MEASUREMENT OF THE WATER VAPOUR PERMEABILITY OF FILMS

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A method has been developed for the measurement of the water vapour permeability of various types of film. The amounts of water diffusing through were determined in a system of constant vapour content by using H_2O labelled with H^3 and by measuring the activities. The method was used to determine the water vapour permeabilities (WVP) of various films. In the case of different thicknesses it was possible to determine characteristic values of the permeability constant (PC) for the individual films. The method is suitable for the comparative characterization of various paint films and protective coatings.

In the study of corrosion processes and in the establishment of the quality of protective coatings an important role is played by the examination of the water permeabilities of the various protective layers.

Both gravimetric and radioactive isotope methods have been described for the study of the water permeabilities of paint films [1—3]. The gravimetric methods require much time and are rather difficult to carry out, while special methods have been worked out with the aid of the reported radioactive isotope methods.

The aims of the present work were the development of a generalizable method suitable for the detection of a few µg of water, the study of the applicability of the method in various paint films and, on the basis of measurements, to give characteristic data for the different paint films, permitting the comparison of films of varying qualities and thicknesses.

A definite pressure of water vapour labelled with H^3 was maintained on one side of the film to be examined, and the amount of water permeating through in unit time was determined by measurement of the activity. Our measurements were carried out in an atmosphere of 50% relative vapour content, provided by the vapour pressure above a 42% H_2SO_4 solution.

The free film to be examined was stretched onto a glass vessel with a ground rim containing a drying agent, fixed with a plexi foil provided with a hole. The appropriate sealing was ensured by silicone grease.

The samples thus pre-prepared were placed into an atmosphere containing H^3-labelled water vapour of known specific activity, at 23°C. After a definite time, the drying agent (anhydrous $CaCl_2$) was washed out of the vessels with ethanol into K-free Packard cells, and a scintillation liquid (toluene solution containing 0.8% PPO and 0.01% POPOP) was added for the activity measurements. The activity was measured with a PACKARD—TRICARB single-channel scintillation counter, which at an amplification of 50 with a window-width of 50—1000 measures the tritium with an efficiency of about 22%.

From the knowledge of the specific activity (7247 cpm/mg) of the applied H^3-labelled water, the activity values obtained in the measurements were used to determine the water vapour permeability (WVP) used [1] for the comparison of films of identical thickness:

$$WVP = \frac{\text{amount of water permeated (g)}}{\text{surface of examined film (cm}^2) \cdot \text{time (hr)}}$$

and also the permeability constant (PC), an indicator [1] suitable for the comparison of studies carried out with different vapour contents and films of different thicknesses:

$$PC = \frac{WVP\ (g \cdot cm^{-2} \cdot hr^{-1}) \cdot \text{film thickness (cm)}}{\text{pressure of system (mmHg)}}$$

In accordance with the above, measurements were made on cellulose-based industrial foils of various water permeabilities (Tables I and II) and on films of various thicknesses prepared from different types of paint.

Films of 20—150 μm thicknes were prepared for our studies; times of measurement applied were 6—90 hrs. The films were made from paints based on an air-drying cellulose derivative, on a rubber derivative, and on a two-component polyurethane, and from two paints based on epoxide resin. As an example the results obtained in one series of measurements are given in Table III.

Table I

Foil of 27 μm-thickness

Measurement time hr	Activity cpm	WVT	Average WVT	PC
		$g \cdot cm^{-2}\ hr^{-1}$		$g \cdot cm^{-1}\ hr^{-1}\ mmHg^{-1}$
1.0	1318	$3.41 \cdot 10^{-5}$		
12.0	19726	$4.27 \cdot 10^{-5}$		
18.0	23502	$3.39 \cdot 10^{-5}$		
30.5	64986	$5.54 \cdot 10^{-5}$	$(4.65 \pm 0.37) \cdot 10^{-5}$	$(1.02 \pm 0.09) \cdot 10^{-8}$
46.0	78817	$4.45 \cdot 10^{-5}$		
55.6	112794	$5.27 \cdot 10^{-5}$		
70.0	155800	$5.78 \cdot 10^{-5}$		
93.0	179713	$5.02 \cdot 10^{-5}$		

Table II

Foil of 30 μm-thickness

Measurement time hr	Activity cpm	WVT	Average WVT	PC
		$g \cdot cm^{-2}\ hr^{-1}$		$g \cdot cm^{-1}\ hr^{-1}\ mmHg^{-1}$
23.3	1692	$1.89 \cdot 10^{-6}$		
46.3	3616	$2.03 \cdot 10^{-6}$		
70.3	6606	$2.44 \cdot 10^{-6}$	$(2.18 \pm 0.10) \cdot 10^{-6}$	$(5.4 \pm 0.2) \cdot 10^{-10}$
94.7	8210	$2.25 \cdot 10^{-6}$		
118.7	10494	$2.29 \cdot 10^{-6}$		

Table III

Paint films of different thicknesses

Thickness μm	Time of measurement hr	Activity cpm	WVT g·cm^{-2} hr^{-1}	PC g·cm^{-1} hr^{-1} mmHg^{-1}
30	23.0	3953	$4.47 \cdot 10^{-6}$	$1.11 \cdot 10^{-9}$
43	23.0	2210	$2.50 \cdot 10^{-6}$	$0.89 \cdot 10^{-9}$
45	71.7	8473	$3.07 \cdot 10^{-6}$	$1.14 \cdot 10^{-9}$
50	47.3	5908	$3.25 \cdot 10^{-6}$	$1.34 \cdot 10^{-9}$
55	30.5	3555	$3.03 \cdot 10^{-6}$	$1.38 \cdot 10^{-9}$
65	22.0	2453	$2.90 \cdot 10^{-6}$	$1.55 \cdot 10^{-9}$
75	47.0	4783	$2.64 \cdot 10^{-6}$	$1.64 \cdot 10^{-9}$
97	72.3	5353	$1.92 \cdot 10^{-6}$	$1.54 \cdot 10^{-9}$
110	72.3	5478	$1.97 \cdot 10^{-6}$	$1.79 \cdot 10^{-9}$
111	47.0	3885	$2.15 \cdot 10^{-6}$	$1.97 \cdot 10^{-9}$
144	22.0	1162	$1.37 \cdot 10^{-6}$	$1.63 \cdot 10^{-9}$

Since the PC values calculated from the average of the WVP values are almost the same for different times of measurement (Tables I and II), and since the measurements are reproducible, the characteristic PC values for the individual films can be calculated on the basis of a measurement time of 25—30 hrs.

It can be established from the data of Table III that even in the case of different times of measurement the PC values of films of different layer thicknesses give a constant value characteristic for the film.

Table IV

PC values for different paints

Paint type	PC g·cm^{-1} hr^{-1} mmHg^{-1}	Average error of mean value
Cellulose derivative	$9.8 \cdot 10^{-9}$	$0.7 \cdot 10^{-9}$
Rubber derivative	$1.45 \cdot 10^{-9}$	$0.09 \cdot 10^{-9}$
Polyurethane	$1.66 \cdot 10^{-9}$	$0.03 \cdot 10^{-9}$
	$4.1 \cdot 10^{-9}$	$0.1 \cdot 10^{-9}$
Epoxide resin	$6.4 \cdot 10^{-10}$	$0.2 \cdot 10^{-10}$

Table IV contains the calculated PC values of some films prepared from different base materials, and the average errors of the mean values determined for the individual films. It can be seen from the data of the table that the dependence of the PC values on the quality of the film considerably exceeds the maximum mean error values. This makes it possible to use the calculated data for the characterization of the individual films.

References

[1] *Deterding, J. H., D. W. Singleton, R. W. Wilson:* Farbe und Lack **70**, 35 (1964).
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ИЗМЕРЕНИЯ ВОДОПРОНИЦАЕМОСТИ. ПЛЕНОК МЕТОДОМ ИЗОТОПОВ

Ш. А. Гилде, Ф. Широкман и Е. Хаиду

· Разработана методика прегодная для определения водопроницаемости различных пленок. В системе, обладающей постоянным довлением пара, с применением воды меченной H^3 определили количество продифундировавшей воды по её активности. Этим методом определили водо-пропускающую способность (ВПС) для различных пленок. Путём определения удельной проницаемости пленок различной толщины, были рассчитаны соответствующие константы проницаемости для различных пленок. Предлагаемая методика пригодна для сравнительной характеристики различных защитых пленочных и лаковых покрытий.