Effect of Back Pressure on Gel Pack Permeability during Conformance Control Treatment*

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Abstract

Excess water production has become a significant problem for oil field operations as reservoirs mature. A newer trend in gel treatments is using preformed particle gels (PPGs) to reduce fluid channels through super-high permeability streaks/fractures. Therefore, water production decrease and sweep efficiency increase in mature oilfields. The achievement of the best PPGs treatment mainly depends on whether or not PPGs can successfully reduce the permeability of the channels to the level that we expect. This work sought to determine what factors influence the blocking efficiency of PPG on fluid channels. It will determine what factors effecting on PPGs pack permeability.

Results, Observations, Conclusions

A transparent model was designed to observe the compression of gel particles in fluid channels at different back pressures, and thus to study the effect of different parameters on PPG blocking efficiency. Results presence that:

- PPG pack in the fluid channels affected by the back pressure. It was determined that the increase of the back pressure decreased the PPG pack permeability.
- Gel pack is compressed and its permeability is reduced as back pressure increases.
- A permeable gel pack was formed in fluid channels by gel particles. The permeability of the gel pack depended on particle strength, particle size, brine concentration, and back pressure.

Applications

The results can be used to optimize a PPG design. A gel pack with a desired permeability can be designed by selecting proper gel strength and particle sizes at reservoir pressures. This selection is very important for successful gel treatment because an optimized gel treatment design target on reducing the permeability to the degree as we planned.

Technical Contributions

In field applications, operators often increased either gel particle size or gel strength if they want to increase blocking efficiency. Contrary to the conventional concepts in PPG treatment practices, we find that gel particles can better block fluid channels if either weak and/or small particles are used for conformance control treatments.

Selected References

Bai, B., L. Li, Y. Liu, H. Liu, Z. Wang, and C. You, 2007, Preformed Particle Gel for Conformance Control: Factors Affecting its Properties and Applications: SPEREE, v. 10/4, p. 415-422.

Sydansk, R.D., and G.P. Southwell, 2000, More Than 12 Years of Experience with a Successful Conformance-Control Polymer Gel Technology: SPE Prod & Fac., v. 15/4, p. 270, SPE-66558-PA.

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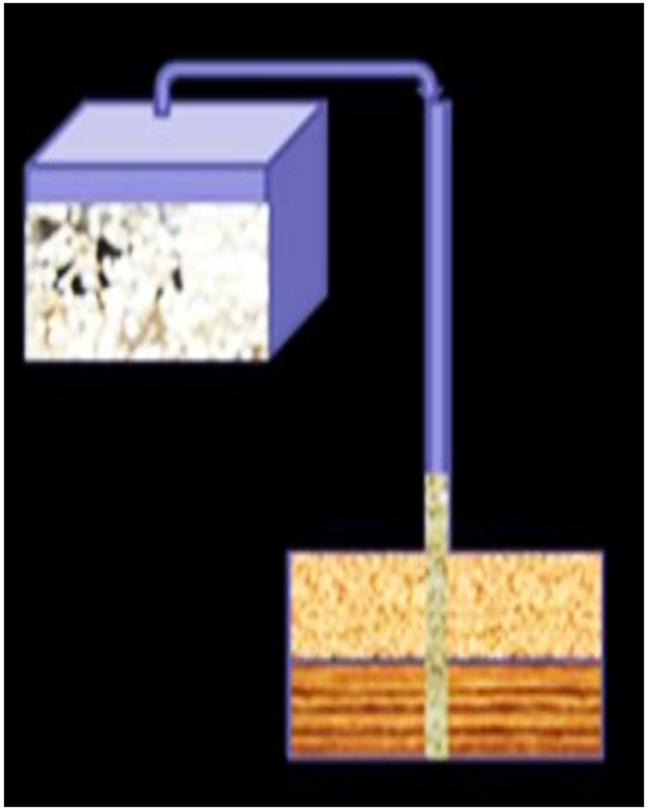
Outlines

- Introduction
- Measurement of PPG Pack Permeability
- Power Law Model
- PPG Strength Measurements
- Conclusions
- Acknowledgments

Introduction

- Excess water production
- Reservoir heterogeneity
- Effect of Preformed Particle Gels (PPGs)



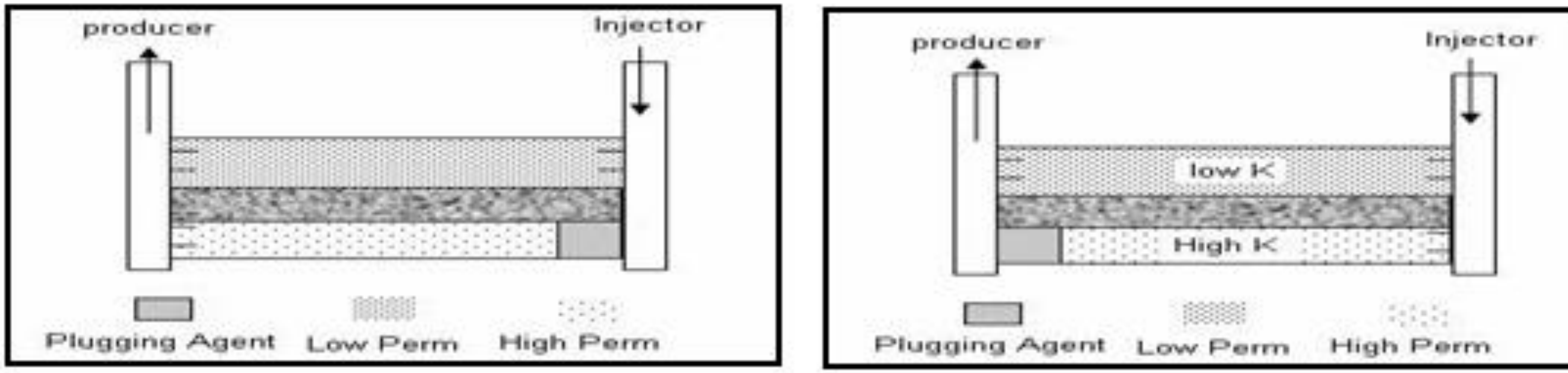
Gel Treatment

- **Gel treatments are:**

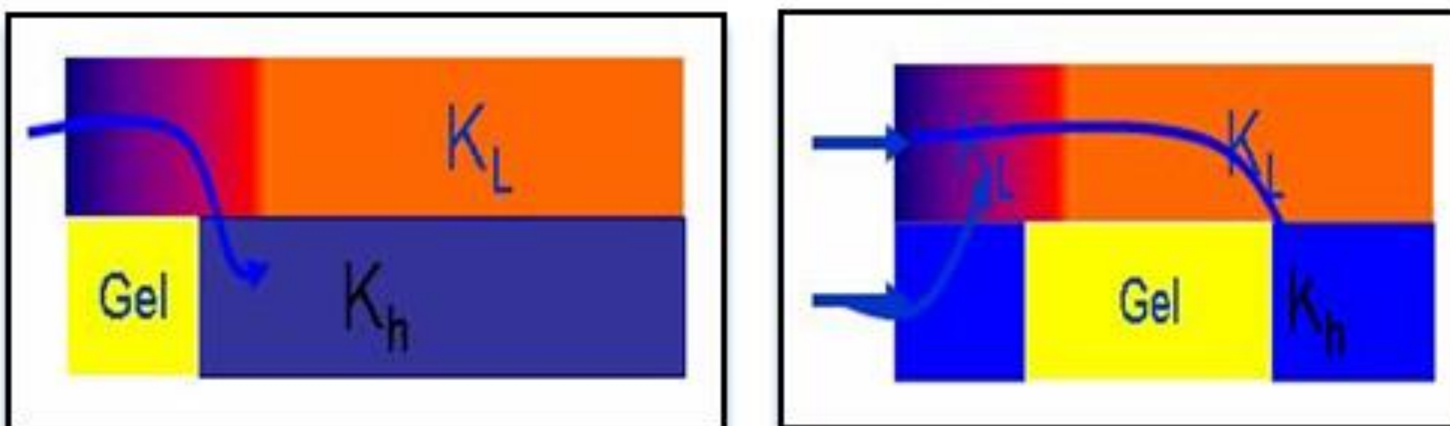
  - **A proven cost-effective method to improve sweep efficiency and reduce excess water production**

  - **Important methods to correct the reservoir heterogeneity**

Gel Treatment to Block/Reduce Water Flow through High Permeability Zones/Streaks



Gel Treatments for Heterogeneous Formation without Crossflow (Bai et al., 2007).

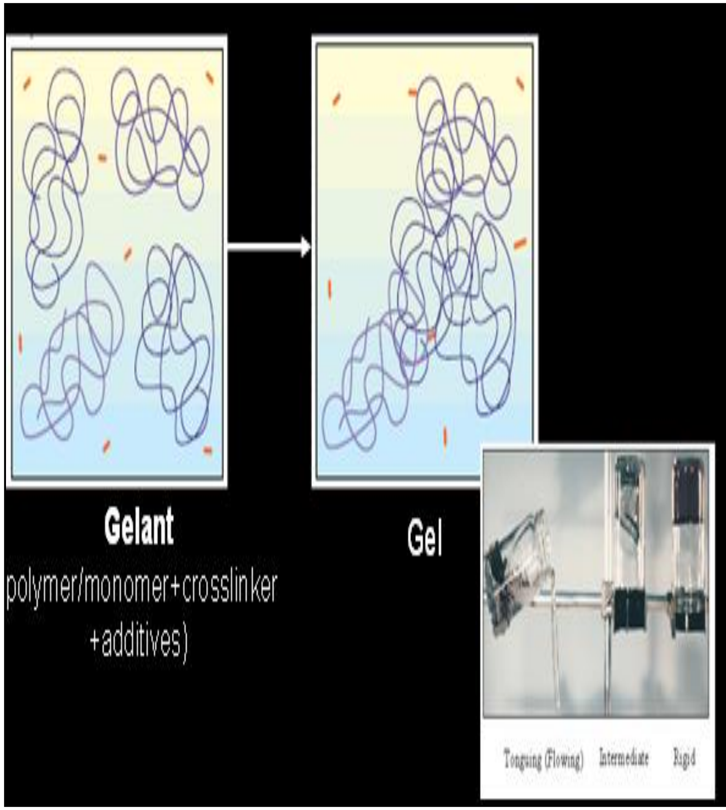


Gel Treatments for Heterogeneous Formation with Crossflow (Bai et al., 2007).

Types of Gels

1- In-Situ Gel:

- **In-situ gels are crosslinked polymers.**
- **The liquid formulation of in-situ gel composition is called a *gelant*.**
- **The gelant is injected into the formation, and the gel forms under reservoir conditions.**
- **Gel strength can be controlled by gelant composition and surrounding conditions.**



Gel composition (Sydansk, 2000)

Types of Gels

2- Preformed Gels :

Various Gels Used in the Oil Industry

Preformed Gel	Related Studies
Performed Particle Gels ,PPG	Coste, 2000; Bai, 2004, 2007, and 2008.
Microgels	Chauveteau, 2000 & 2001; Rousseau, 2005; Zaitoun, 2007.
pH-sensitive Crosslinked Polymers	Al-Anazi, 2002; Huh, 2005; Beson, 2007; Choi & Shrman, 2009.
Bright Water[R]	Pritchett, 2003; Frampton, 2004 Roussennac & Toschi 2010; Ghaddab 2010; Mustoni 2012.

Preformed Particle Gels (PPGs)

- **PPGs are a dried crosslinked polyacrylamide powder.**
- **The gel forms in surface facilities before injecting into reservoirs.**
- **PPG particle size is adjustable from a scale of micrometers to millimeters.**
- **Particles have a swelling ratio of 10-200 times the original volume.**
- **PPGs are resistant to temperature up to 110 ºc.**
- **PPGs can overcome some drawbacks of in-situ gelation systems.**

Objective of This Work

- **Determining what factors affect the permeability of gel pack and improve PPG treatment efficiency from unswept production zones/areas .**

Experimental Materials

- **Preformed Particle Gels (PPGs)**

- **Liquiblock™ 40K is a weak gel particle with an elastic module of ~400 Pa at 0.05% of NaCl (wt %).**

- **DQ is a strong gel particle with an elastic module of ~4100 Pa at 0.05% of NaCl (wt%)**

- **The particle sizes for both gels were from 200 to 40 meshes.**

(a)

(b)

PPGs before and after Swollen: **a)** Daqing Gel and **b)** LiquiBlock™ 40K Gel

Experimental Materials

- **Brine.** **Sodium choloride (NaCl) was used to prepare all brines. Various brine concentrations (0.05, 0.25, 1, 10% NaCl) at room temperature were selected to prepare the swollen PPGs.**

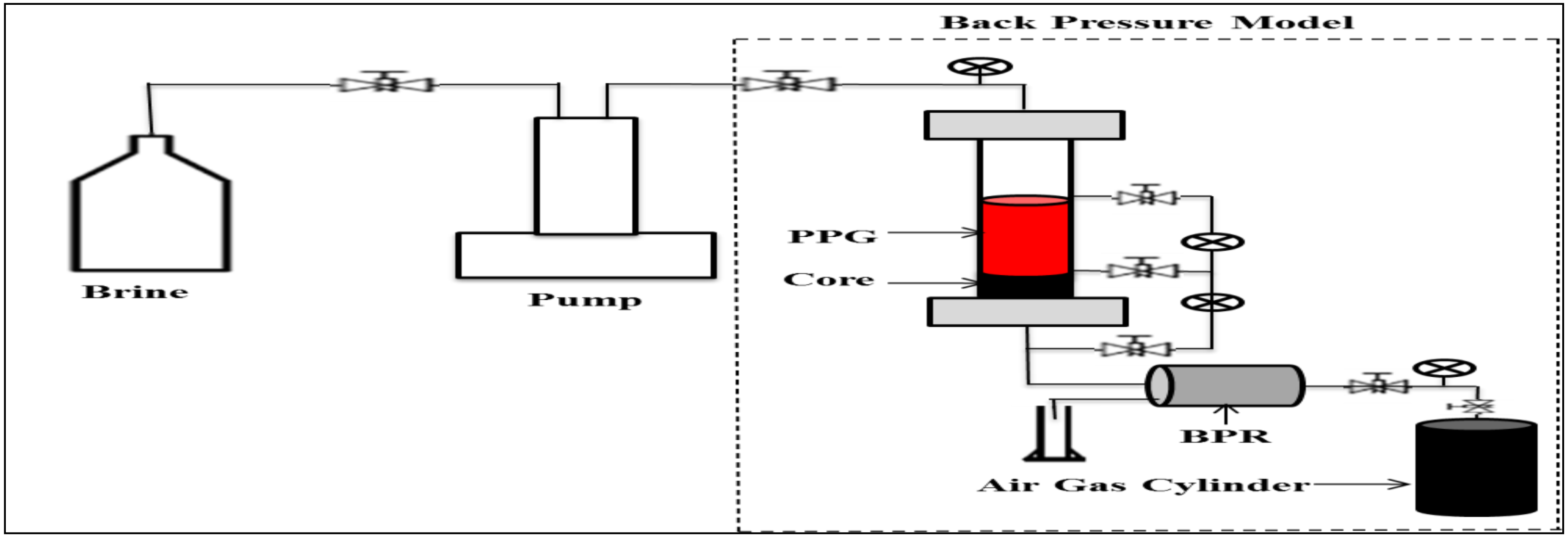
- **Sandstone Core Samples.** **low-permeability Sandstone Cores were used**

Core Vacuumed and Saturated with Brine

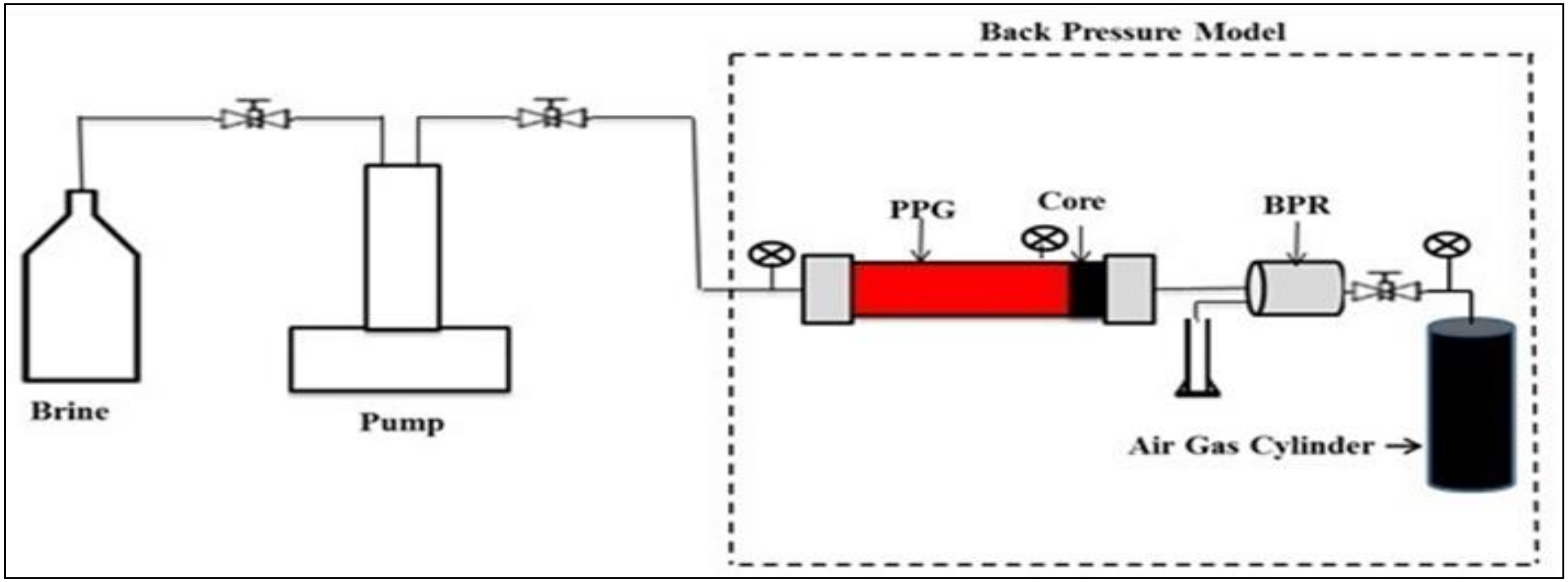
Sandstone Cores Prepared for Experiments

Measurement of PPG Pack Permeability

Back Pressure Model



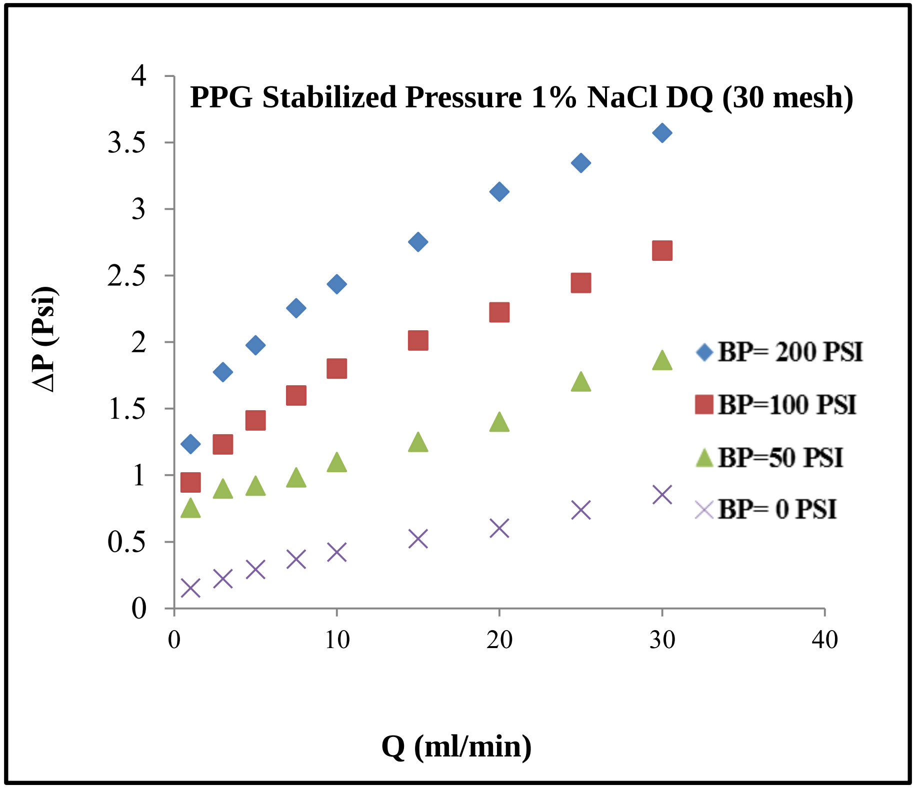
a) Lower Back Pressures



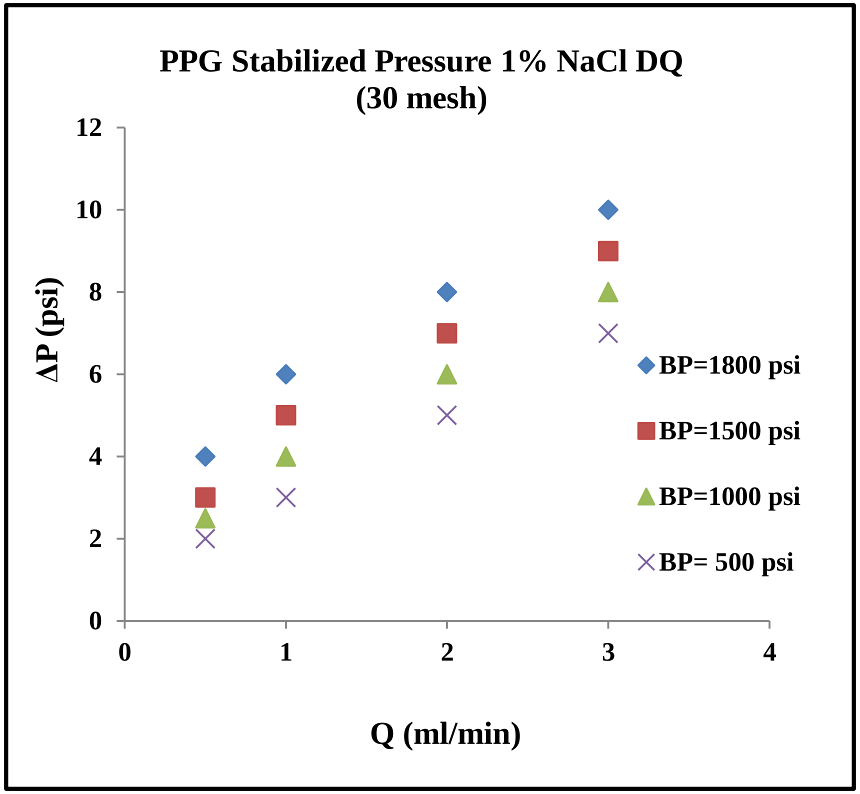
b) Higher Back Pressures

Back Pressure Model Results

- <u>**Effect of Back Pressure on PPG Stabilized Pressure**</u>



(a)

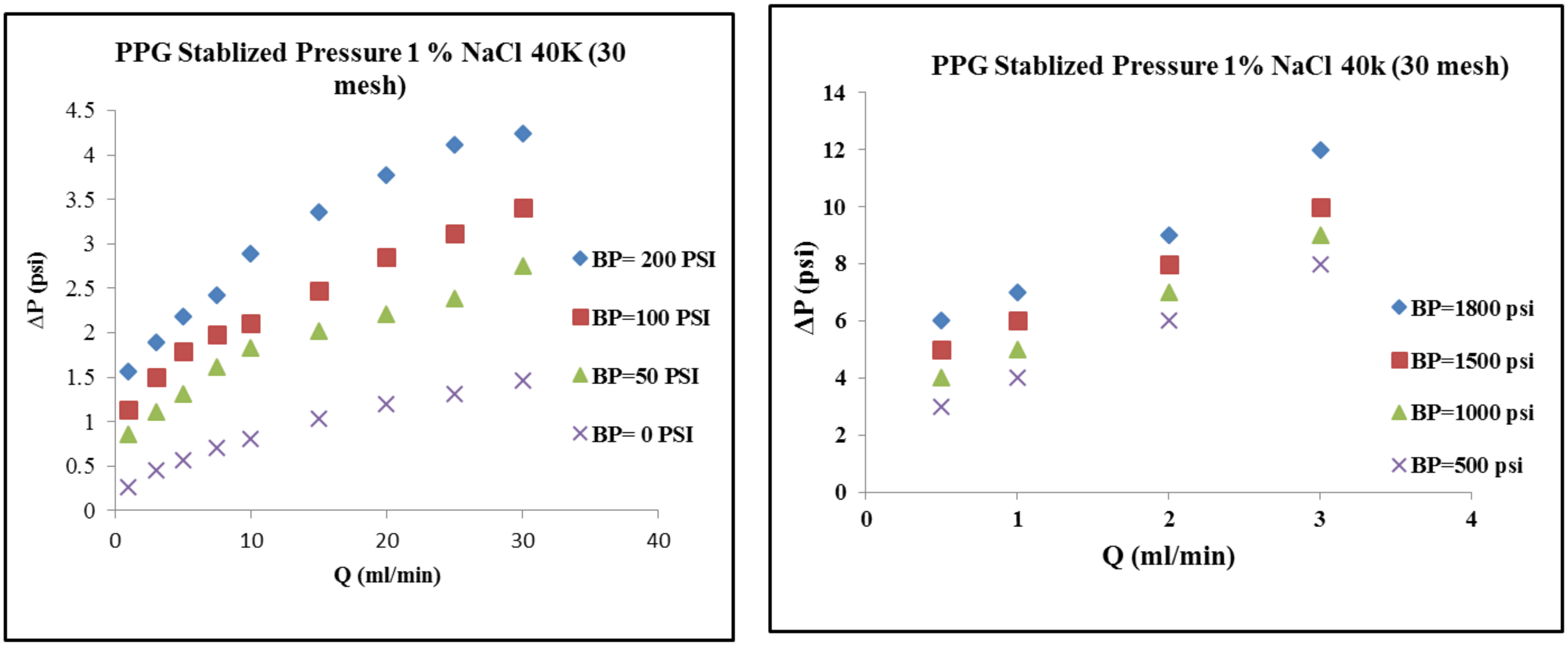


(b)

Stabilized Pressure Results for DQ with 30 mesh **a)** Lower Back Pressures **b)** Higher Back Pressures

Back Pressure Model Results

- **<u>Effect of Back Pressure on PPG Stabilized Pressure</u>**

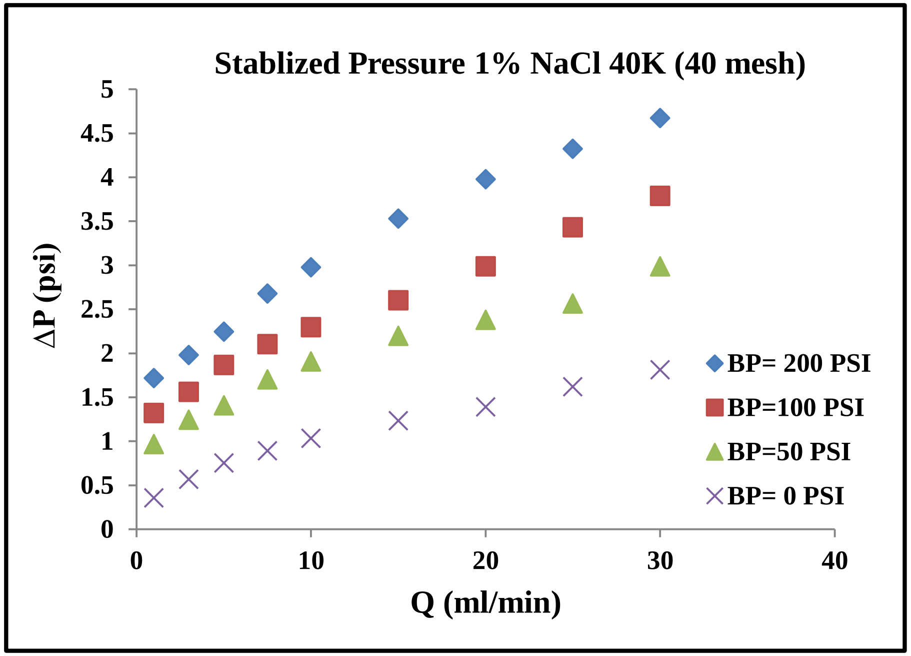


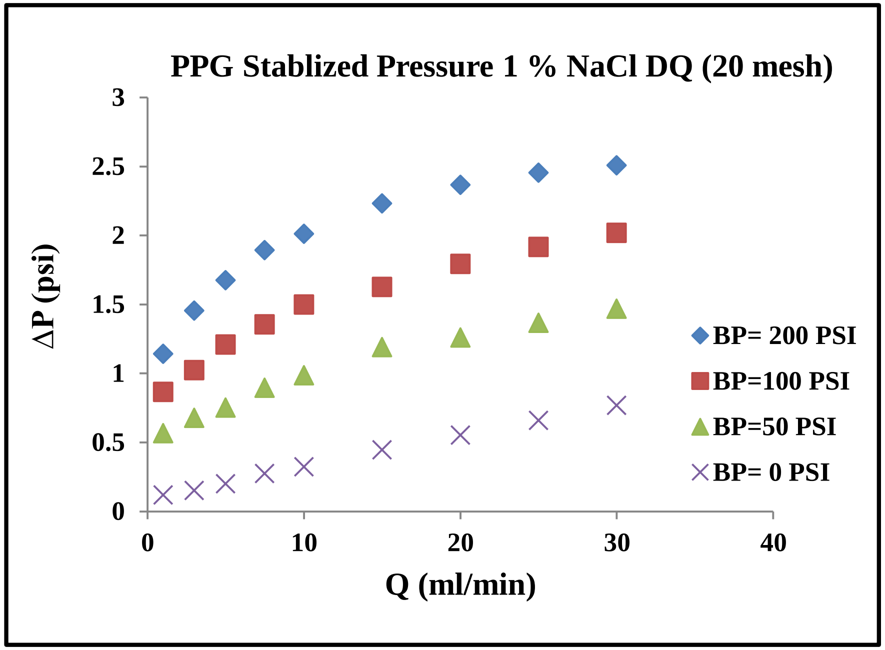
(a) (b)

Stabilized Pressure Results for 40K with 30 mesh **a)** Lower Back Pressures **b)** Higher Back Pressures

Back Pressure Model Results

- **Effect of Back Pressure on PPG Stabilized Pressure**



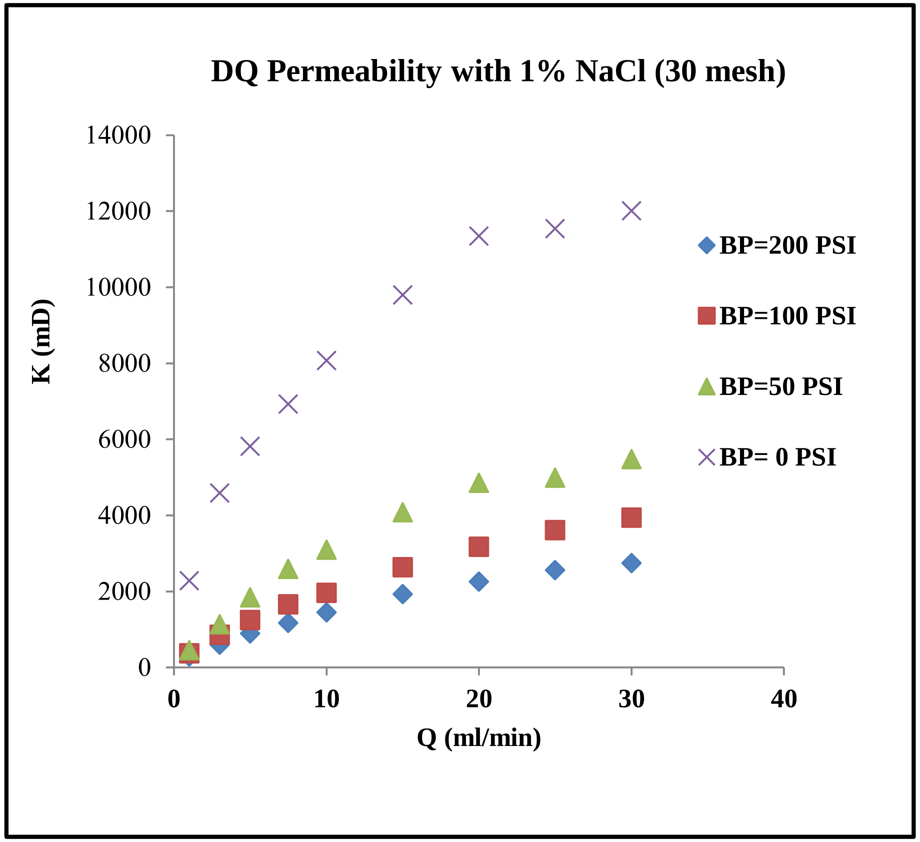


(a) (b)

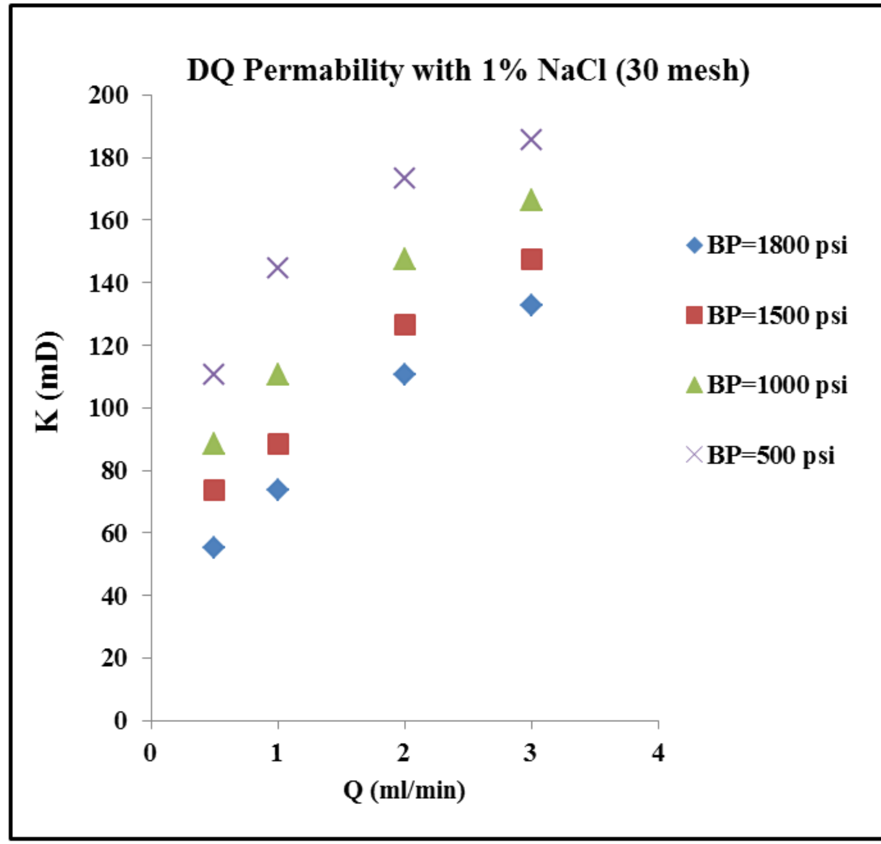
Stabilized Pressure Results for Lower Back Pressures **a)** 40K (40 mesh) **b)** DQ (20 mesh)

Back Pressure Model Results

- **Effect of Back Pressure on the PPG Pack Permeability**



(a)

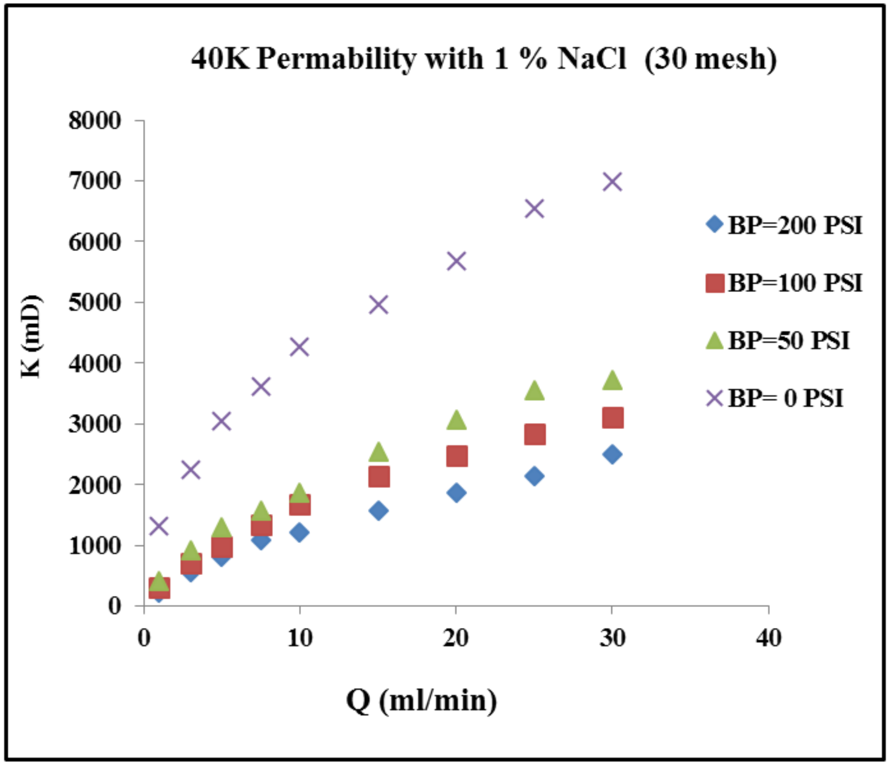


(b)

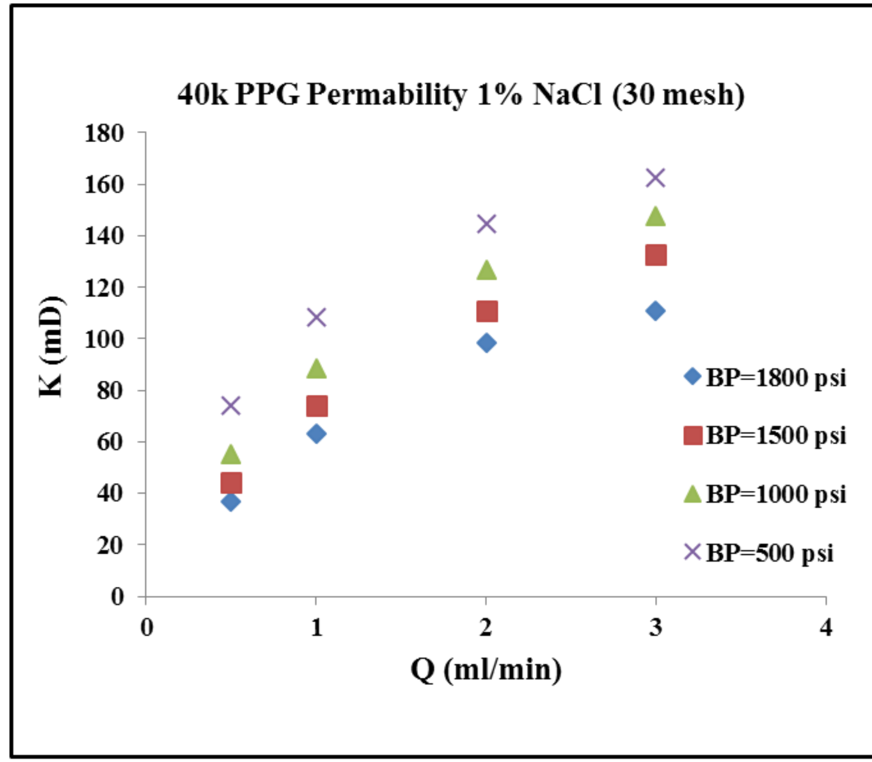
PPG Pack Permeability Results for DQ with 30 mesh **a)** Lower Back Pressures **b)** Higher Back Pressures

Back Pressure Model Results

- **Effect of Back Pressure on the PPG Pack Permeability**



(a)

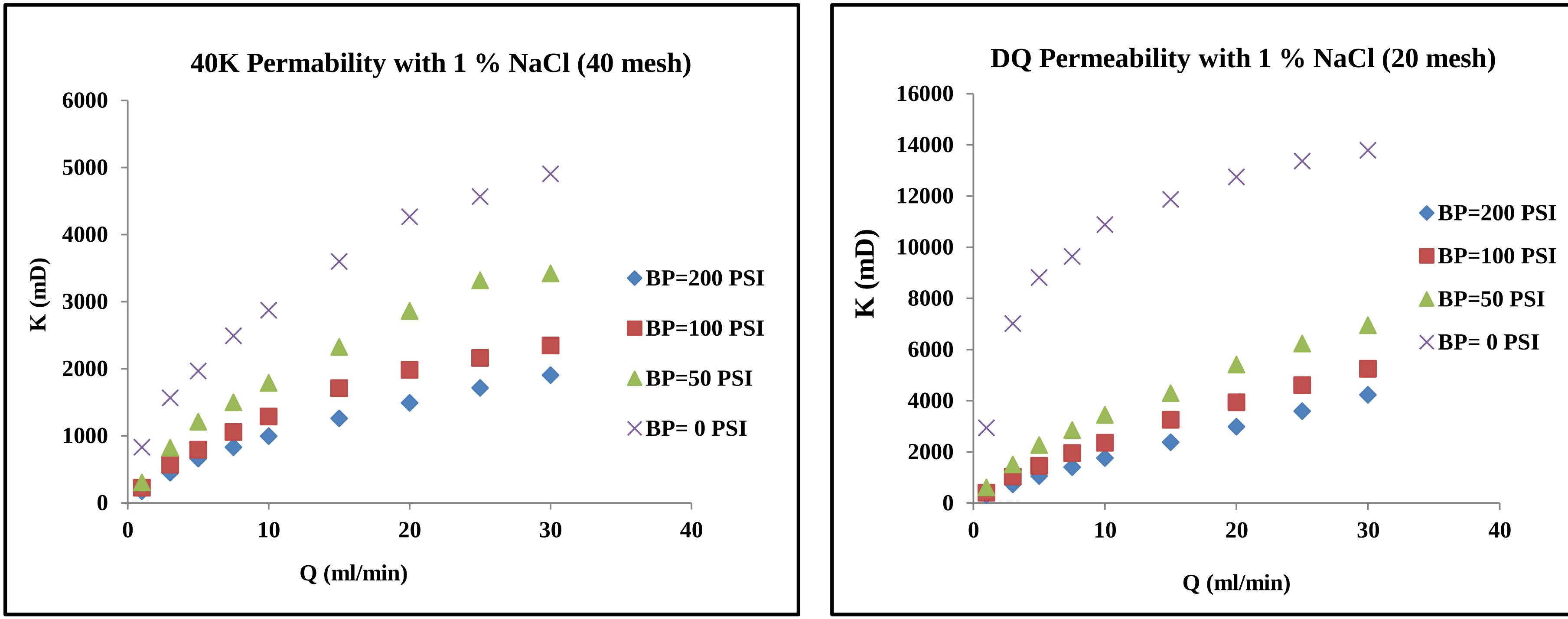


(b)

PPG Pack Permeability Results for DQ with 30 mesh **a)** Lower Back Pressures **b)** Higher Back Pressures

Back Pressure Model Results

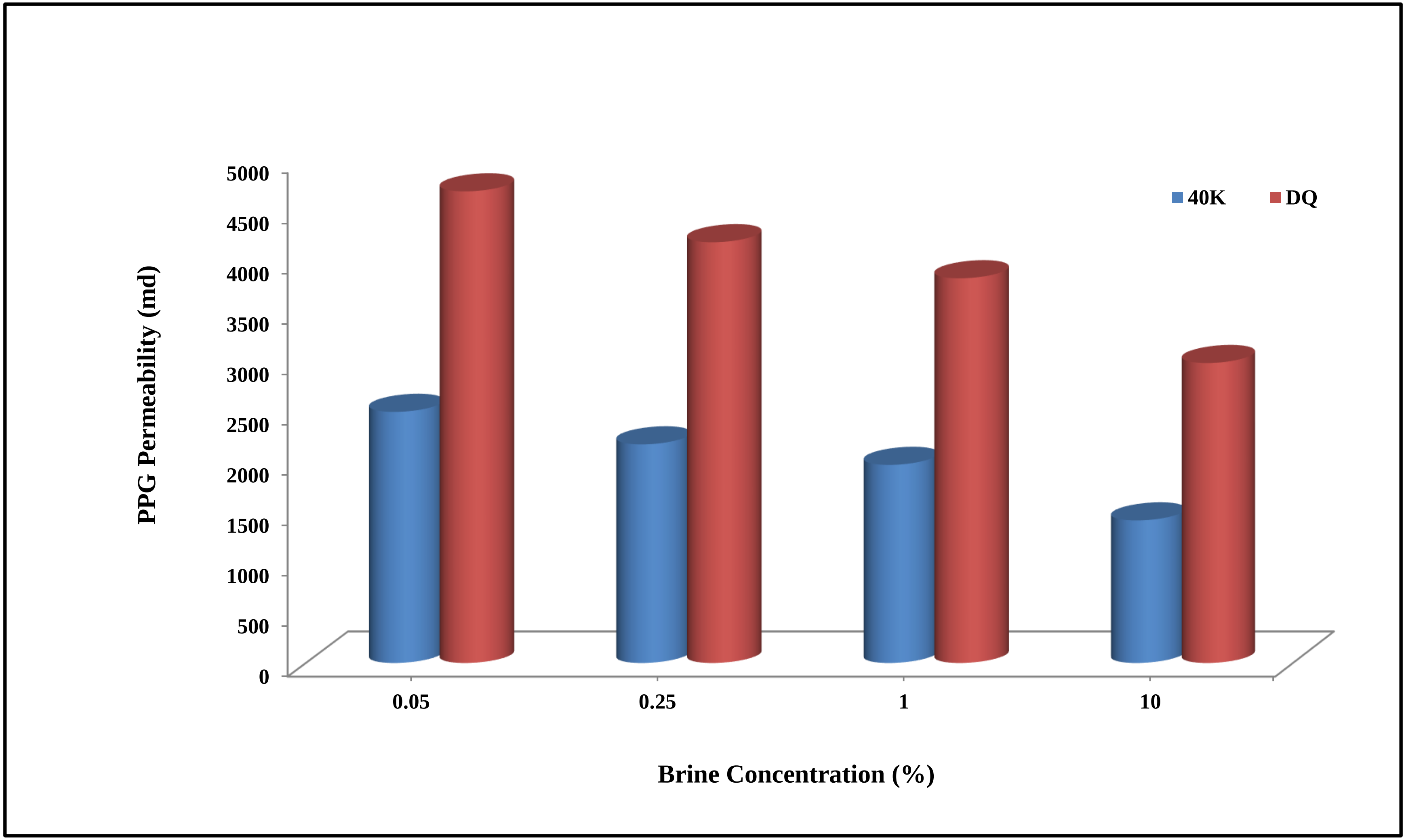
- **Effect of Back Pressure on the PPG Pack Permeability**



(a) (b)

PPG Pack Permeability Results for Lower Back Pressures **a)** 40k (40 mesh) **b)** DQ (20 mesh)

Effect of Brine Concentration on the PPG Pack Permeability



Power Law Model

- Power law model is a time-independent, two parameter, and rheological model.
- The data is a good fit for the power fitting equation.
- The equation for the power law model is:

$$\Delta p = k\,(q)n$$

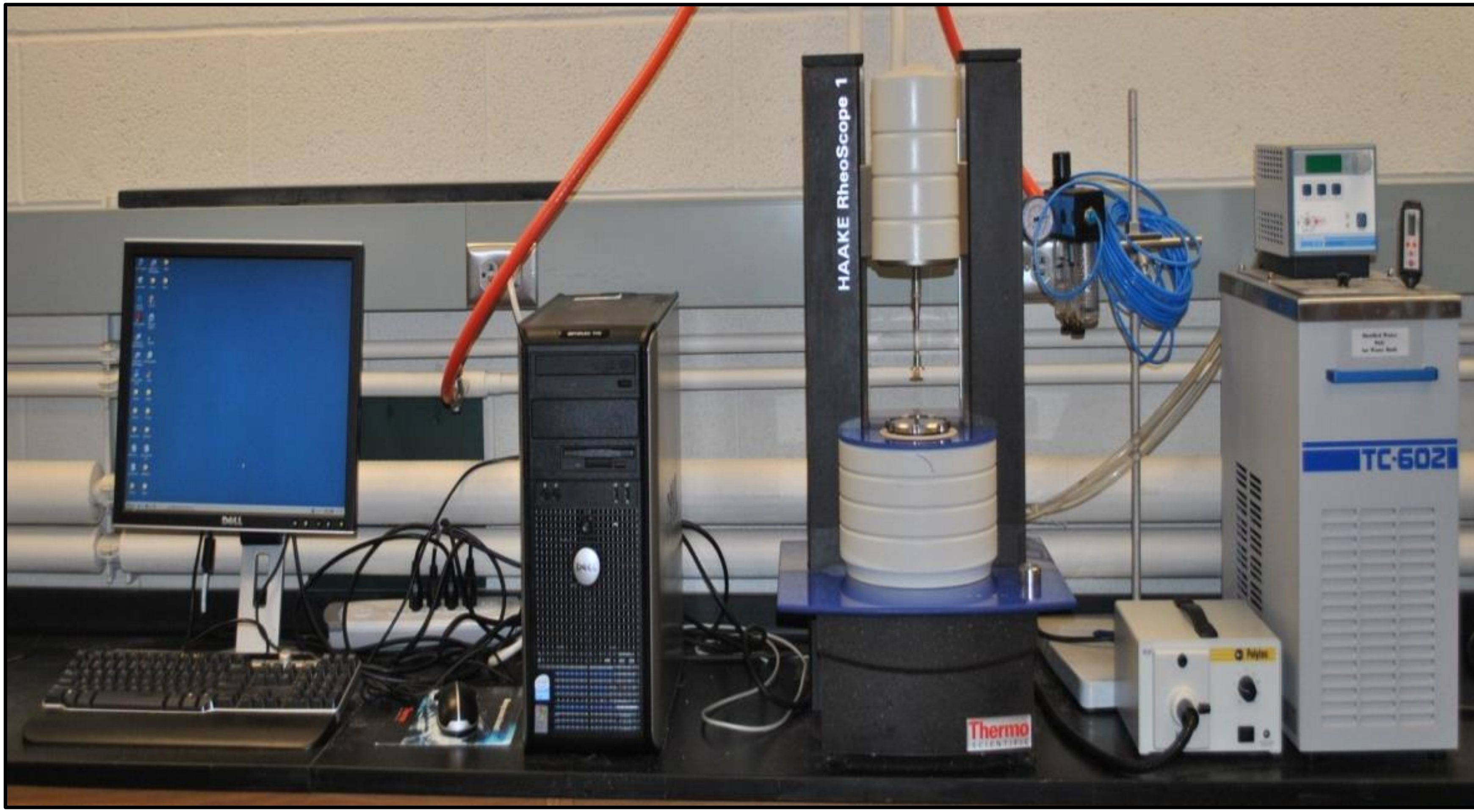
- Where, **n** and **k** are the flow **behavior index** and **consistency index**, respectively.
- Fluids for which n < 1 are termed as pseudoplastic.

Power Law Model

PPGs Size (mesh)	Back Pressure Bp (Psi)	Fitting Equations	K	n	R^2
40k 30 mesh	0	$\Delta p = 0.2592q^{0.5048}$	0.2592	0.5048	0.9983
	50	$\Delta p = 0.7989q^{0.3456}$	0.7989	0.3456	0.986
	100	$\Delta p = 1.069q^{0.323}$	1.069	0.323	0.9855
	200	$\Delta p = 1.4077q^{0.317}$	1.4077	0.317	0.9682
	500	$\Delta p= 4.2166q^{0.5462}$	4.2166	0.5462	0.9884
	1000	$\Delta p= 5.2642q^{0.4507}$	5.2642	0.4507	0.9831
	1500	$\Delta p= 6.2976q^{0.384}$	6.2976	0.384	0.9788
	1800	$\Delta p = 7.405q^{0.374}$	7.405	0.374	0.9463
40k 40 mesh	0	$\Delta p = 0.3475q^{0.4738}$	0.347	0.4738	0.9977
	50	$\Delta p = 0.912q^{0.3164}$	0.912	0.3164	0.9883
	100	$\Delta p = 1.2105q^{0.2921}$	1.2105	0.2921	0.9766
	200	$\Delta p = 1.7307q^{0.2671}$	1.7307	0.2671	0.988
DQ 20 mesh	0	$\Delta p = 0.0932q^{0.5811}$	0.0932	0.5811	0.9535
	50	$\Delta p = 0.5138q^{0.2964}$	0.5138	0.2964	0.9689
	100	$\Delta p = 0.8177q^{0.2593}$	0.8177	0.2593	0.9864
	200	$\Delta p = 1.1435q^{0.2398}$	1.1435	0.2398	0.9954
DQ 30 mesh	0	$\Delta p = 0.1536q^{0.4546}$	0.1536	0.4546	0.9718
	50	$\Delta p = 0.4234q^{0.3279}$	0.4234	0.3279	0.9773
	100	$\Delta p = 0.935q^{0.2835}$	0.935	0.2835	0.9752
	200	$\Delta p = 1.2518q^{0.2976}$	1.2518	0.2976	0.9923
	500	$\Delta p = 3.1418q^{0.699}$	3.1418	0.699	0.9949
	1000	$\Delta p = 3.9254q^{0.6407}$	3.9254	0.6407	0.9989
	1500	$\Delta p = 4.7022q^{0.5999}$	4.7022	0.5999	0.9921
	1800	$\Delta p = 5.7696q^{0.5003}$	5.7696	0.5003	0.9951

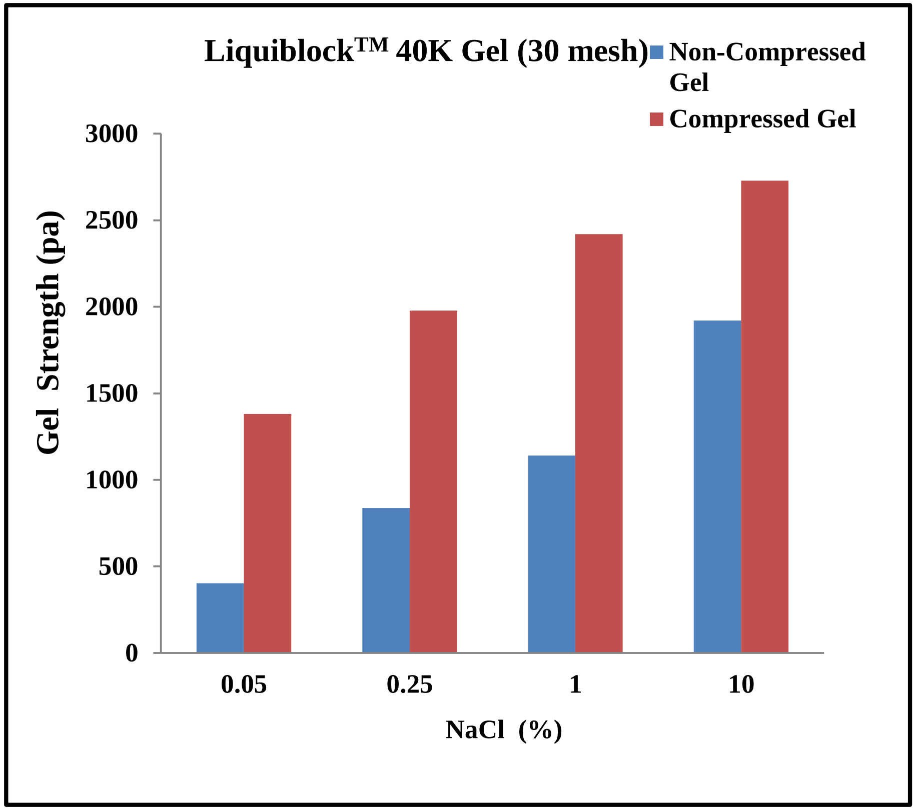
PPG Strength Measurements

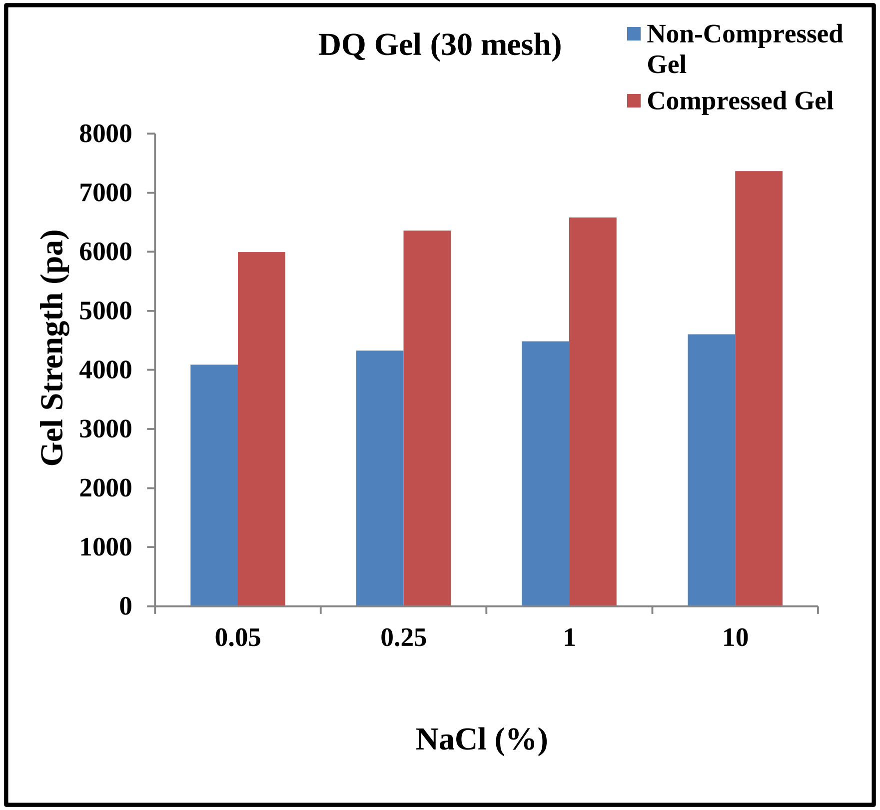
Rheometer, KAAKE RheoScope1 (Thermo Scientific)



Gel Strength Measurement Instrument

PPG Strength Measurements Results





Gel Strength Results for Different Brine Concentration **a) Liquiblock TM 40K Gel b) DQ Gel**

Conclusions

- **Gel particles have form a permeable gel pack in fluid channels rather than fully block these fluid channels.**

- **The gel packed in the fluid channels could be compressed under a back pressure. Its permeability was reduced as back pressure increased.**

- **The permeability of the PPG packs was affected by PPG particle size, gel strength, types, brine concentration, and back pressure.**

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- **McCoy School of Engineering at Midwestern State University.**

- **The Petroleum Engineering Department at Missouri University of Science and Technology.**

- **Baker-Hughes .**

Publications

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Any Questions ?

THANK YOU !