Evaluation of Permeability of Battery Components for Strong Chemicals at Elevated Temperatures and High Pressures

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ABSTRACT

Techniques have been developed for measurement of permeability of battery and fuel cell components for strong chemicals under high pressures and elevated temperatures. Instruments developed based on these techniques are described. These techniques and results obtained using these techniques are discussed.

Introduction

Extensive research is being carried out worldwide to develop more efficient, more compact, more powerful and more cost effective batteries and fuel cells. Liquid permeability of innovative components that are being devised needs to be accurately measured in order to evaluate the suitability of these components. Gas permeability of gaseous reaction components is also important. Batteries and fuel cells can use very strong liquid chemicals. The operating pressures are often high. Operating temperatures above room temperature are also encountered. One goal of fuel cell designers is to raise the temperature of operation in order to increase the efficiencies of the electrochemical processes that occur in the system. Techniques have been developed, suitable instruments have been fabricated, and permeability of a number of battery components under true simulated service conditions has been measured. The results show interesting possibilities.

Technique

Principle: Liquid from a tube of known volume is forced through the sample. The pressure on the liquid as well as the volume of the liquid forced out of the tube are measured. Alternatively, the liquid is pressurized to force it through the sample and the volume of liquid coming out of the sample is measured. Liquid permeability is computed from the pressure on the liquid, the volume of liquid passing through the sample and the sample dimensions.

For determination of gas permeability, pressure and flow rate of a gas is measured as it passes through the sample.

Features of Instruments

Use of Strong Chemicals: The instrument used in this investigation was designed to test samples with strong alkaline solutions such as saturated KOH, acids such as Phosphoric acid, and salts such as saline solutions. Suitable disposal and drainage systems were provided to protect the operator. Arrangements for washing of the instrument to prevent chemical accumulation were also provided. The instruments were tested for prolonged periods to evaluate their suitability for these applications.

Fig.1 The PMI liquid permeameter used in this study.

High Pressures: Many battery and fuel cell components operate under high pressures. High pressure could increase the pore size by stretching the sample or decrease the pore size by compressing the sample. The change in pore size can considerably modify permeability. It is therefore more appropriate to determine permeability under simulated service pressure. The permeameter used in this study was designed to perform tests at pressures up to 200 psi.

Elevated Temperature: The electrochemical reactions in batteries occur at temperatures above room temperature. The current trend is to raise the operating temperature of devices to increase efficiencies. The pore structures of components as well as the properties of fluids used in batteries can change considerably with increase in temperature. It is therefore appropriate to measure pore characteristics at elevated temperatures. In instruments with high temperature capability, the fluid is preheated to the desired temperature. The sample chamber and samples are also heated to avoid any chilling effect. The temperatures are accurately controlled and monitored.

Full Automation: All instruments were fully automated. Operation of the instrument, data acquisition and data reduction were carried out automatically. The windows based operation of the instruments was very simple.

Gas Permeability: The gas permeability instrument used in this study was capable of accurately measuring gas flow rate and gas pressure at the specified temperature and pressure. The measurements were used to compute gas permeability

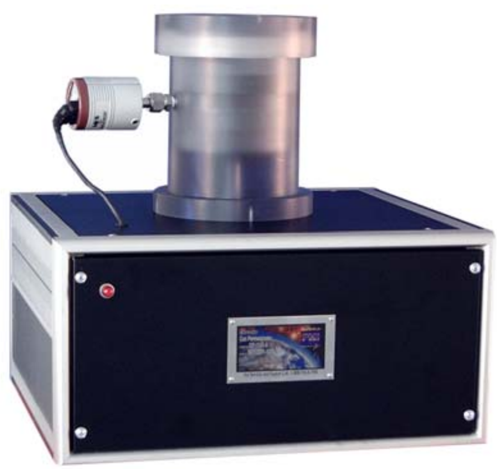

Fig.2 The PMI Gas Permeameter.

Multiple Options: The instruments used are designed to perform tests in various ways. The tests can be very rapid or somewhat slow and accurate. Permeability may be computed in various units such as Darcy, Frazier, Gurley, Raley or simply volume per unit time per unit area. Permeability at any specified pressure can also be computed. Samples may be cut from a larger bulk piece of material and loaded in the sample chamber, or long strips of material can be slid into the sample chamber without the material being cut or damaged in any way. Multiple sample chambers can be used for high volume testing. The testing sequence for multiple samples can be either in series or parallel.

Fig.3 Sample chamber that does not require samples to be cut.

Results and Discussion

Strong chemical Environment: In batteries and fuel cells, components are required to perform under strong chemical environments. Chemicals like potassium hydroxide and phosphoric acid are often used. Figure 4 shows data on the flow rate of a saturated potassium hydroxide solution through a separator. The permeability, k is computed from the measured quantities using the following relation [1].

$$\underline{F} = k \, (A / \mu \, l) \, p \qquad (1)$$

where:

$\underline{F}$ = liquid flow rate at average pressure

A = area of sample

μ = viscosity of sample

l = thickness of sample

p = differential pressure across the sample.

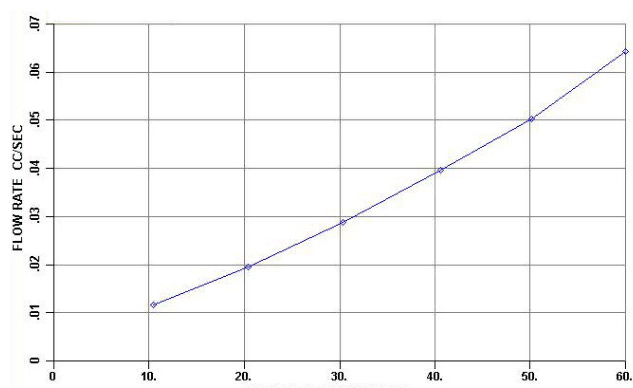

Fig.4 Permeability of 31% KOH solution

The results show an increase in permeability with an increase in differential pressure. This could arise because of two reasons. If the sample is not completely wetted by the liquid, an increase in pressure will allow liquid to flow through smaller pores and increase the permeability. If the increase in differential pressure stretches the sample, pore diameters will increase and the permeability will also increase. If the salt from the solution or dirt from the solution deposits on pores, the pore size as well as the permeability will decrease

Materials saturated with a chemical often swell, their pore sizes change and the permeability is altered. The pore size of samples saturated with chemicals can be determined by PMI porometers [2,3]. Figure 5 shows an example of determination of pore size in a material saturated with a KOH solution.

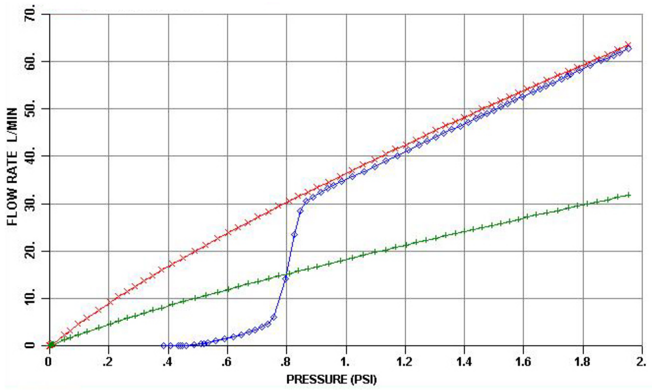

Fig.5 Pore size of separator determined using KOH solution

A number of components often lose their integrity in the presence of chemicals. Therefore, testing has to be done only in the presence of such chemicals. Figure 6 shows data on permeability of such a component for saturated saline solution. The decrease in permeability at higher pressures may be attributed to blockage of pores due to precipitation of salt in small pores.

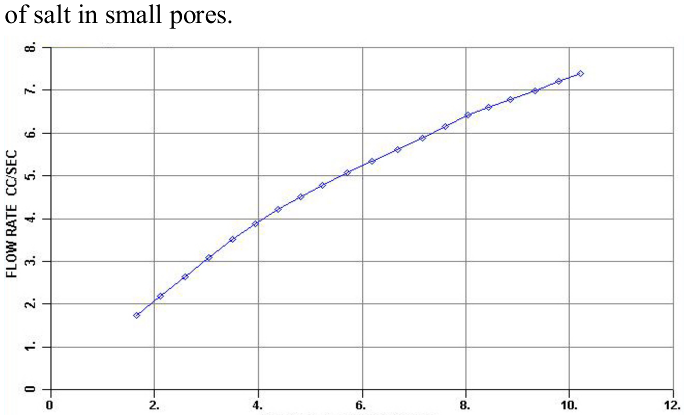

Fig.6 Permeability of a saline saturated sample

High pressures: Pore structure and pore distribution as well as permeability can change when the sample is under compressive stress [4]. PMI liquid permeameters can measure permeability of a liquid through a porous material at pressures up to 200 psi. Figure 7 shows permeability data obtained at 160 PSI.

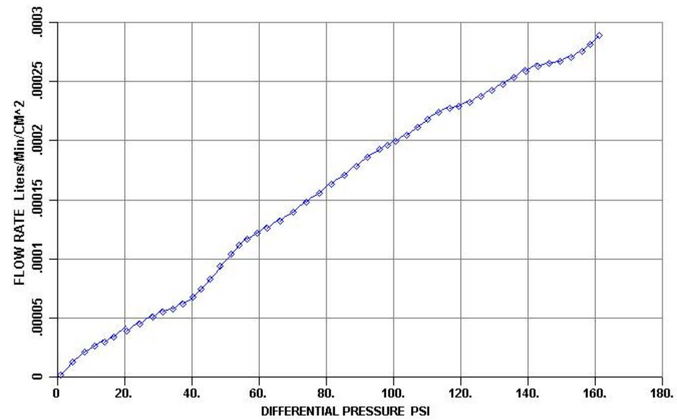

Fig.7 Permeability at 160 PSI

High Temperature: Temperatures under true service conditions can influence pore properties considerably. The permeameters used in this investigation were designed to perform tests at temperatures up to 100°C. The data on gas permeability are presented in Figure 8. It shows that operating temperature may have considerable influence on the flow rate of gas through a sample. Most of the difference is due to change in the viscosity of the gas. However, the instrument has the ability to detect small changes in permeability due to changes in temperature.

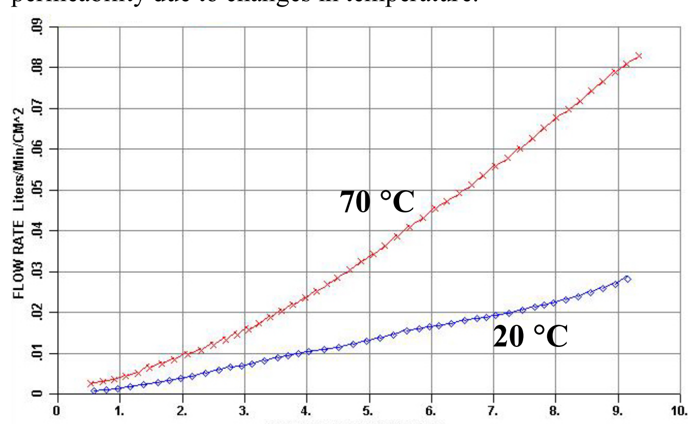

Fig.8 Gas permeability at two temperatures. Red 70 °C. Blue 20 °C

Advantages of the techniques

- Chemical resistant construction for use with strong chemicals
- Temperature controlled environment for use at elevated temperatures
- Multiple sample chambers for high volume testing
- Multiple sample loading mechanisms

- Multiple options for test modes
- Many data reduction options
- Completely automated.
- Easy to use
- Short test duration.
- Robust - requires very little maintenance

Summary and Conclusion

- Many unique features and convenient options available in permeameters used in this investigation have been described.
- Measured permeability for chemicals, potassium hydroxide, phosphoric acid and saline solutions have been reported
- Pore structure of material saturated with chemicals has been determined.
- Liquid permeability at pressures up to 160 psi has been reported
- Gas permeability at temperatures up to 70 C has been reported.
- Effects of chemical nature of the fluid, pressure, temperature and saturation of material with liquid can be considerable on permeability.

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