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METHOD FOR DETERMINING THE GAS PERMEABILITY OF UREA FORMALDEHYDE FOAM INSULATION SAMPLES

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ABSTRACT

The resistance to air flow was measured for UFFI and other insulating materials using a simple test developed for this purpose. The resistance to air flow of a foam specimen may give an indication of its structure and the amount of degradation that has occurred. When compared to other insulating materials, UFFI had a high resistance in most cases.

METHOD FOR DETERMINING THE GAS PERMEABILITY OF
UREA FORMALDEHYDE FOAM INSULATION SAMPLES

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It was believed that the gas permeability of urea formaldehyde foam insulation (UFFI) was an important material property that could provide the basis for an assessment of the extent and effective size of foam cell interconnections, and therefore the ease of removal of off-gases by air flow through the foam.

Preliminary tests established that a linear relationship existed between the volume of air flowing through a given thickness and area of foam and the pressure drop required to sustain the flow. It was therefore possible to determine the resistance-to-flow factor that would characterize the given sample. The following relationship was developed:

$$R_f = \frac{(P_1 - P_2)\ A}{Vh} \quad \text{(mm Hg/(mm/min)/cm thickness)*}$$

* (pressure drop per unit linear velocity per unit thickness of sample)

Where: P_1 is total pressure drop, mm Hg
P_2 is total pressure drop across empty funnels, mm Hg
V is volume of air per unit time, t, $(mm)^3/min$
A is cross-sectional area of sample, $(mm)^2$
h is sample thickness, cm

This note describes the proposed test method and gives some typical results. This may provide the basis for comparison between different foams and other insulating materials.

EXPERIMENTAL

Sample Preparation

The sample for testing must be an undisturbed piece of UFFI. From this, a core was taken with a thin-walled tube (similar to a cork borer) as shown in Figure 1 to provide a cylindrical specimen about 2 mm greater in diameter than the inside diameter of the funnel into which it is pressed. It was important that the sizes of the specimen and the funnel were such that there was an airtight seal between the foam and the funnel so that air did not bypass the sample.

The specimens were made by rotating the sharp cutter as it was gently pressed into the foam. The ends of the specimen were cut flat with a sharp knife to make the specimen 50 mm long. The cutting was done while the specimen was pushed out of the cutter.

Apparatus

The apparatus for these experiments was made from standard laboratory equipment (Figure 2). UFFI specimens were held between two sintered glass funnels (Pyrex 36060, 60 mL, coarse frit) sealed together with PVC electrical tape. The pressure drop across the specimen was measured with a mercury filled U-tube manometer with a mirrored scale calibrated in mm. Flow rate was measured with a rotameter (Fisher and Porter Stabl-Vis Flowrator #LK-7355) and pressure was controlled with a gas regulator. All connections were made with Tygon tubing.

Test Procedure

Prior to the testing of foam specimens, the assembly of the two funnels (without a specimen) was connected into the apparatus. Pressure across the funnels was adjusted using the regulator to different values indicated on the manometer, and these were recorded with the corresponding flow rate as points on a graph. This measurement represented a blank value, necessary to correct values obtained with the specimen.

This test was repeated in duplicate for each specimen to check for changes that might have occurred on increase and decrease of pressure. If a change occurred between the first and second tests, it indicated that the sealing of the sample in the funnel had changed, allowing air to bypass the specimen around its edges. Once samples were satisfactorily put into the funnels, cracking and splitting were not a problem.

RESULTS AND DISCUSSION

In all cases, the pressure vs. flow curves were straight lines with very little scatter (Figure 3). The permeability (p) of a specimen was defined to be the slope of this line minus the slope of the line plotted for empty funnels. The resistance of a sample to air flow (R_f) could then be calculated from p after measuring the specimen diameter and thickness.

Initial measurements were done using funnels chosen at random from lab stock. Some of these measurements showed a decrease in resistance to air flow with repeated applications of pressure (Figure 4), and resistance increased when the specimen was compacted.

To check the possibility that air passed between edges of the foam and the funnel rather than through the foam, the measurements were repeated with high vacuum stopcock grease on the inside of the funnels to seal the edges of the specimen. The measurements done in this manner were reproducible even after application of a 75 mm Hg pressure difference, and the resistance decreased when the sample was compacted. Further investigation showed that some funnels had a slightly larger inside diameter than the mean of the lab stock (one mm smaller inside diameter than the inside diameter of the cutter), so these were removed from the stock. With smaller funnels (at least 2 mm smaller inside diameter than the inside diameter of the cutter), there was no evidence of air bypassing specimens at pressures up to 100 mm Hg. Subsequent measurements were done with the smaller diameter funnels and no grease.

The resistance to air flow of four specimens each of four UFFI samples was measured, and the average results are given in Table 2. The resistance to air flow of foam specimens varied by 20% to 50% for each foam sample. Three of the samples (foams A, B and D) had high resistance that decreased when the specimens were compacted. This indicated that cell walls in foam structure were fractured leading to an increase in the effective size of interconnecting channels. Foam D was an exception because its resistance decreased and then increased inexplicably on compaction.

An exception to this behaviour was Foam C. It had a low initial resistance that increased when the foam was compacted. In this case, compaction tended to decrease the effective size of interconnecting channels which must have been large to start with. (The microstructure of UFFI is reported in another note).

It is realized that compaction may increase the path length per unit thickness and that a factor may need to be applied if compacted samples were to be used.

When the resistance of UFFI to air flow was compared to the resistance of other insulation types (Table 3), UFFI appeared relatively impermeable, except Foam C.

CONCLUSION

The resistance to air flow was measured for UFFI and other insulating materials using a simple test developed for this purpose. The resistance to air flow of a foam specimen may give an indication of its structure and the amount of degradation that has occurred. When compared to other insulating materials, UFFI had a high resistance in most cases.

TABLE 1. Resistance Measurements of UFFI Showing Bypass of Air Around Sample

Foam Thickness* (cm)	Resistance (R_f) (mm Hg/(mm/min)/cm)
4.5	0.25×10^{-3}
2.0	1.8×10^{-3}
1.5	3.2×10^{-3}

* Compacted from 5 cm thickness.

TABLE 2. Resistance to Air Flow of UFFI Samples

Foam Thickness* (cm)	Resistance (R_F) (mm Hg/(mm/min)/cm) $\times 10^{-3}$			
	Foam A	Foam B	Foam C	Foam D
4.5	6.4	16.	0.088	8.1
3.0	4.8	4.8	0.19	4.8
2.0	3.6	2.4	0.73	7.3

* Compacted from 5.0 cm thickness.

TABLE 3. Resistance of Various Insulating Materials to Air Flow

Material	Resistance (mm Hg/(mm/min)/cm)
Fibreglass Batt	0.036×10^{-3}
Fibreglass Sheathing	0.15×10^{-3}
Blown Cellulose	0.15×10^{-3}
UFFI (Average)	8×10^{-3}

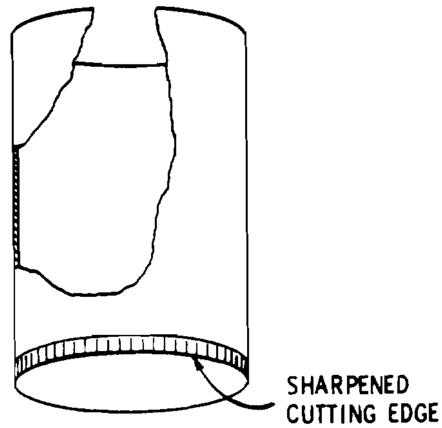

FIGURE 1

SPECIMEN CORE CUTTER FOR MAKING UFFI SPECIMENS

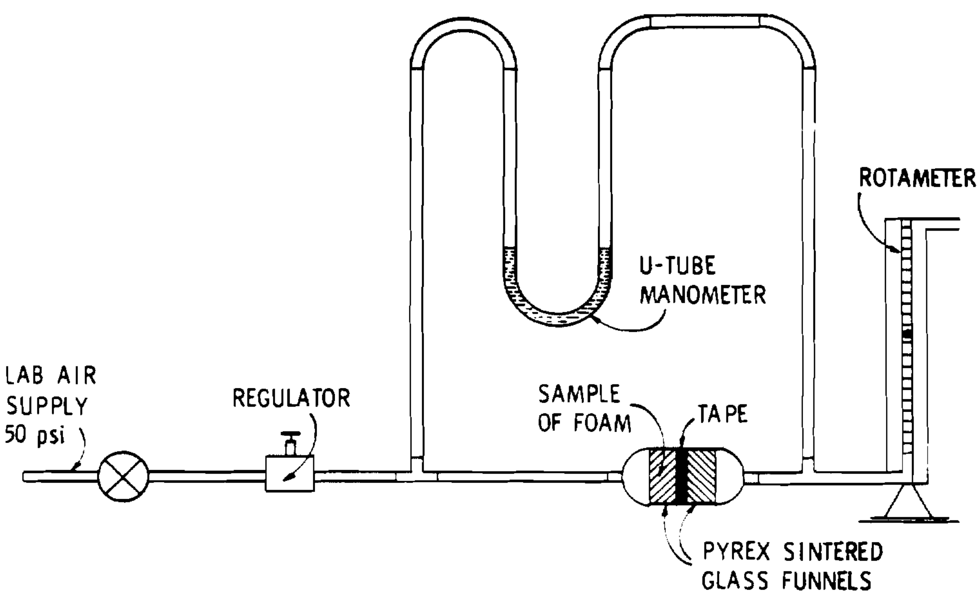

FIGURE 2

TEST APPARATUS FOR PERMEATION MEASUREMENTS

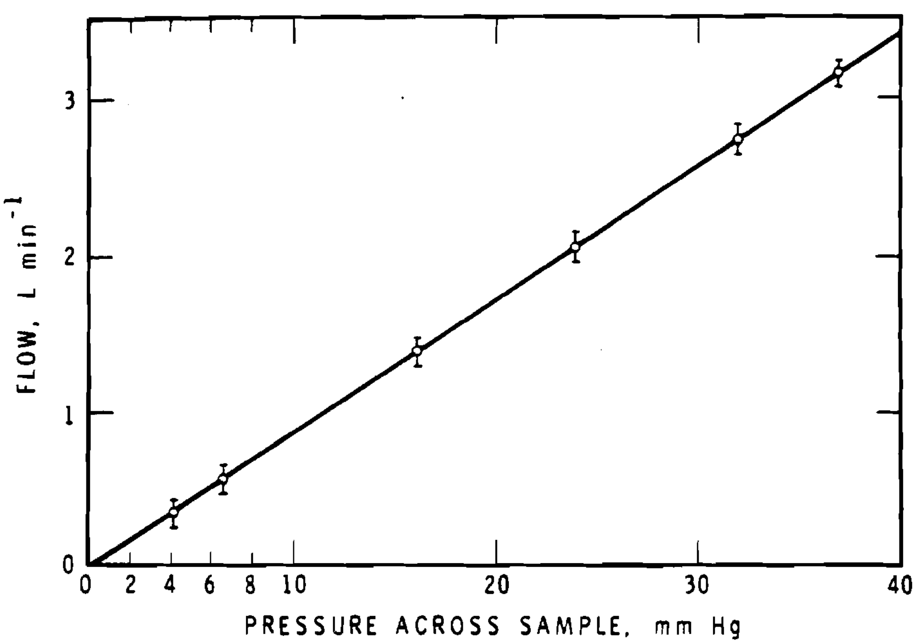

FIGURE 3

FLOW RATE VS PRESSURE DROP FOR FOAM B

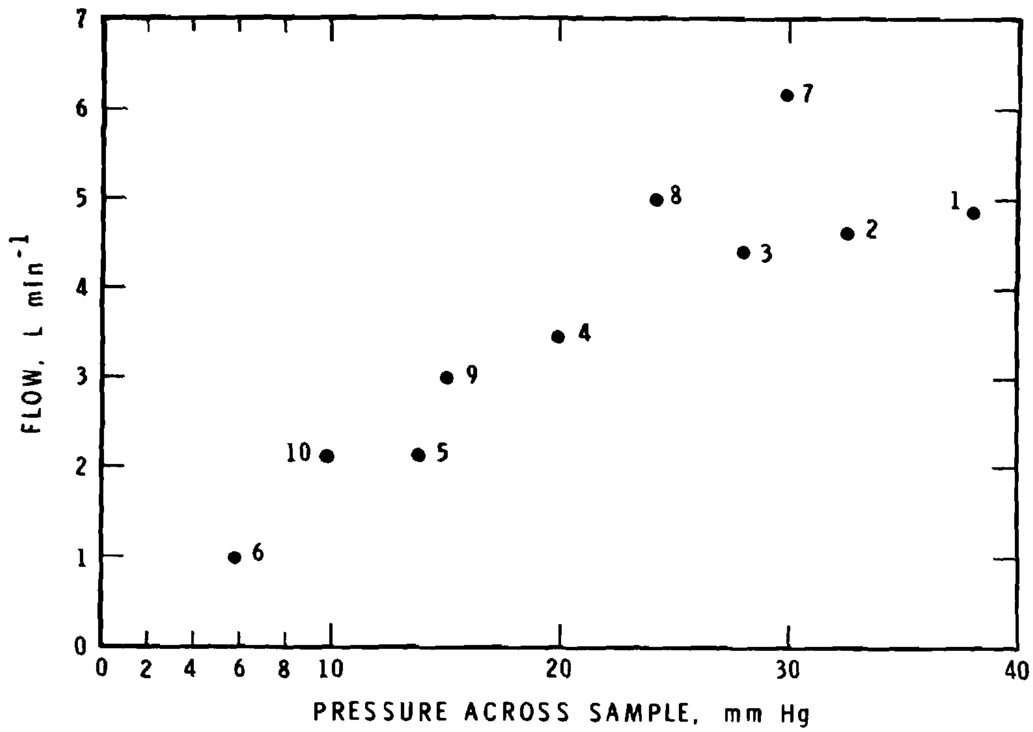

FIGURE 4

FLOW RATE VS PRESSURE DROP FOR UFFI SPECIMEN SHOWING BYPASS OF AIR. NUMBERS INDICATE THE ORDER IN WHICH THE MEASUREMENTS WERE MADE