PMI Pulse Decay Permeameter for Shale Rock Characterization

Yang Yu, Scientist
Porous Materials Inc., 20 Dutch Mill Road, Ithaca NY 14850

This document describes the application of Pulse Decay Permeameter to measure gas permeability of unconventional rock samples . Multiple tests were performed using different types of shale plugs. The presented results were given to demonstrate the reliability and practical performance of the instrument.

Introduction

The PMI Pulse Decay Permeameter is designed to measure the gas permeability for tight rocks, gas or oil shale samples with ultra-low permeability. The gas permeability is determined by pulse decay technique, which allows more rapid and accurate measurement the measurement more rapid and accurate compare with conventional steady - state method.

The system provided with a software for the data acquisition and system control, from which the measurement can be operated either automatically or manually . During the pulse decay period, the differential pressure (ΔP) across the sample, the downstream pressure (P2), and elapsed time are monitored . With or without considering the adsorption effect, permeability is calculated from a linear regression performed on the pressure time data, the properties of core sample a nd gas, and gas reservoir volume.

Product Description

Specifications

- Permeability range: 1 nD to 0.1 mD
- Confining pressure: Up to 10,000 psi
- Core sample dimension: 1” or 1.5” in diameter, 2” to 3” in length
- Temperature: Ambient
- Pore pressure: Maximum 2,000 psi
- Pressure accuracy: 0.1% FS

Apparatus Setup

Figure 1 shows the PMI Pulse Decay Permeameter. It consists of two upstream gas reservoirs with different sizes, two downstream gas reservoirs with different sizes, a pressure transducer for measuring the downstream pressure, a differential pressure transducer for measuring the pressure difference between the two small reservoirs, a pressure gauge for measuring the confining pressure, a core sample holder, a hand hydraulic pump, and valves.

Fig 1: PMI Pulse Decay Permeameter

When performing a test, a core sample is placed Table 1. Operating parameters into the core holder a nd confining pressure is applied. From Figure 1, with valves AV1 through AV 5 open, t he Pulse Decay Permeameter system, including all reservoirs, lines and sample, is filled

Parameter	Value
Temperature, °C	24
Atmospheric pressure, psia	13.5
Gas source	N_2
Gas viscosity, cP	0.0176
Gas compressibility, psi^{-1}	0.0009381
Mean pore pressure, psi	1,050
Confining pressure, psi	4,000
Upstream volume, cc	54.8
Downstream volume, cc	29.57

with gas to a desired pore pressure, then close AV1. When the system pressure becomes stable, close valve AV2. With the needle valve nearly closed, open AV6 and allow the downstream pressure in reservoirs of V2 and V3 to bleed off to develop a target differential pressure, typically less than 50 psi. Then close AV 6 and monitor ΔP and P2. When the mean pore pressure becomes constant, close valves AV3 and AV5. The test will be end when ΔP drops to zero and the logged data will be saved . Then develop a semi-log pulse-

decay plot, log differential pressure (ΔP) times mean pressure (p m) versus time (t) and determine the slope of the beginning linear portion of the generated curve. With or without considering the adsorption effect, the pulse decay permeability is calculated from the slope, core sample properties, gas compressibility and viscosity, and gas reservoir volume s.

Performance Test

Two types of outcrop shale samples were used for the performance test: Marcellus and Eagle Ford,

shown as Figure 2. The permeability of each sample was measured two times to verify the accuracy and repeatability of the instrument.

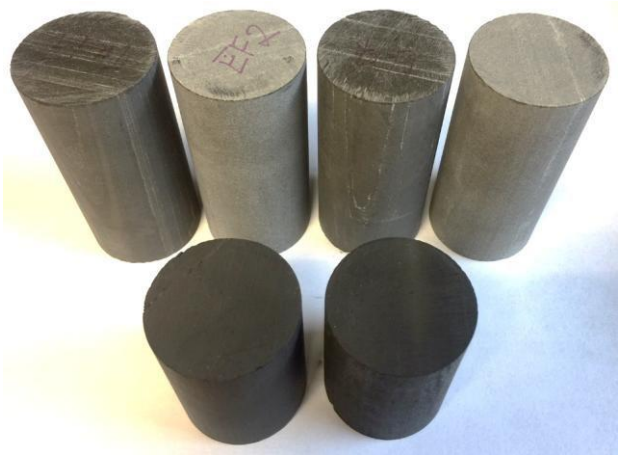

Figure 2. Core plugs used for permeability measurement

Nitrogen was used as the gas source. All tests were performed at room temperature. The operating parameters are given in Table 1.

Measurement Method

Results

Twelve series of tests were performed on six shale core samples, and the permeability of each sample were measured two times at same operating conditions. The sample information and permeability results are given in Table 2. ***M*** and ***EF*** represent the rock type, Marcellus and Eagle Ford, respectively. Figures 3 to 14 show the pressure profiles and slope determination graphs for each pulse decay test.

Table 2. Core plug sample dimensions and test results

Test No.	Sample ID	Length (cm)	Diameter (cm)	Pm (psig)	Slope	k (nD)
1	M1	5.09	3.77	1016	- 0.0000475	100.9
2	M1	5.09	3.77	1037	- 0.0000519	110.3
3	M2	5.10	3.76	1045	- 0.0000854	182.8
4	M2	5.10	3.76	1050	- 0.0000821	175.7
5	EF1	7.62	3.77	1026	- 0.0017071	5438.5
6	EF1	7.62	3.77	1041	- 0.0017205	5481.2
7	EF2	7.60	3.74	1011	- 0.0000338	108.9
8	EF2	7.60	3.74	1039	- 0.0000324	104.4
9	EF3	7.61	3.76	1039	- 0.0003298	1050.7
10	EF3	7.61	3.76	1037	- 0.0003319	1057.4
11	EF4	7.63	3.77	1023	- 0.0000463	147.4
12	EF4	7.63	3.77	1049	- 0.0000457	145.5

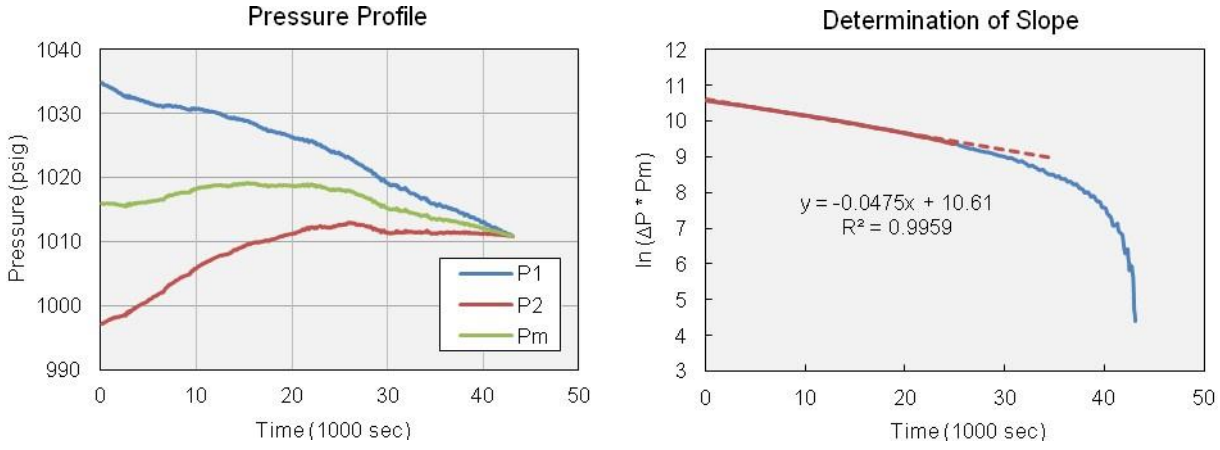

Figure 3. Experimental data for test 1(core M1)

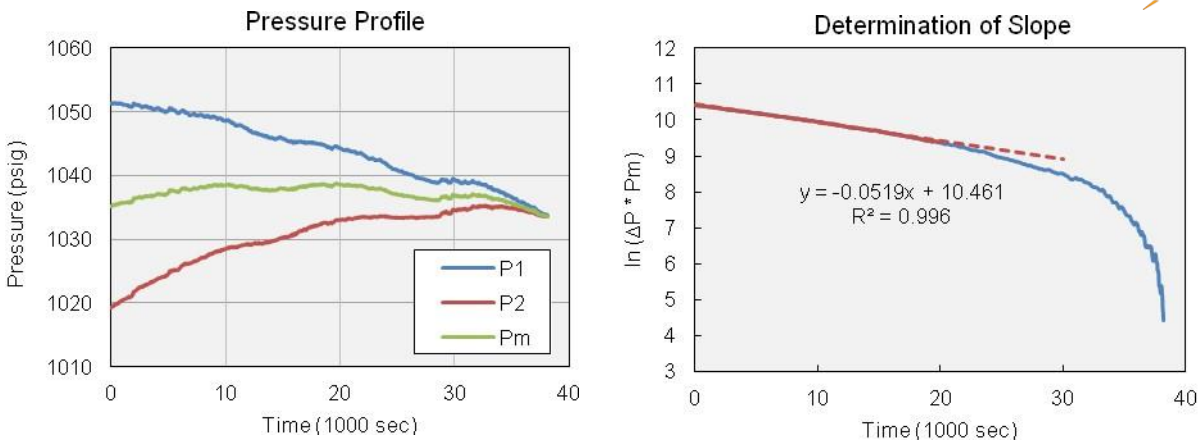

Figure 4. Experimental data for test 2 (core M1)

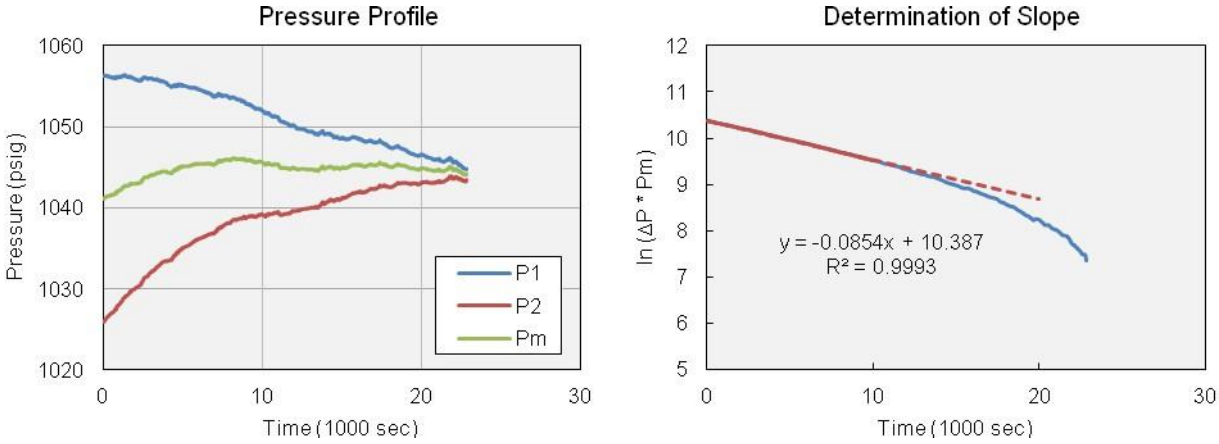

Figure 5. Experimental data for test 3 (core M2)

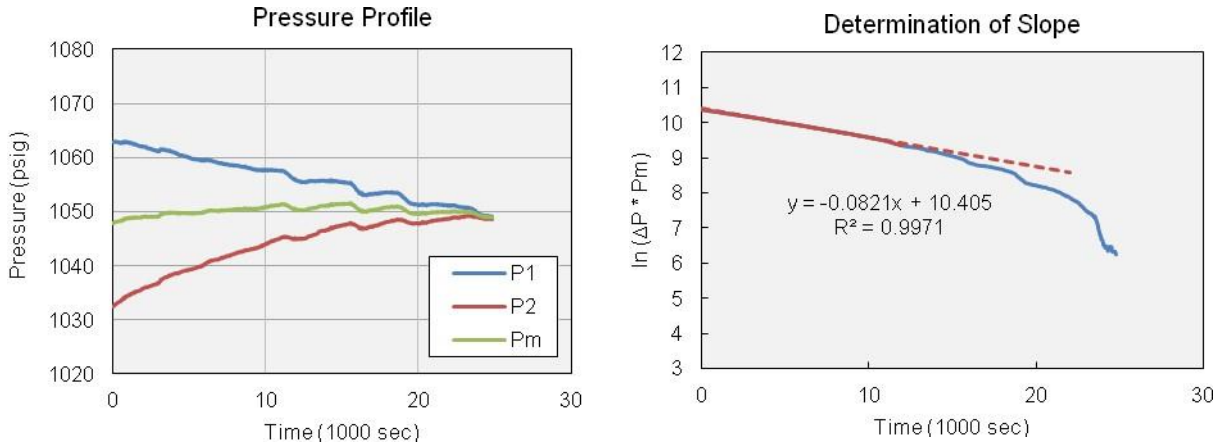

Figure 6. Experimental data for test 4 (core M2)

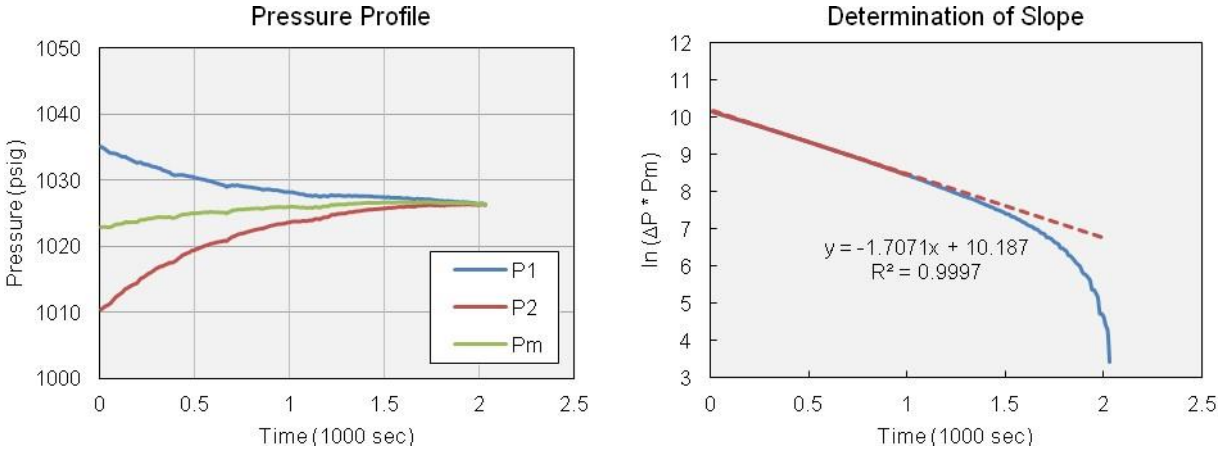

Figure 7. Experimental data for test 5 (core EF1)

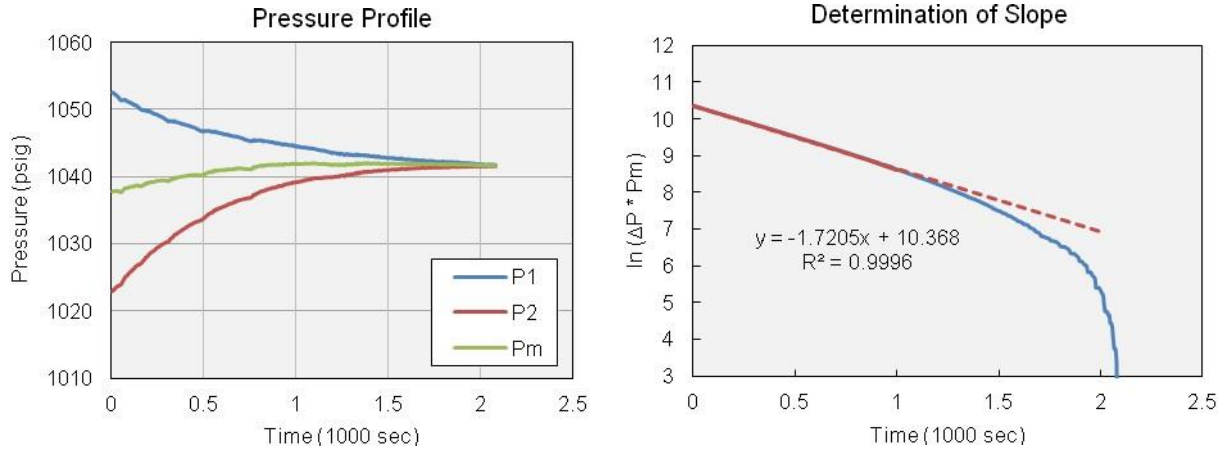

Figure 8. Experimental data for test 6 (core EF1)

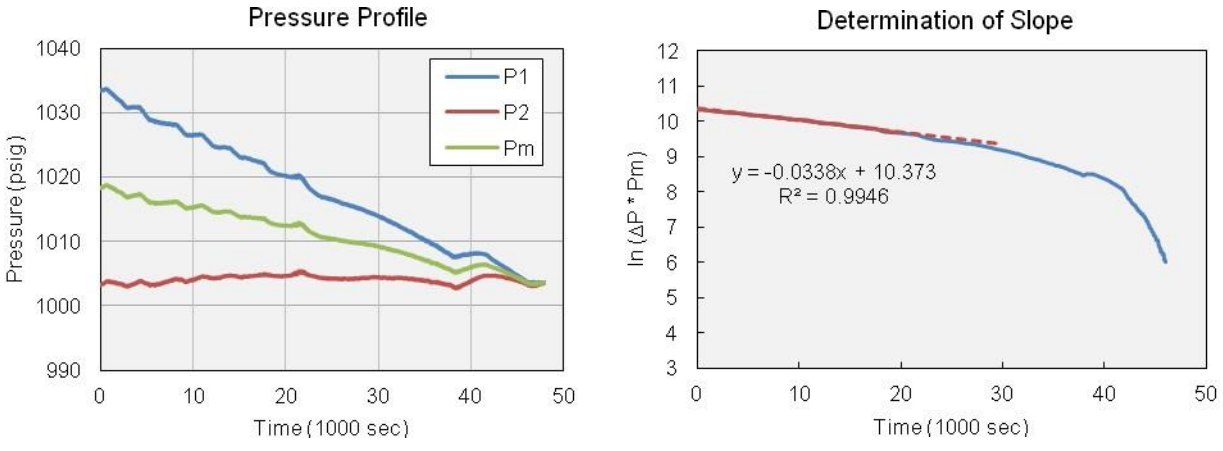

Figure 9. Experimental data for test 7 (core EF2)

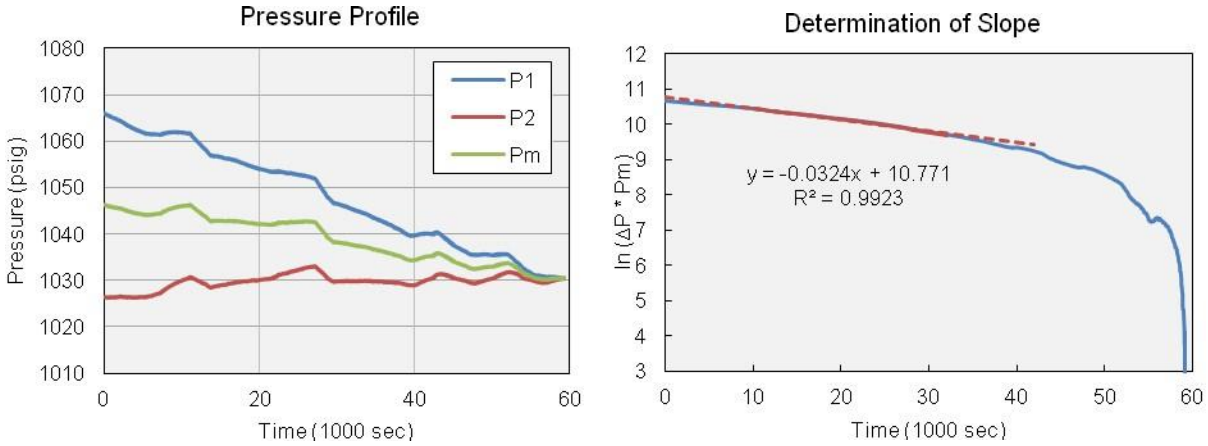

Figure 10. Experimental data for test 8 (core EF2)

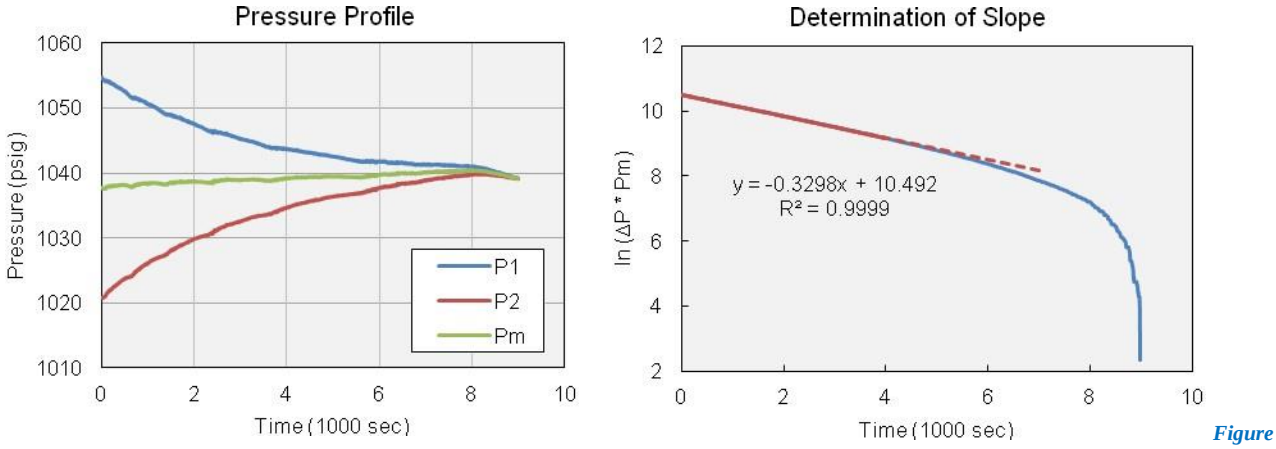

Figure 11. Experimental data for test 9 (core EF3)

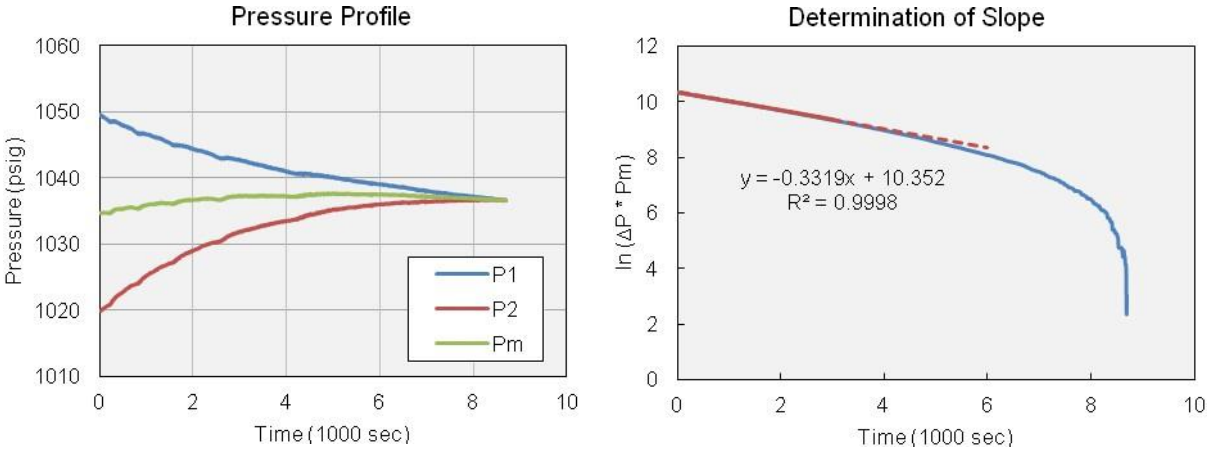

Figure 12. Experimental data for test 10 (core EF3)

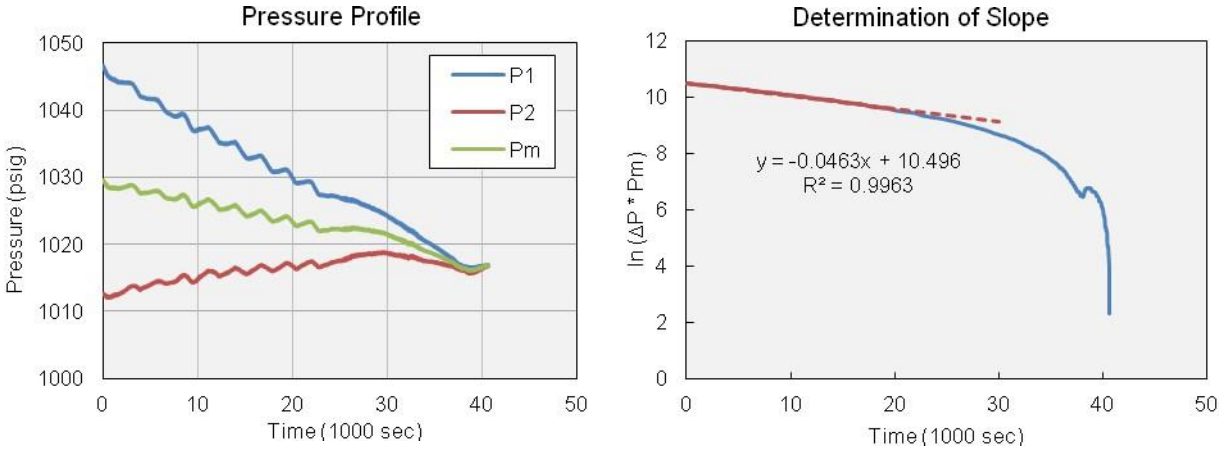

Figure 13. Experimental data for test 11 (core EF4)

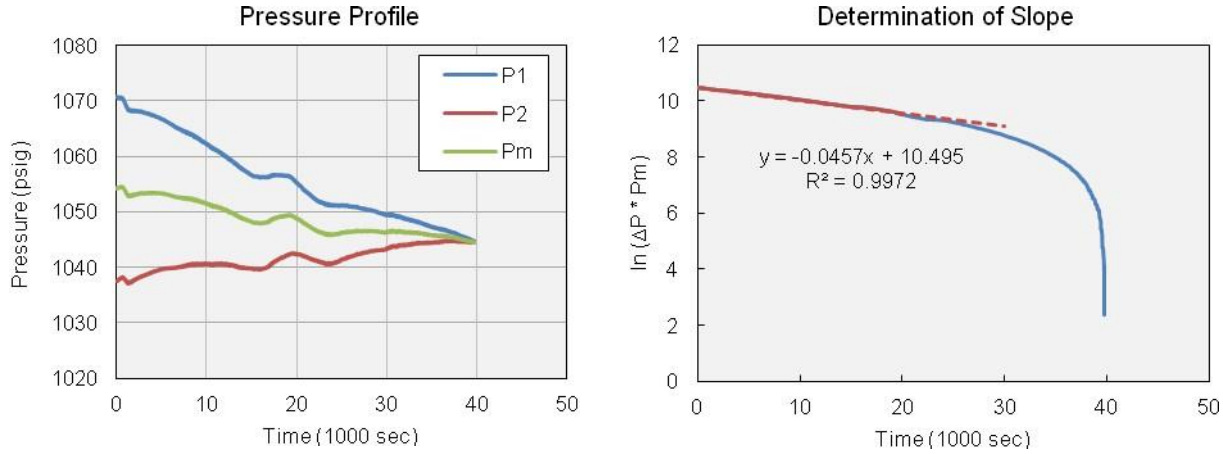

Figure 14. Experimental data for test 12 (core EF4)

Conclusion

This report introduces the application of PMI Pulse Decay Permeameter. Different shale plugs were used to conduct the performance test and experimental data were presented. The consistency of results proved the reliability and repeatability of PMI's Pulse Decay Permeameter.

Reference

American Petroleum Institute. "Recommended Practices for Core Analysis" API-RP40 (Second Edition, February 1998)

Jones, S. C. "A technique for faster pulse-decay permeability measurements in tight rocks." *SPE Formation Evaluation* 12.01 (1997): 19-26.