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On the Scientificalness and Rigor of Gas Permeability Test Using Differential-Pressure Method

Abstract: this article presents a comprehensive introduction to differential-pressure method in terms of its source, test condition and power of test so as to illustrate the scientificalness and rigor of gas permeability test using differential-pressure method.
Key Words: Differential-Pressure Method, time lagged method, high vacuum method, test condition, lower test limit

Being the main method of gas permeability testing, Differential-Pressure Method occupies an important position in the field of gas permeability testing. This method employs auxiliary pressure device to maintain the 0.1Mpa differential pressure on two sides of specimen. Test gas transmits through film into low pressure side and causes a pressure variation there, by which GTR can be calculated. This article presents a comprehensive introduction to differential-pressure method in terms of its source, test condition and power of test so as to illustrate the scientificalness and rigor of gas permeability test using differential-pressure method.

1． Scientific Source of Differential-Pressure Method

In the initial research period of gas permeability of polymer, theories and test methods of membrane technology industry are taken as the reference to evaluate properties of materials.

In membrane technology industry, test methods of diffusion coefficient include variable capacitance method, transformation method and etc. High vacuum method of transformation method is the most commonly used one. Since its diffusion coefficient is calculated with time lagged method, high vacuum method is also called time lagged method. Its test principle is shown as below:

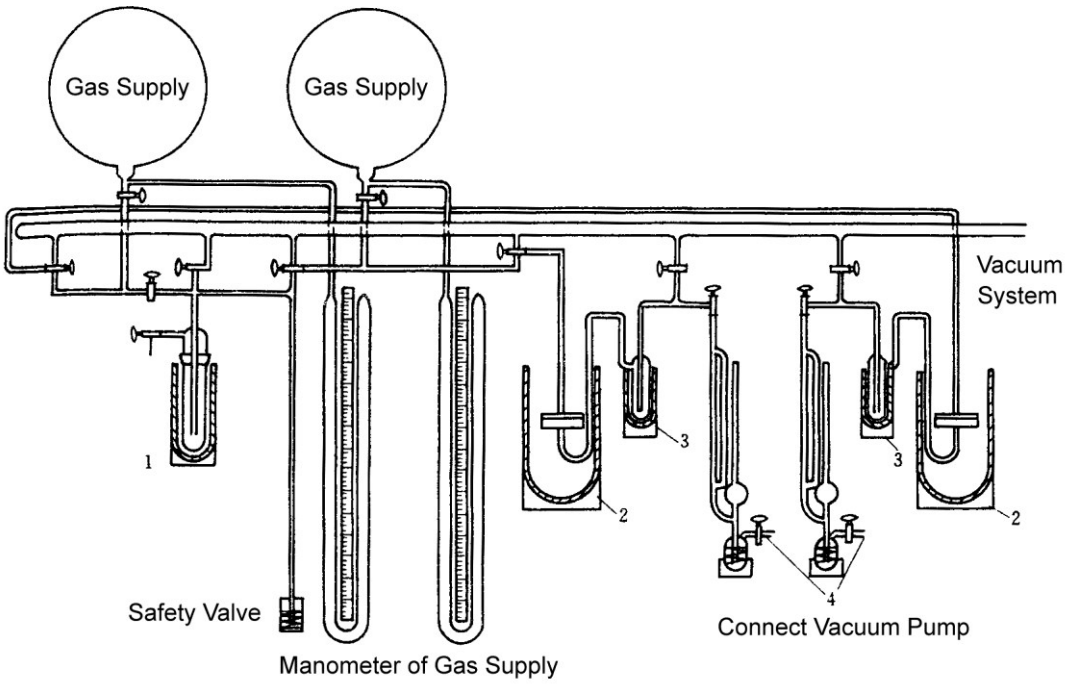

Figure1. Test principle of gas permeability using high vacuum method

1. Gas purification collector2. Gas permeability test tank in constant temperature bath 3. collector4. Vacuum meter, connected to vacuum pump

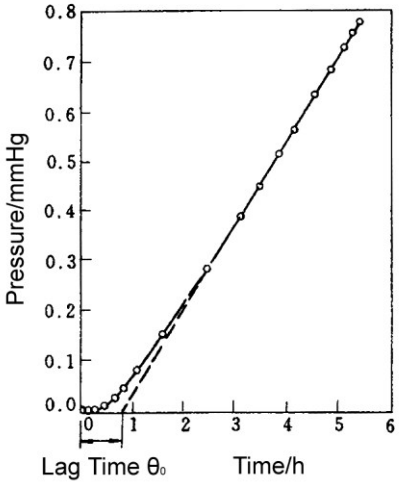

Figure2. Pressure-time graph of high vacuum method

Lag time θ_0 of the Pressure-time relation is needed to calculate diffusion coefficient in high vacuum method (see figure 2). Users can obtain diffusion coefficient through the relation of lag time and diffusion coefficient (l is the thickness of film). Since permeability coefficient of polymer can be directly tested, diffusion coefficient can be calculated. In this way, all the parameters used to describe barrier property of materials can be obtained only through one test.

For its stable and reliable test conditions as well as its simple and clear test principle, high vacuum method has long been used as the most common method in membrane technology field to test barrier property of, diffusion property and solubility of membrane materials. High vacuum method is also widely applied in other fields of material. The differential pressure method, used for gas permeability testing of flexible package, originates from high vacuum method. At the same time, based on characteristics of gas permeability testing of flexible materials, the testing of high barrier property materials is also taken into consideration in selecting test components. At present, the lower test limit has reached 0.05cm^3/m^2·24h·0.1MPa.

2 . Advantages in Controlling Test Conditions

Test condition is the main factor influencing test results of flexible package. Moreover, consistency of test condition is the premise of data comparison, just as data comparison has no significance when friction coefficient of materials is tested under different test speeds or when material thickness is measured under different pressure.

Based on the characteristics of high polymer, test conditions of gas permeability testing mainly include temperature and humidity of test environment and pressure controlling on two sides of specimen. At present, the controlling of temperature and humidity has obtained better application. However, pressure controlling on two sides of specimen is not consistent in several gas permeability test methods. As is well know only when the pressure on two sides of specimen reaches equilibrium could the specimen maintain stabilized physical state. If such equilibrium is destroyed, differential pressure on the high pressure side will act on the film and result in film deformation. The specimen will be damaged if there is irregular supporting around it (for example: the edge of test chamber). That is why test results obtained with different test methods cannot be compared directly. Even to

the same kind of test method, pressure controlling on two sides of specimen cannot secure consistency. Therefore, the method that can provide stable pressure controlling and specimen protection measures possesses more advantage in data comparison.

Gradient direction of differential pressure in differential-pressure method is determined. Users can adopt certain measures to lessen the affection of differential pressure. Empirical tests have proved that using porous paper to support low pressure side of specimen can better eliminate the influence of differential pressure on specimen and can and prevent specimens from distortion under higher pressure. The large quantity of tests of Labthink barrier property laboratory also prove that the existing of differential pressure in differential-pressure method do not affect gas permeability of specimen. At the same time, since differential pressure method has accurate requirements on vacuum degree and pressure of high-pressure side, the pressure between tow sides of specimen in each test can reach better consistency. Consequently, test data posses better comparability.

In equal-pressure method, to control the differential concentration of gases on two sides of specimen, gas flow should be regulated. However, to make static gas flow, dynamic gas source is needed. Therefore, the pressure must be changed to regulate gas flow. Because the requirements on flow rate of upper and lower chambers vary in different standards and there are influencing factors existing such as manual regulating of flow, lower precision of controlling device and ambient gas flow, only very careful and strict performance during actual application can ensure consistent pressure on two sides of specimen without any specimen distortion .Otherwise, there is differential pressure on two sides of specimen. However, in equal-pressure method, since specimen is hanged in test chamber, there is no support on either side of specimen. Therefore, even a very small differential pressure on two sides of specimen will cause a higher the distortion rate of specimen than that of differential-pressure method (The protrusion or notching of specimen depends on the gradient direction of differential pressure. the gradient direction cannot be determined). The edge of chamber in such situations will impose applied force on specimen directly, for which the specimen may appear crack, become thinner or increase preamble area. Moreover, the above mentioned influences are difficult to be quantified. The accuracy of data comparison will be affected.

From the above analysis we can see that differential pressure method has absolute advantage in aspects of stably controlled test conditions. It reduces the influences of various factors to a minimum state, which is also a prominent display of the rigor of differential pressure method.

3． No Restriction on Limitations of Detectability

Lower test limit is a key factor in evaluating detectability of barrier test instruments.

Users should pay attention to the relationship between test methods and specific test instruments. For a test method (differential pressure method), so long as there is no limitation to the development of vacuum technology, the test method also has no detectability limitation. For specific test instrument of differential-pressure method, the detectability limitation directly relates with current vacuum technology.

Due to the limitation of vacuum technology level in the past, test instruments are rather backward in terms of vacuum ability and vacuum degree, which cause some relevant factors (such as ambient temperature. The fluctuation of temperature obviously affects barrier property of specimen and equilibrium of transmission) of test easy to change. Therefore, differential-pressure method instruments at that time were somewhat disappointing. With its development of 30 years, vacuum technology has made substantial headway. Test precision of differential pressure method has advanced from initial $10cm^3/m^2 \cdot 24h \cdot 0.1MPa$ to $0.05cm^3/m^2 \cdot 24h \cdot 0.1MPa$. Simultaneously, with the overall development of

vacuum technology, future differential-pressure instrument still posses great development potential. The statement that differential-pressure method instruments are low in precision and are not able to meet test requirements of high barrier materials just describes the technical level of 1970s. It is very absurd to cite these words for present situation.

4 . Conclusion

In summary, differential-pressure method has scientific source and incomparable superiority over other test methods. Therefore, it is completely mistake and unscientific for some documents to say that differential-pressure method instruments are low in precision and are not able to meet test requirements of high barrier materials. Differential-pressure method has no limitation to detectability. Moreover, key components of differential-pressure method test instruments can be calibrated with higher precision manometer. Such calibration method has been approved by metering institutions and can be used by any third party, thus is more objective, more accurate and fairer. Due to the above mentioned merits, differential-pressure method has always been the fundamental test method of gas permeability testing of flexible package.