A New Approach to Monitor Liquid Permeability through Plastic Containers

Due to a growing use of plastic bottles for the storage of chemicals, for example, hydrocarbons, there is always an interest in measuring the liquid permeability through plastic containers. For example, for safety reasons the department of transportation (DOT) requires that the liquid permeability through a plastic container be less than a certain limit, defined in g/day units. Restrictions on permeability by the DOT have led to the development of several new technologies to reduce permeability. This dictates the need for permeability analysis at the research as well as production levels.

While the science of diffusion and permeability measurements is well developed and the complications known,[1,2] we have concentrated on developing a simple, low cost method of monitoring the liquid permeability through plastic containers for research and production sites. At this point, we wish to briefly describe a couple of crude tests being used. A conventional permeability test involves clamping a small piece (i.e., disc 1.5 in. diameter) on top of a metal cup containing the liquid of interest. By monitoring the weight of the assembly over several days, the permeability of the solvent through the plastic can be evaluated. A second method is to immerse a piece of the plastic in solvent, periodically remove it and weigh. This so called "weight-gain" test, has the disadvantage that the solvent can penetrate through the edges of the piece and get trapped; this would not provide the real weight gain due to diffusion. Moreover, since the diffusion is not taking place strictly through the thickness direction, the role of a barrier layer may be underestimated.

The objective of this report is to describe a simple and low cost test, developed for monitoring liquid permeability. Our approach is intended not only for production sites but also offers the potential for scientific studies on diffusion through plastics.

EXPERIMENTAL

As indicated in Figure 1, the bottle is filled with the liquid whose permeability is to be determined. The filled bottle is then placed in an outer jar containing an alcohol which dissolves the permeating

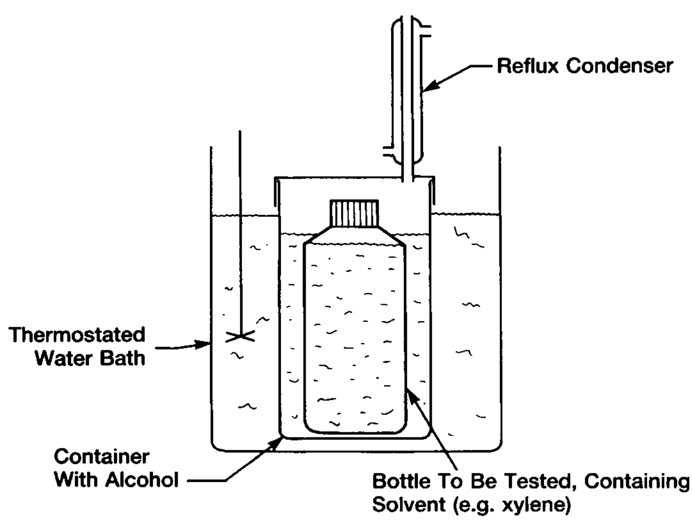

Fig. 1. Design of an apparatus for testing bottle permeability.

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TABLE I
Permeation of Xylene Through Polyethylene Based Bottles

	Time (h)	Differential refractive index ($\Delta n \times 10^4$) HDPE control	HDPE/polyamide
@ 60°C	1	0.0	0.0
	4	0.9	0.0
	7	1.9	0.0
	24	8.8	0.6
@ 70°C	1	0.0	0.0
	3	0.9	0.0
	6	2.9	0.0
	24	14.9	0.7

liquid. The concentration of the liquid in the alcohol is followed by determining the differential refractive index (Δn) of small samples of alcohol taken periodically from the outer bottle.

The validity of our approach has been tested by studying the permeability of xylene through high density polyethylene (HDPE) and HDPE/polyamide bottles; the latter having a polyamide resin as a barrier.

RESULTS AND CONCLUSIONS

The data in Table I and Figure 2 clearly show that our proposed procedure is valid in distinguishing the bottle materials with respect to the permeability; the bottle with barrier (HDPE/

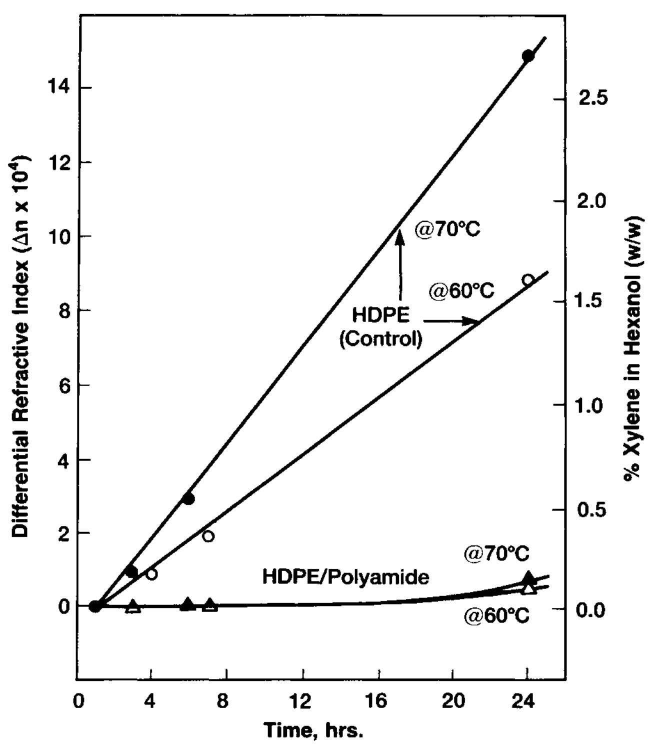

Fig. 2. Permeation of xylene through polyethylene and polyethylene/polyamide bottles.

TABLE II
Permeation of Alcohol Through Polyethylene Based Bottles

Time (24 h @ °C)	Differential refractive index ($\Delta n \times 10^4$)	
	HDPE (control)	HDPE/polyamide
60	−1.9	0.0
70	−3.6	0.0

TABLE III
Absorption of Xylene in Polyethylene Based Bottle Materials
(% Weight of Xylene Absorbed in 1 h @ 60°C)

Material	Weight gain (%)
HDPE (control)	7.52
HDPE/polyamide	4.72

polyamide) being more resistant to permeability. The difference between the bottles can be detected within 1–3 h (Fig. 2). The differential refractive index has also been obtained for the xylene within the bottles in order to provide information about the permeation of the surrounding alcohol into the bottles (Table II). Interestingly, alcohol permeation occurs only in the control HDPE, probably due to the swelling of the HDPE by xylene. This is again a confirmation of the differences in the two bottle materials.

A "weight-gain" test already in practice in the industry, has also been applied presently. Although the results (Table III) support the superiority of the HDPE/polyamide bottle, it is erroneously indicated that both the bottles are permeable to xylene (e.g., compare Tables I and III). In addition to the problems indicated earlier, this type of test causes delamination and overlooks defects such as holes or thin spots.

Our procedure can be readily calibrated (Fig. 2) such that the data can be obtained in the units of gm/day as per DOT regulations. Using kinetic methods, the experimental time-temperature permeability data can be used to predict the long term permeability of liquids through plastic containers.[3]

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