisting of 14 valid diurnal cycles. The first three days of test data were not used in determining individual per container permeation rates due to high variability.

A sample of the CERT fuel was submitted for analysis and the density determined to be 2793.3 grams/gallon.

A total of thirty 5-gallon containers were tested during the study. The test containers were molded in four nominal wall thicknesses: 0.225”, 0.200”, 0.150” and 0.080”. None of the containers in these sample sets were subjected to the durability procedure as specified in Test Method 513, Section 7.

After the first phase of testing all containers were opened, blown dry, and re-weighed to determine an accurate tare weight. The containers were then immediately re-filled with commercial fuel, capped, and allowed to continue to soak for another 12 weeks. Just prior to the second phase of testing the containers were again drained, blown dry with compressed zero air, filled with fresh CERT fuel, and re-sealed with a fusion welder. After the second phase of testing the containers were again emptied and new tare weight data collected. All containers remained filled with fuel for the duration of the 24-week study period.

Results

The goal of the study was to determine the effect of container wall thickness on average permeation rates from untreated HDPE portable fuel containers. Previous data submitted for review from Phillips Petroleum Company suggested that increasing the container wall thickness does mitigate the effects of permeation from plastic containers. However, it was not clear from a review of the data if this is a temporary condition. Staff had concerns that increasing container wall thickness would only delay the onset of steady state permeation rates recorded in earlier tests. To address these concerns staff elected to increase the preconditioning cycle time required in Test Method 513 from four weeks to twelve weeks, with follow up tests after a second twelve week preconditioning period.

The average permeation rate from test containers with a nominal wall thickness of 0.225” from the first phase of testing was determined to be 0.41 grams/gallon/day. This rate is based on data averaged from 6 individual containers and represents a total of 120 individual 24-hour cycles. Follow up tests conducted after an additional 12 weeks of preconditioning on these 6 containers show a 6.8% increase in this average rate. The average permeation rate during the second phase of testing was 0.44 grams/gallon/day.

The average permeation rate from test containers with a nominal wall thickness of 0.200” was determined to be 0.52 grams/gallon/day. This rate is based on data averaged from 6 individual containers and represents a total of 120 individual 24-hour cycles. Follow up tests conducted after an additional 12 weeks of preconditioning on these 6 containers show a 5.5% increase in this average rate. The average permeation rate during the second phase of testing was 0.55 grams/gallon/day.

The average permeation rate from test containers with a nominal wall thickness of 0.150" was determined to be 0.59 grams/gallon/day. This rate is based on data averaged from 6 individual containers and represents a total of 120 individual 24-hour cycles. Follow up tests conducted after an additional 12 weeks of preconditioning on these 6 containers show a 3.3% increase in this average rate. The average permeation rate during the second phase of testing was 0.61 grams/gallon/day.

The average permeation rate from test containers with a nominal wall thickness of 0.080" was determined to be 0.93 grams/gallon/day. This rate is based on data averaged from 12 individual containers and represents a total of 240 individual 24-hour cycles. Follow up tests conducted after an additional 12 weeks of preconditioning on 9 of these containers show a 3.1% increase in this average rate. The average permeation rate during the second phase of testing was 0.96 grams/gallon/day.

As in previous tests, not all data points recorded in the attached data sheets were used in determining the various average permeation rates. Several data points were not included in the average calculations for reasons identified in the field data sheets. Attachment 2 presents the results of the all the tests. The following table best illustrates the permeation test results.

Table 1

Phase I Tests*		Phase II Tests**		Overall	
Wall Thickness (inches)	Average Rate (g/gal/day)	Wall Thickness (inches)	Average Rate (g/gal/day)	Combined Average (g/gal/day)	% Difference Phase I vs. Phase II
0.225	0.41	0.225	0.44	0.43	6.8%
0.200	0.52	0.200	0.55	0.54	5.5%
0.150	0.59	0.150	0.61	0.60	3.3%
0.080	0.93	0.080	0.96	0.95	3.1%

* Phase I Tests conducted after 12 weeks of preconditioning
** Phase II Tests conducted after 24 weeks of preconditioning

Conclusions

As shown in Table 1, increasing nominal wall thickness has a significant effect on average permeation rates of HDPE portable fuel containers. At a nominal wall thickness of 0.225" several of the containers tested during the study would initially adhere to the proposed permeation standard of 0.4 grams/gallon/day. However, these same containers show a slight increase in average permeation rates when exposed to a second 12-week preconditioning period. This seems to indicate that the containers have not reached a maximum saturation level.

Previous tests conducted by staff, as well as data supplied by resin manufacturers, indicate that containers with nominal wall thicknesses of 0.080” can reach full saturation with less than 4 weeks of preconditioning. Based on this statement, comparing the data from both phases of testing for the 0.080” containers leads staff to the conclusion that the 3.1% change in average permeation rates is attributed to the variability of the test method. Therefore, the increase in average permeation rates for the 0.225” containers is approximately 4% when compared to the first phase of testing. Exactly when the containers with significantly increased wall thicknesses will reach full saturation cannot be determined from this study.

Attachment 1

1 Day / 24 Hour / 1440 Minute Variable Temperature Profile

HOUR	MINUTE	ET / MIN	TEMP °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