

## Testing | Instrumentation

# Cake Forming Porometer – Advanced Technology for Evaluation of Filtration Media

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The porometer is capable of creating cakes on the sample in situ in the sample chamber under various conditions of pressure and flow and measuring pore structure characteristics including bubble point, mean flow pore diameter, pore distribution, and liquid permeability. The technique saves considerable time for filter evaluation.

Filtration characteristics are governed by the characteristics of the filtration media, the properties of the cake created on the filtration media, influence of continuously accumulating sediments, and filtration characteristics of the composite consisting of the media and the cake. Such filtration involves many complex variables including, liquid flow rate, concentration of impurities, rate of cake formation, properties of the oil, and characteristics of the filtration media. Consequently, evaluation of the filtration

process can be very complex, time consuming, and expensive. In this presentation a novel technology is presented for cost effective and time saving evaluation of filtration.

### THE INNOVATIVE TECHNOLOGY

A wetting liquid spontaneously fills the pores of the filtration media. Differential pressure of a non-reacting gas displaces the liquid from pores and flows through empty pores (Figure 1). The pressure required to displace the wetting liquid from a pore is given by [1,2]:  $p = 4 \gamma \cos \theta / D$  (1) where  $p$  is differential pressure,  $\gamma$  is surface tension of the wetting liquid,  $\theta$  is the contact angle of wetting liquid on the pore surface and  $D$  is pore diameter. Pore diameter is defined as the diameter of a circular opening such that the perimeter to area ration of the pore cross-section is the same as that of the circular opening. The pore diameters computed using Equation 1 are the pore throat diameters of through pores [2]. The measure differential pressures and flow

rates through dry and wet samples yield all the pore structure characteristics relevant for filtration.

For liquid permeability, increasing differential pressure on excess liquid maintained on the sample and flow rates of liquid are measured. Permeability is computed using Darcy's law.

$F = k (A / \mu l) (p_i - p_o)$  (2) where  $F$  is liquid flow rate,  $k$  is permeability,  $A$  is area of sample permitting flow,  $\mu$  is viscosity,  $l$  is thickness of sample,  $p_i$  is inlet pressure and  $p_o$  is outlet pressure.

### THE NOVEL INSTRUMENT DESIGN

The Cake Forming Porometer is shown in Figure 1. It has one chamber for testing filtration media, a separate chamber is for in situ cake formation on the filtration media, and a third chamber is for liquid permeability. The flow diagram in Figure 2 shows the mechanism of controlled in situ cake formation on filtration media. Liquid and particles are loaded in the slurry tank and constantly stirred with a variable speed stirrer. The slurry is pumped to a cylindrical con-



Figure 1. Cake forming Porometer

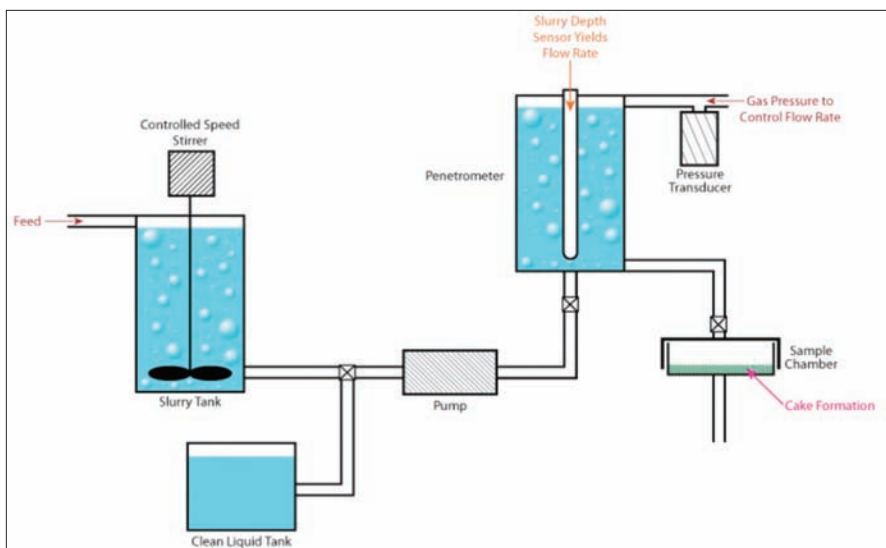


Figure 2. Flow diagram for in situ cake formation on filtration media under controlled conditions

tainer of uniform diameter. Pneumatic pressure at any desired value is applied on the top of the slurry column and a depth sensor measures the change of the height of the liquid in the cylindrical container and determines the flow rate. Slurry from the cylindrical container enters the sample chamber. Liquid from the slurry drains out through the sample while the sediments accumulate on the sample to form cake. With continuous use, the plumbing can get dirty and clogged. A clean liquid tank is provided so that clean liquid is pumped through the plumbing to clean the system.

### FULL AUTOMATION

The technology is fully automated. The cake is created under desired conditions of pressure and flow. Pressure limits can be set between any desired values. For formation of the cake under flow, the initial and final flow values can be set. Cake formation can be continued after interruptions for pore structure characterization. Test execution is fully automated. Differential pressures and flow are recorded. The operator involvement is

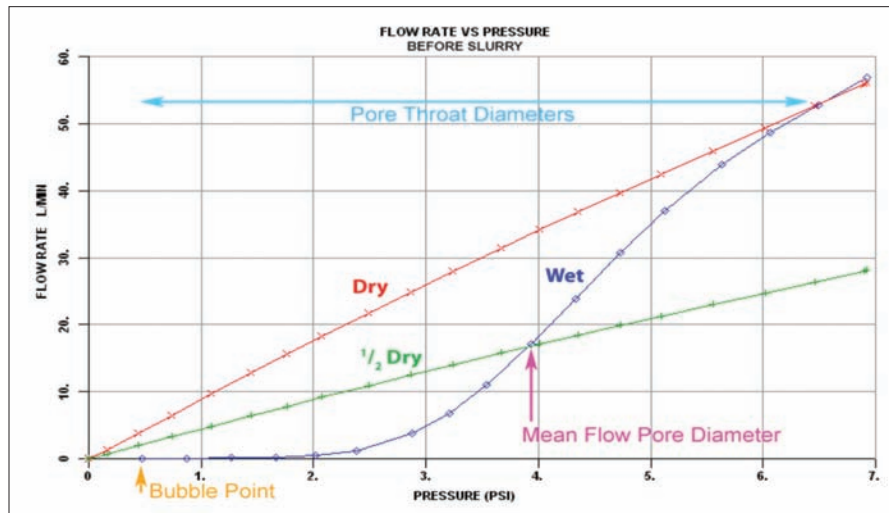


Figure 3. Wet and dry flow rates of a test with media

minimal. Acquired data are converted to pore structure characteristics using the report software. Tabular as well as graphical results can be generated.

### APPLICATION

Dry and wet flow rates were measured through the filtration media and the media containing the cake as a function of differential pressure. The cake was pre-

pared with the slurry consisting of SAE 30 Motor Oil and ISO 12103-1 A2 Fine (1 g/L). Typical flow rates are shown in Figure 3 for a test with media. The pressure for initiation of wet flow yields bubble point. The differential pressures yield through pore throat diameters. The half-dry curve computed from dry curve yields half of the flow rate through dry sample at a given differential pressure and

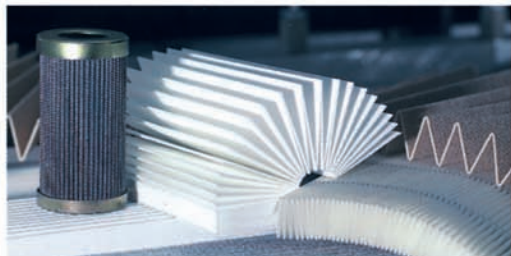
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	Bubble Point		Mean Flow	
	Pressure psi	Diameter micron	Pressure Psi	Pore Diameter micron
Media	0.469	25.920	3.907	3.112
Media with Cake	1.702	7.145	5.929	2.051
Change		72 %		34 %

Table 1. Bubble points and mean flow pore diameters of media with and without cake

Pore Diameter	Media µm	1 <sup>st</sup> Deposit µm	Change	2 <sup>nd</sup> Deposit µm	Change
Bubble point	6.32	2.98	53%	1.09	83%
Mean flow pore diameter	2.83	0.715	75%	0.237	92%

Table 2. Effect of second deposition of the high concentration slurry on pore structure of media II

the mean flow pore diameter. All the relevant through pore throat diameters are listed in Table 1. Cake appreciably reduces the pore diameters.

## PORE DISTRIBUTION

The pore distribution is presented in terms of pore distribution function,  $f[2]$ .  $f = - [d(F_w/F_d) \times 100] / dD$  (3) where  $F_w$  is wet flow and  $F_d$  is dry flow. The area under the

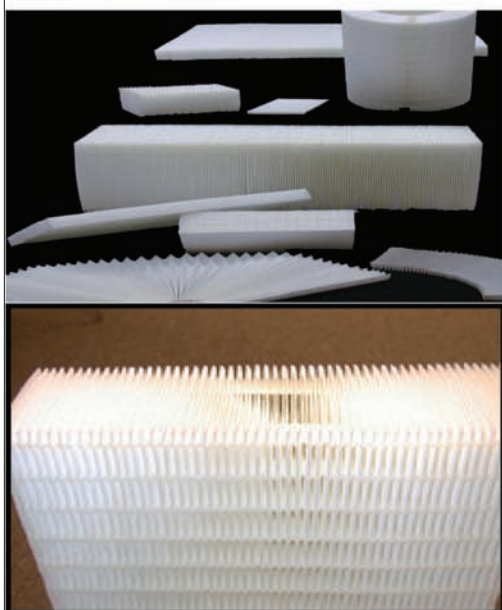
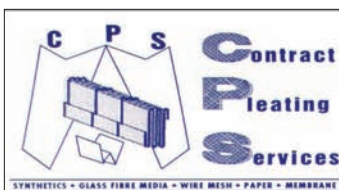
distribution curve in any pore diameter range is the percentage of flow in the specified pore diameter range. Figure 4 shows the distribution of pores in the sample with and without cake. The peak position has changed from about 3 to 2 microns. The peak also has become very narrow. Consequently, the spread is considerably reduced.

## LIQUID PERMEABILITY

Liquid flow rate through the sample was measured with increasing differential pressure. The liquid permeability was computed using Darcy's law. Liquid flow rates through media with and without cake demonstrate considerable influence of cake formation on liquid permeability (Figure 5).

## EFFECT ON PORE STRUCTURE

A second filtration media, media II, was tested without cake as well as with cake. The cake was created using the slurry containing motor oil and 10 g/L dust. The first layer of cake was deposited



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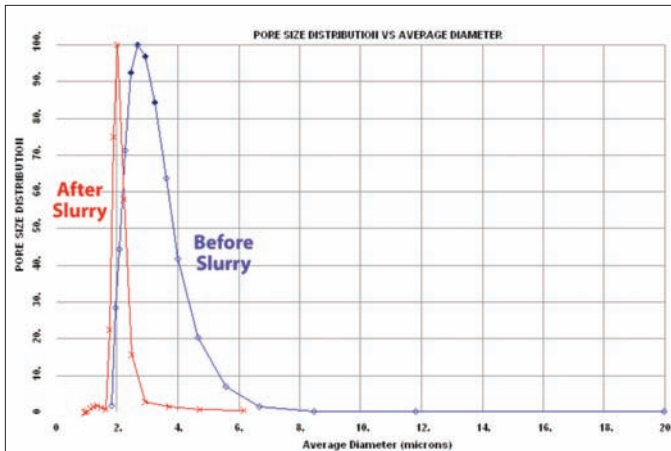


Figure 4. Pore distribution of media with and without cake

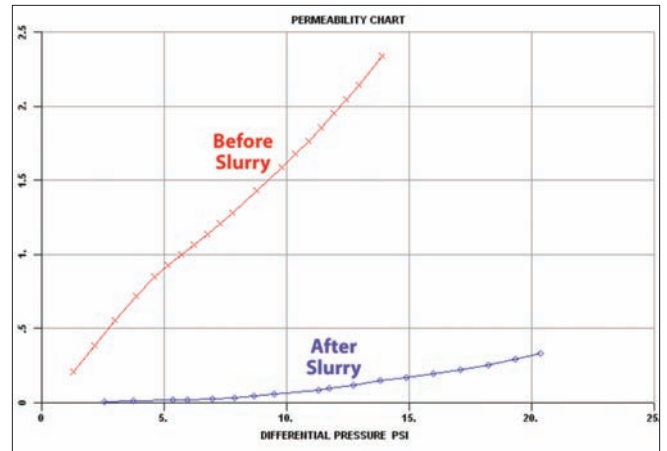


Figure 5. Liquid flow rate through media with and without cake

at a pressure of 50 psi and at flow rates of 500-100 cc/min. After the media with deposit was characterized for the pore structure, a second deposit was made at a pressure of 50 psi and flow rates of 100-50 cc/min. The results are listed in Table 2.

The second media also showed considerable changes in the pore diameters. With increasing deposition pore diameters decreased further, but the rate of decrease became less. The distributions shifted to lower pore diameters and the spread in the results was much less.

#### SUMMARY AND CONCLUSION

An innovative technology capable of evaluating filtration processes has been discussed. The capability of the technique includes characterization of pore structure of media, in situ cake formation on media, and characterization of the pore structure of media with cake. In situ cake formation, cake formation under pressure, cake formation at desired flow, and automatic cleaning are some of the unique features of the technique. Examples of application of the technology demonstrate its ability to form cakes in situ under a wide variety of conditions and to measure all the pore structure characteristics relevant to filtration. The developed technology would make it easier and save considerable time to investigate the pore structures of media with and without the cake.

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