NEW RESIN TECHNOLOGY INCREASES PROPPANT APPLICATIONS

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ABSTRACT

New resin chemistry and coating technology has increased the areas of application for resin coated proppants. Curable resins have been changed to reduce fluid interaction, improving compatibility and retained conductivity. The changes in curable proppants have been related to coating technology and resin chemistry. In addition to improved fluid compatibility the changes in these coatings reduce the risk of consolidation in highly deviated or horizontal wells. Recent developments in pre-cured resin coated proppants place these materials in the intermediate strength range of light weight ceramics but with better economics.

Areas of applications will be presented to support the new proppant technology. Comparisons in resin coatings and coating technology will show the advancements made in this class of proppants.

INTRODUCTION

The use of resin coated proppants is documented in both SWPSC proceedings and SPE proceedings. Resin coated proppants have varied applications.[1,2,3] They range from proppant flowback control to intermediate strength applications. Phenolic resins are generally used for curable proppants to form a physical bond. Recent changes in coating technology and phenolic chemistry have improved the quality and results with curable materials. Pre-cured phenolic and furan resins are used for intermediate strength applications where the resin coating improves the grains ability to withstand closure pressures. Patents covering the pre-cured resin coating process, resin chemistry, and applications are listed.[4,5,6,7]

BACKGROUND AND DEVELOPMENT

Curable coatings can be divided into three general groups, curable, dual coated and partially cured coatings. There are points in common and differences. The resin is applied at a coating facility. The curability and bond strength of the coatings vary with resin volume, chemistry of the resin and the coating procedure. Bond strength varies based on curing temperature, closure pressure and chemistry of the carrier fluids. Curing of the resin coating is a function of temperature and time. Bonding of curable grains is a function of curability and grain contact. Without grain to grain contact curable proppants will not bond together. Therefore some amount of stress, to accomplish grain to grain contact, is required for bonding. Depending on the type of coating, the force needed will change.

The resin volume, percent by weight, is currently used for identification of proppants. The resin volume, 1.6 percent to 4.0 percent by weight, plays an important role in the bonding and final conductivity a pack will have, but it is not the only factor. Curable coatings tend to generate more fines when handled than harder pre-cured coatings. Four percent curable resin coated proppants tend to be more sensitive to erosion in handling than 2 percent curable coatings. Fines increase the surface area and can increase chemical interaction. Table 1 shows resin volume, (LOI, loss on ignition), and percent fines on the pan in standard API sieve tests from several field samples.

Mesh distribution plays as large a part as resin volume in proppant performance. Table 2 shows the differences in "20-40 mesh" materials. Standard API 20-40 mesh sand and two low resin proppant sieve tests from field and published information are listed. The resin coated proppant samples are within API specifications but they do not have the same permeability. The result is a loss of 10 to 50 percent of the permeability depending on closure pressures. (Figures 1, 2)

In the development of proppants that will control proppant flowback, the industry has attempted to design a product that would not bond in the wellbore but with minimal closure it would bond in the fracture. It would have intermediate proppant strength and virtually no dusting. It would be compatible with fracturing fluids and economical. Some of the guideline have been meet with lower volume curable resin proppants and dual coated proppants. Lower resin volumes limit bonding and dusting because of the amount of curable resin. Low resin coatings give economical and conductive advantages over dual coatings.(Figures 3, 4) Dual coated sand has a pre-cured under coating of 1 to 2 percent and a curable outer coating of 1.5 to 2 percent. This process gives bond strength at atmospheric pressure and minimal closure pressure comparable to low resin proppants. Bond strength data, as stated in compressive strength (psi) in a free standing test, is shown in Figure 5. In a clean sample dual coatings had similar fluid interaction level to lower resin coatings.[8] The flexible nature of the dual coatings compares to higher volume curable resin coatings because the amount of resin is similar. In field samples and lab testing the tendency to erode when handled corresponds. The increased surface area in field samples of dual coatings gave higher fluid interaction when compared to partially cured coatings. (Figure 6)

New developments in coating techniques and phenolic resins have produced changes in partially cured coatings. To make a partially cured proppant the curing process is monitored. At a given point the curing process is stopped. This requires control of the manufacturing procedure and the chemical reaction. The benefits of this system are resistance to bonding in the wellbore, required directional pressure such as closure stress to bond, resistance to damage in handling, low fluid interaction and improved economics to a two step coating process.

Partially cured and pre-cured proppants have proved fruitful with economic increases in conductivity and production as in the AWP (Olmos) field.[9] The current testing of resin coated proppants for long term permeability results in high retained permeability. In recent fines migration testing the effects of migration in long term evaluations shows additional loss of permeability.[10] The loss of permeability at lower closures with sand is considerable. In side-by-side testing pre-cured proppants showed little or no loss. The resin coating resisted crushing at high closure pressure. When grains did fail the resin coating encapsulated the fines, reducing the possible damage to the proppant pack.

Pre-cured resin coated proppants are not typically recommended for flowback control because curing has taken place in the manufacturing process. In curing, the active sites are used, making the resin resistive to fracturing chemistry. Pre-cured coatings are essentially dust free because the resin coating is hard. Pre-cured phenolic low resin coatings provide more permeability at a given cost than sand at closures over 3,500 psi depending on the supplier. Figures 1, 2, 3 and 4 show the relationship of various phenolic coatings, both curable and pre-cured, to permeability and economics.

The development of furan resin coatings increased the economic benefits of resin coated proppants. Furan resin coating technology addressed the need for stable high temperature pre-cured resin coated proppants. Long term data at 250^{0}F shows furan resin coated sand has higher permeability than pre-cured phenolic coatings. (Figure 7) The hard furan coating does not chip or erode with normal handling. Initial long term permeability data indicated, given mesh, furan coated sand exhibited permeabilities similar to light weight ceramic proppants. Changes in light weight ceramic products have improved the conductivities but the economics of ceramics continue to limit their application range. The significant cost savings of furan resin coated sand creates an economic advantage ceramic proppants can not reach. Conductivity comparisions are in Figures 8 and 9.

APPLICATIONS

Partially cured resin coated proppant has been used in a variety of areas and under a number of conditions. General recommendations are based on a need for proppant consolidation in addition to the proppant strength. The majority of the applications had maximum closure pressures of 2,000 psi to 9,000 psi and temperature ranges of 160^{0}F to 275 ^{0}F.

Furan resin coated proppants have been successfully utilized in closure range of 4,000 psi to 11,000 psi and bottom hole temperatures from 110^{0}F to 350 ^{0}F. Table 3 contains a list of formations and type coating used with success.

CONCLUSIONS

The type of curable coating used should be determined by application and based on reducing fines and fluid interaction. Lower resin curable coated proppants have specific areas of applications based on economics and conductivity needed. The partially cured coating protects the grain and resists damage. Partially cured coatings have less fluid interaction than current curable proppants and dual coated materials.

Low resin pre-cured phenolic coatings have economical applications. Furan resin coated sand has extended the temperature and pressure application range of pre-cured resin coated sand into the ranges previously reserved for low density ceramics.

ACKNOWLEDGEMENTS

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Table 1
Volume of Curable Resin and Fines Present

	ACLR	SCLR	APCR	SCDL	ACHR	SCDH
% RESIN	2.0	2.0	3.7	3.0	4.0	4.0
FINES TEXT	0.3	0.5	0.2	0.0	0.3	0.0
FINES FIELD	0.5	1.3	0.3	0.9	0.7	1.2

Volume of Pre-cured Resin and Fines Present

	APLR	SPLR	AFR	SPR
% RESIN	2.0	2.0	4.0	3.0
FINES TEXT	0.1	-	0.1	-
FINES FIELD	0.2	0.3	0.1	0.2

% Resin - volume in percent by weight.
Fines Text - as published in technical literature.
Fines Field - reported from API seive analysis on well site samples.

A(CL) - company A
S(CL) - company S
CLR - curable low volume resin
PCR - partially cured resin
CDL - curable dual coated low volume resin
CHR - curable high volume resin
CDH - curable dual coated high volume resin

PLR - pre-cured low volume resin
FR - furan pre-cured resin
PR - phenolic pre-cured rešin

Table 2
Comparison of Mesh Distribution
API Sieve Analysis
Resin-Coated Proppants
20 - 40 Mesh

Size	Field Samples		Published Mesh		
Sieve	ACLR	SCLR	ACLR	SCLR	Sand*
20	1.5	0.1	3.6	0.42	0.7
25	29.9	0.8	30.2	4.70	2.5
30	31.4	12.9	29.2	28.45	29.0
35	22.3	65.4	20.2	44.16	42.5
40	11.8	15.6	13.4	15.61	19.3
50	2.5	4.4	3.0	6.16	5.8
pan	0.6	0.8	0.4	0.50	0.2

Data shown as percent of split sample on screen.
* Sand is Northern White Sand.

Table 3
Areas of Application of Partially Cured and
Furan Resin-Coated Proppants

Area/Formation	Resin Coating	Area/Formation	Resin Coating
Permian Basin		South Texas	
Atoka	FR	Frio Sand	PCR
Bell Canyon	PCR	Olmos	FR & PCR
Bone Spring	FR & PCR	Vicksburg	FR & PCR
Clearfork	FR	Wilcox	FR & PCR
Dean	FR	Woodbine	PCR
Delaware	FR & PCR		
Devonian	FR & PCR	Northern Louisiana	
Morrow	FR	Cotton Valley Sand	PCR
Spraberry	FR & PCR	Gray Sand	FR & PCR
Strawn	FR	Hosston	FR & PCR
Wolfcamp	FR & PCR		
Rocky Mountains		East Texas	
Codell	FR	Cotton Valley Sand	PCR
Dakota	FR & PCR	Hosston	PCR
Frontier	FR & PCR	Travis Peak	PCR
Mesa Verde	FR & PCR	Wilcox	PCR
Niabrara	FR	Woodbine	PCR
Sussex	FR & PCR		
Vermejo	FR & PCR		
Mid-Continent		California	
Granite Wash	FR & PCR	Diatomite	PCR
Morrow	FR & PCR	Sespe	PCR
Prue	FR & PCR		
Redfork	FR & PCR		
Skinner	FR & PCR		
Spiro	FR & PCR		
Springer	FR		

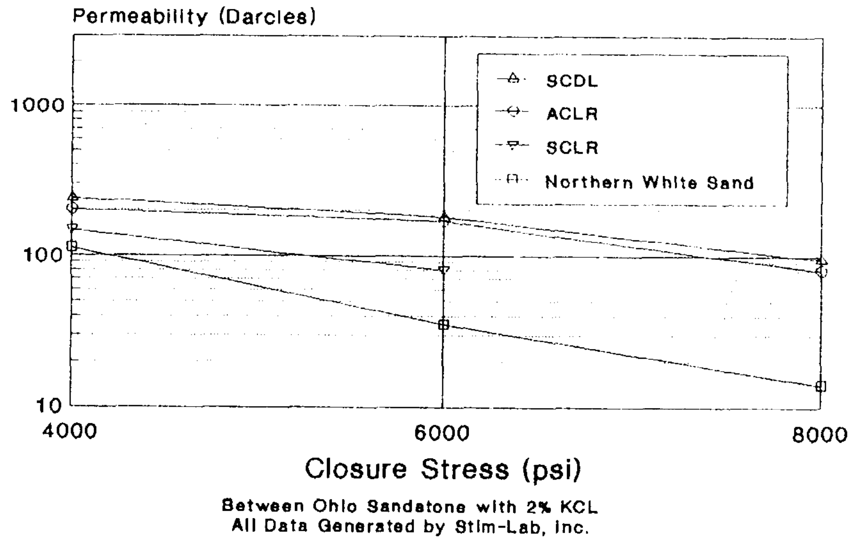

Figure 1 - Long-term permeability (2 lb/sq ft 20/40 proppant at 250°F)

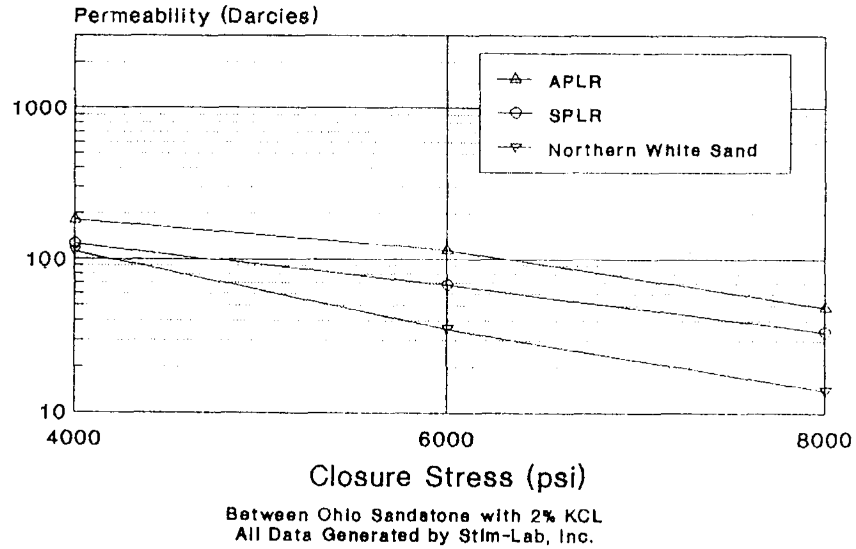

Figure 2 - Long-term permeability (2 lb/sq ft 20/40 proppant at 250°F)

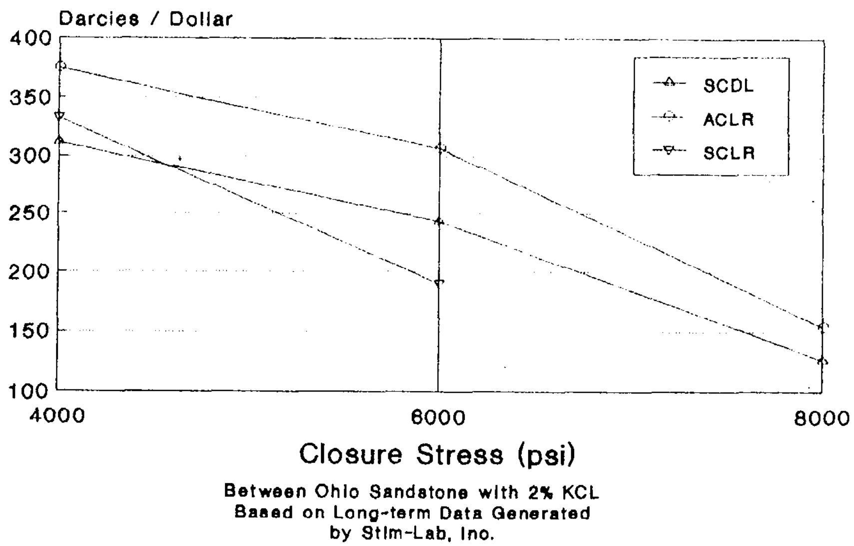

Figure 3 - Cost of permeability vs. closure stress
(2 lb/sq ft 20/40 proppant at 250°F)

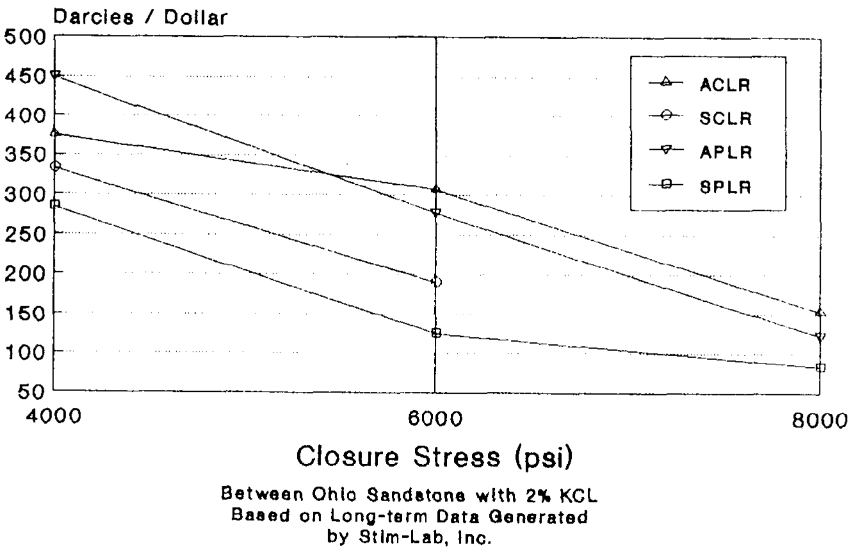

Figure 4 - Cost of permeability vs. closure stress
(2 lb/sq ft 20/40 proppant at 250°F)

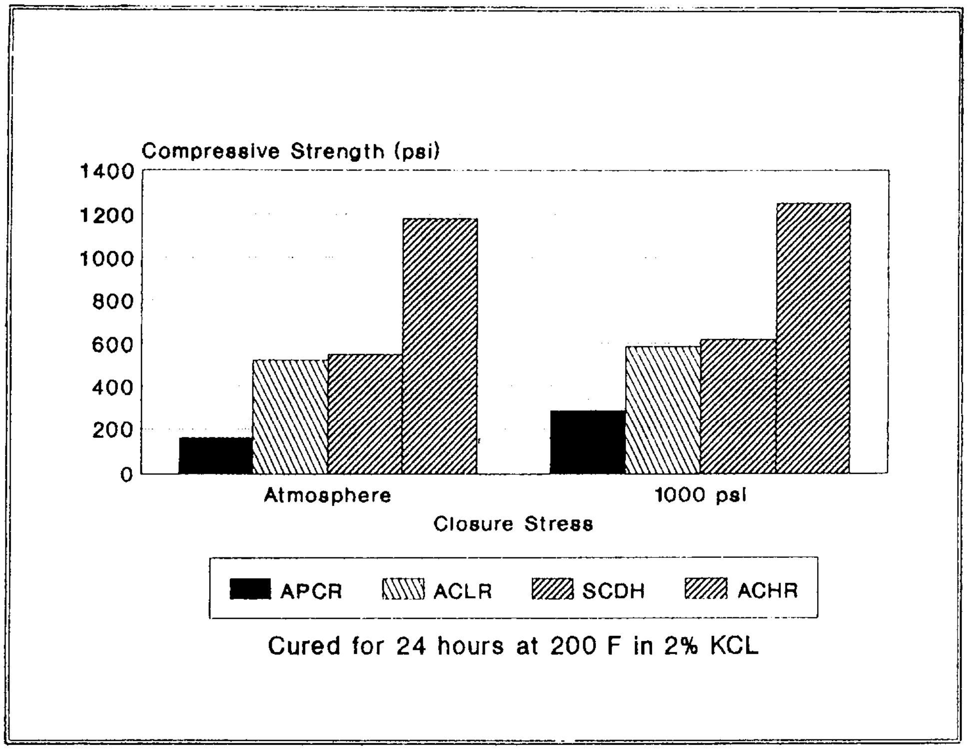

Figure 5 - Consolidated properties of curable resin-coated proppants

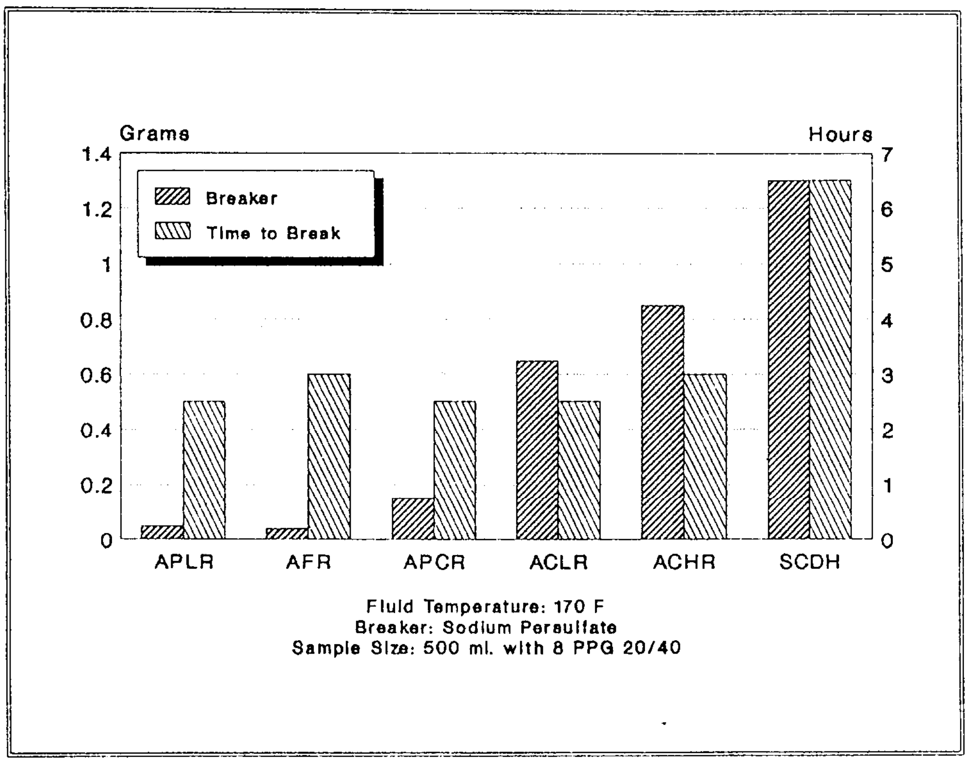

Figure 6 - Breaker interaction (40 lb/M gal titanate x-link guar gel)

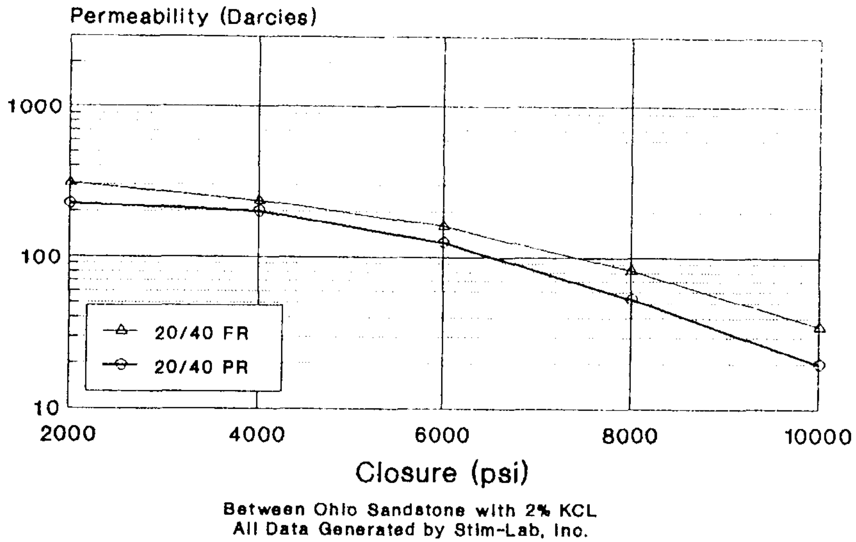

Figure 7 - Long-term permeability (2 lb/sq ft proppant at 250ºF)

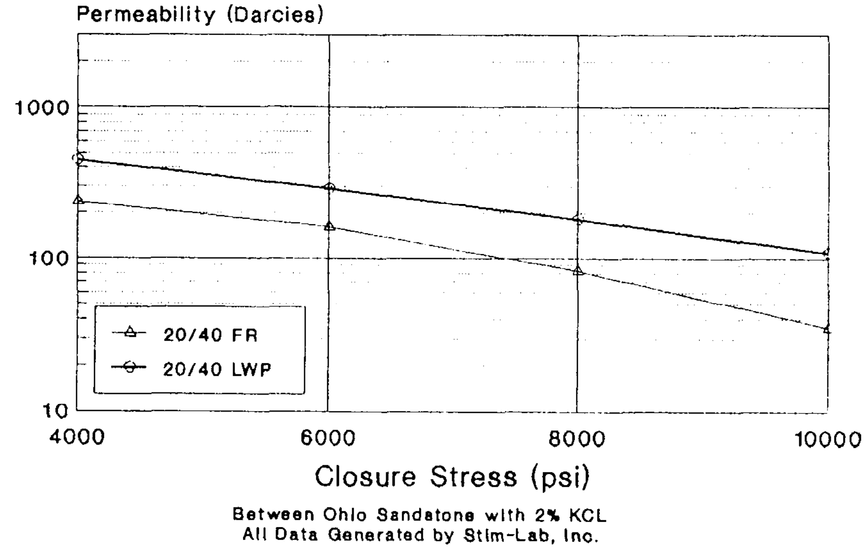

Figure 8 - Long-term permeability (2 lb/sq ft proppant at 250ºF)

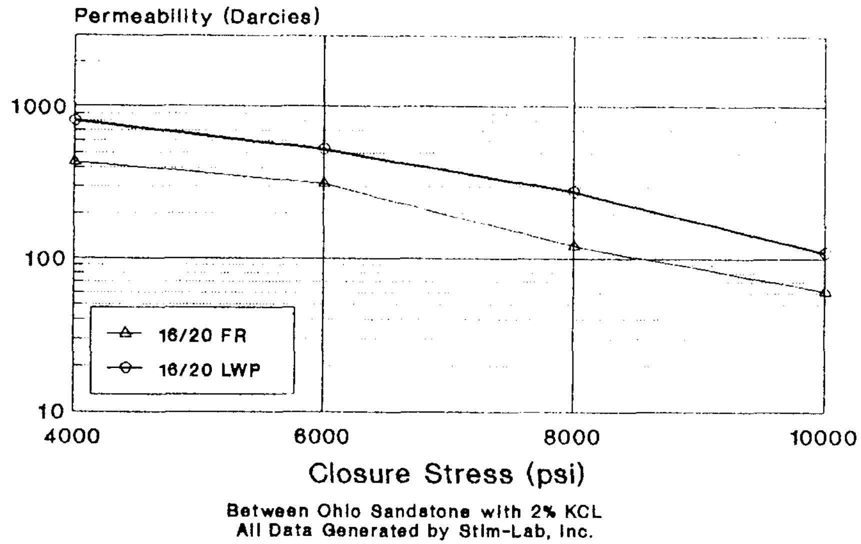

Figure 9 - Long-term permeability (2 lb/sq ft proppant at 250ºF)