

## Filtercake Breaker Evaluation Pitfalls: Lessons Learned Through Testing

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### Abstract

Breaker systems feature innovative chemistries to efficiently remove deposited filtercake and maximize well productivity. The design and selection phase of a breaker system requires thorough laboratory testing to build the proper chemistries needed for efficient filtercake removal. A final breaker selection decision is usually made after performing a return permeability test with a reservoir core plug to assess the benefit of using a breaker system on near-wellbore permeability and, hence, well productivity.

Return permeability testing is intended to simulate the entire completion phase and to evaluate the damage potential from candidate fluids<sup>1</sup>. Test procedure errors and practice variations show that filtercake breaker evaluation can be inconsistent with real-world conditions. This can result in a misinterpretation of results and expensive retests or rejection of an effective treatment.

This paper reviews a number of errors encountered, common mistakes, and attempts to address scenarios where filtercake breaker treatments perform worse than untreated filtercake. The objective is to understand the causes responsible for poor return permeability test results involving filtercake clean-up with a breaker and find appropriate solutions.

The two-phase investigation first reviews breaker chemistry selection techniques prior to return permeability testing and the second phase reviews test procedures and results, including different types of reservoir drill-in fluids and breaker systems used for a range of reservoir core properties.

### Introduction

Overbalance drilling through a reservoir (porous and permeable formation) causes invasion of drilling fluid into the formation and results in filtercake deposition. This invasion induces additional pressure losses in the vicinity of the wellbore, which can negatively affect the overall well performance. The impact of invasion can be minimized by using a less damaging fluid (reservoir drill-in fluid or RDF) designed with an acid soluble bridging package selected based

on reservoir properties (pore sizes and structure). The bridging package is usually made of sized calcium carbonate selected to quickly bridge the reservoir formation pores and minimize further invasion by depositing a thin and ultra-low permeability filtercake. In cased hole completions, the invaded zone is bypassed after the casing is perforated. Acid treatment, if needed, will aim to stimulate the reservoir matrix and increase near wellbore permeability.

For open-hole completion techniques, the filtercake and near wellbore damage can be removed either mechanically, by produced fluids when the well is brought onto production, or by external chemicals, such as acids or filtercake breaker treatments. Breaker treatments are preferred over acids because they provide a more uniform treatment across the entire filtercake. Acids also tend to present higher corrosion rates compared to engineered filtercake breaker chemistry.

This paper describes different steps required to select appropriate breaker chemistries, reviews some return permeability tests data, and provides recommendations to effectively evaluate breaker chemistry selections.

### Breaker Chemistry Selection Process

The main objectives of a breaker system in open-hole completions are to lower the risk of residual skin by evenly removing near wellbore damage and reducing the possibility of plugging the completion screens once the well is brought onto production. Depending on types of well and open-hole completion techniques, the breaker chemistry is selected to either disperse (producer wells) or completely dissolve the filtercake (injector wells or producer wells with fine stand-alone screens and/or gravel-pack completions).

The breaker disperses the filtercake by targeting specific filtercake components and, in effect, alters the filtercake integrity, thus leading to the removal of all or most filtercake materials during production. Injector wells require a complete dissolution of all the components of the filtercake to allow a matrix injection of fluids (gas or water) into the reservoir for hydrocarbon recovery enhancement.

The process of selecting a breaker system to remove near wellbore damage in open-hole completions can be grouped into three steps:

- The base brine is selected based on anticipated breaker density and its compatibility with the RDF, completion fluids, reservoir rock, and fluids.
- Active chemicals, to either disperse and/or completely dissolve filtercake, are selected based on: filtercake composition, base brine chemistry, and the ability to delay the breaker action and minimize corrosion of completion hardware at the expected reservoir temperature.
- Validation in regards to the effectiveness of the breaker candidate in dispersing and/or dissolving filtercake is then assessed by performing a series of high pressure, high temperature (HPHT) fluid loss, breaker soak, and flowback tests.

**Base Brine Selection: Filtrate and Formation Compatibility**

A key driver in base brine selection is the density; however, at varied levels of saturation or dilution, many stock brines may achieve the required density. To maintain compatibility, the preferred base brine is the same used as the base fluid of the RDF. If sufficient free water is unavailable, the alternative brine should be tested for compatibility with the RDF base fluid.

The breaker-base brine should also feature similar shale inhibition characteristics and demonstrate compatibility with formation water (precipitation risk) and reservoir crude oil (emulsification risk).

**Filtercake Removal Additives**

The selection of breaker chemical additives is dictated mainly by the nature and composition of the filtercake. **Table 1** lists typical filtercake components and required breaker additives to disperse or dissolve them. Drilled solids and other components, such as lubricants and shale inhibitors, can reduce the effectiveness of the breaker additives and cause poor filtercake cleanup.

Table 1- Typical Filtercake Components and Breaker Additives

Filtercake Components	Breaker Additives
Starch	Enzyme
Xanthan gum	Oxidizer
Calcium carbonate	Chelant or acid precursor
Drilled solids (non-carbonate)	None

Breaker additives must be chemically compatible with the base brine. Any incompatibility, such as solid precipitates, will induce further formation damage.

Early reaction between the breaker and filtercake can result in premature loss of completion fluids into the formation, which results in uneven filtercake removal while spotting a breaker system across an open-hole section. For this reason, it is crucial to delay the reaction of the breaker with the filtercake for at least the period of time elapsed between the moment the breaker is spotted in the open-hole section and the time the fluid loss control valve is closed.

Using chelants or acid precursors, such as esters, will slow down the reaction with the filtercake. Also, increasing the rheology of the breaker by adding chemicals such as hydroxyethyl cellulose (HEC) may help achieve the required time delay given the reservoir temperature.

Breaker systems may contain chemical additives that are naturally corrosive to metals, which may affect the integrity of the completion hardware. Corrosion products, such as iron, promote and stabilize emulsions with some crude oils.

The slow acting nature of many filtercake breaker additives minimizes corrosion. As the chemistry acts on the most soluble material, it is neutralized by the filtercake material it encounters. In other conditions, a supplemental corrosion inhibitor is necessary.

For anticipated reservoir temperatures higher than 200°F, chelants will induce less corrosion compared to an acid precursor used with a corrosion inhibitor (**Figure 1**).

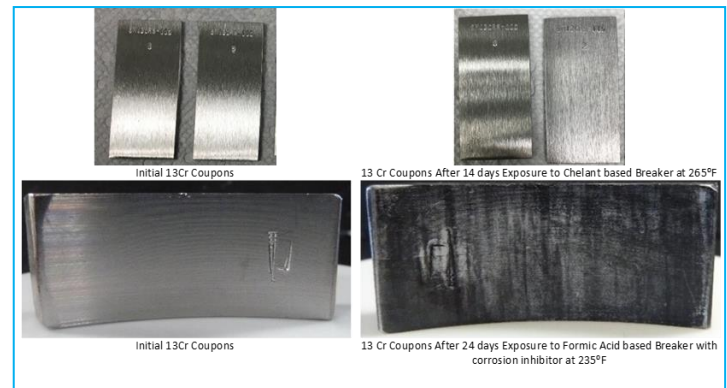


Figure 1- 13 Cr metal coupons corrosion tests using chelant- and formic acid-base breakers.

## Breaker Formulation Assessment

The initial breaker selection process will result in one or more formulations for performance testing. Filtercakes are prepared on aloxite media using a modified HPHT cell at bottom hole temperature. These filtercakes are exposed to candidate formulations for comparison and further testing in a return permeability test.

The screening test objectives are summarized as follows:

- To achieve the required time delay for placement of the breaker in the open-hole section
- To clean the filtercake without producing solid precipitates and plugging the aloxite disk
- To minimize corrosion of completion hardware
- And to restore initial permeability and allow production or injection of fluids through the disk

The flowback test involves passing fluid through a new aloxite disc at various pressure to measure baseline flow rates. The disc is then used to form a filtercake with the selected RDF in a modified HPHT test, typically for 4 hours.

After filtercake formation, the RDF is decanted and a candidate breaker solution is placed in the cell. The modified HPHT cell is closed and re-heated, and the breaker is allowed to soak for a specified time period (**Table 2**). Once the soak is complete, flow is measured at the same pressures used for baseline rates. The final flow rates are compared to the baseline as a percentage, which are referred to as the return to flow.

Several additional measurements are made during the flowback test:

- Delay—The time elapsed from the beginning of breaker soaking until breakthrough is known as the delay period. The definition of breakthrough varies based upon equipment and preference. The authors consider breakthrough the continuous flow of fluid from the valve stem. Breakthrough is also defined as a total volume of filtrate after breaker application by some in the field.
- Dispersion and residual solids—Any residue is tested to identify it. Droplets of hydrochloric acid will effervesce in the presence of residual calcium carbonate. Iodine will turn purple in contact with residual starch.

The breaker candidate for return permeability is chosen based on delay time and filtercake cleanup and return to flow percent (obtained by comparing the final flowrates to initial flowrates).

Table 2- Typical Soak Times

Active Product Type	Temperature	Typical Soak Time
Chelant, low pH	> 110°F	3 – 5 days
Chelant, Neutral pH	> 110°F	10 – 14 days
Chelant, Neutral pH	< 110°F	10 – 14 days
Ester	All Temperatures	3 days
Enzyme	All Temperatures	3 days
Internal Oxidizer (no chelant/enzyme)	All Temperatures	3 days

## Breaker Evaluation through Return Permeability Testing

Once the screening process previously described is completed, most operators would finalize their decision on breaker selection after performing return permeability tests using actual formation core plugs to evaluate the benefit of utilizing breaker candidates for near wellbore damage removal.

### Return Permeability Testing

Return permeability testing introduces more realistic conditions to testing. In most cases, actual formation material is used as the reservoir media and the core is saturated in formation water. The return permeability test provides the capability to more accurately simulate pressures downhole and allows for dynamic fluid placement.

In this paper, testing focuses on methods used in a Hassler cell configuration. While testing equipment varies, many of these concepts translate to other return permeability testers.

The return permeability test starts by establishing an initial baseline permeability (**Figure 2**). The RDF is circulated across the core face to generate the filtercake. In this stage, the Hassler cell features a spacer ring between the circulating head and the core face. This, in effect, determines the filtercake thickness as the height of the spacer ring.

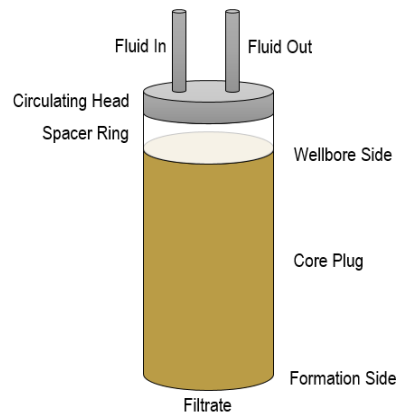


Figure 2- Hassler cell set-up during mud off

When a breaker is not applied, the test concludes by establishing a permeability measurement. The return permeability is a percentage of the baseline.

For a breaker treatment application, a new thicker spacer ring is placed in the cell and the circulating head installed with extensions that circulate the breaker solution close to the filtercake (**Figure 3**).

In a gravel pack simulation, an additional spacer ring is placed on top of the filtercake, and a gravel pack slurry is placed in the spacer ring. A screen is placed on top of the slurry to retain the gravel.

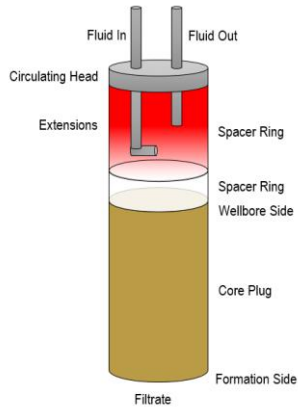


Figure 3-Breaker soak simulation.

Several errors in the placement of a breaker associated with this configuration are noted.

Without the use of an extension, the breaker chemistry may not reach the filtercake, instead circulating out of the cell through the nearby outlet. In a field application, a proper displacement to the breaker solution will allow for direct contact with the filtercake (**Figure 4**).

In one example, a larger gap between the inlet and outlet on the circulating head of two testers resulted in two laboratories achieving somewhat different results on the exact same fluid tested.

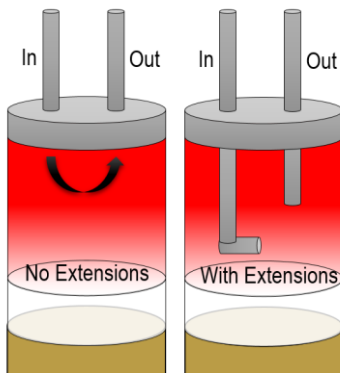


Figure 4- Breaker soak setup with and without extensions.

Breaker volumes are another element requiring consideration. In the setup described, the spacer ring volume is lower than the volume to surface area ratio in a reservoir. Circulation of additional breaker volume throughout the test will allow more active breaker chemical exposure similar to well conditions.

Overbalance pressure is frequently defined by kick tolerance ranging from 300 to 500 psi. Once the reservoir is isolated with a fluid loss control mechanism, the hydrostatic pressure is removed from the well and subsequent overbalance may be reduced.

In an isolated reservoir, near equilibrium pressure with the formation means that overbalance will be minimal. The authors recommend testing no more than 50 to 100 psi overbalance during breaker soak, with some experts in the field requesting zero overbalance pressure.

Gravel pack simulation includes a more complex setup (**Figure 5**), including the slurry and screen. This provides even less volume for the breaker solution to soak. The challenge is further increased by potential dilution from the gravel pack carrier fluid and the confinement of the gravel against the filtercake. One method to address this is to pump a more concentrated breaker solution. A second key strategy is to effectively displace the carrier fluid by using a breaker solution with a density greater than the carrier fluid<sup>2</sup>.

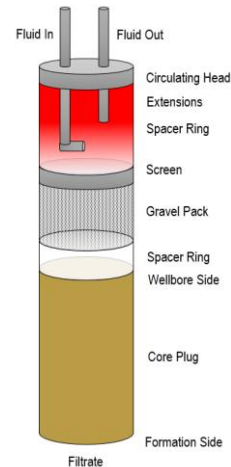


Figure 5- Breaker soak post-gravel pack simulation.

## Case Histories

The use of a filtercake cleanup treatment should result with an increase in return permeability values compared to a baseline test without breaker treatment. Many return permeability tests featuring breaker applications have shown poor results despite excellent results obtained during breaker formulation selection process.

For most of the cases, the return permeability tests failed because of poor procedure followed during testing rather than the breaker chemistry selected. A successful return permeability test is a result of both breaker chemistry selected and testing procedure used.

Case histories below analyze some return permeability tests, give possible causes for the failed tests and propose guidelines in order to achieve successful test results.

### Case #1- Poor Cleanup and Fair Return Permeability

A biopolymer-free RDF system was designed based on given reservoir characteristics and a breaker was selected to completely dissolve the filtercake before the well was brought onto production.

The breaker candidate for return permeability testing was selected after a successful flowback assessment. The breaker cleaned the filtercake completely without any residue (no starch and no calcium carbonate left on the disk, **Figure 6**) and the return to flow at 10 psi was 98% (**Table 3**). However, the return permeability test results were considered poor at 51%. The filtercake was not fully dissolved after 2 days breaker soak (**Table 4** and **Figure 7**).



Figure 6- Aloxite disk after a 2-day break soak-no filtercake residue left on the disk.

Table 3- 10.6 lb. /gal Chelant-Base Breaker Flowback Assessment Results

Flowback Data	
<b>HPHT Filtration</b>	
Aloxite disk	FAO-05
Temperature (°F)	169
Overbalance (psi)	500
RDF exposure time (Hours)	4
Total filtrate (mL)	12.2
<b>Breaker Soak</b>	
Proppant size	20/40
Volume of breaker (mL)	80
Breakthrough time (Hour)	0.5
Soak time (Days)	2
<b>Flowback Results</b>	
Flow initiation pressure (psi)	1
Return to flow at 10 psi (%)	98

Post-test review focused on the filtercake formation. The original testing used the traditional 500 psi overbalance for 4 hours. The return permeability test required 1000 psi overbalance for 16 hours.

The high overbalance scenario likely resulted in additional filtercake compaction, which can require further bridging optimization beyond what is observed on aloxite media.

For a repeat test, the breaker was allowed to soak for a total of 4 days, which allowed the chemistry more time to act on the filtercake materials. This resulted in a return permeability of 72%.



Figure 7- Core plug after return permeability test showing filtercake not dissolved after a 2-day breaker soak.

Table 4- 10.6 lb. /gal Chelant-Base Breaker Return Permeability Results

Test Properties	
Temperature (°F)	169
Net Confining Pressure (psi)	500
System (pore) Pressure (psi)	500
Core Properties	
<b>Berea Core</b>	
Diameter (in)	1.49
Formation Fluids Used	
Simulated Produced fluid	Mineral Oil
Simulated Formation water	10% NaCl Brine
Mud off Parameters	
Net Overbalance	1000
RDF Exposure Time (Hours)	16
Total Filtrate collected during Mud off Period (mL)	12
Breaker Soaking Parameters	
Soaking Period (days)	2
Proppant carrier fluid	10.6 lb./gal Breaker
Proppant size	20/40
Net overbalance Pressure (psi)	100
Breaker Invasion after Breakthrough	Yes
Test Results	
% Return	51.7
Flow initiation Pressure (psi)	5.5

### Case#2- Good Cleanup and Low Return Permeability

Another biopolymer free RDF system was designed to drill a high pressure and less consolidated oil reservoir and a chelant-base breaker was selected to completely dissolve the RDF filtercake after gravel pack operations.

The breaker candidate for the return permeability test was selected based on flowback results shown in **Table 5** and **Figure 8**.

The return permeability test was run using the actual reservoir core plug (unconsolidated sand formation) and showed complete filtercake cleanup, but an unacceptably low return permeability of 20.8 % (**Figures 9** and **10** and **Table 6**).

The analysis of return permeability test results led to the conclusion that the main cause of poor permeability obtained after the 4-day breaker soak was water blocking caused by breaker invasion after breakthrough occurred. An increase in

permeability was observed after centrifuging the core, thus confirming that the decrease in permeability was caused by the change in brine saturation of the core (relative permeability effect). The invasion of the high-density breaker-base brine into the core induced some fines migration and restricted the total recovery of the initial permeability.

Since the customer requested to observe the breakthrough occurrence, the formation side valve was open during the breaker soak. After breakthrough, leak off was allowed to continue throughout the test. This resulted in the injection of excess volume of fluid. In a well scenario, extended leakoff is not expected as overbalance is relieved when the reservoir is isolated with a mechanical fluid loss control device.

The effect of saturation change on return permeability is higher for gas reservoir compared to oil reservoirs.

As suggested previously, the breaker soak must be done with minimal overbalance pressure (50-100psi) and the formation side valve closed to minimize breaker invasion into the core in order to simulate the actual well scenario.

Table 5- 15.5 lb. /gal Chelant-Base Breaker Flowback Assessment Results

Flowback Data	
HTHP Filtration	
Aloxite Disk	FAO-05
Temperature (°F)	200
Overbalance (psi)	500
Time (Hours)	4
Total filtrate (mL)	11.2
Breaker Soak	
Proppant size	20/40
Volume of Breaker (mL)	80
Breakthrough time (Hour)	4
Soak time (Days)	5
Flowback Results	
Flow initiation Pressure (psi)	1
Return to Flow at 5 psi (%)	83



Figure 8- Aloxite disk after a 5-day break soak; no filtercake residue left on the disk.



Figure 9- Core plug after return permeability test showing filtercake completely dissolved after 4 days breaker soak.



Figure 10- Core plug –Proppant removed

Table 6- 15.5 lb. /gal Chelant-Base Breaker Return Permeability Results

Test Properties	
Temperature (°F)	165
Net Confining Pressure (psi)	500
System (pore) Pressure (psi)	500
Core Properties	Formation Core
Diameter (in)	1.50
Formation Fluids Used	
Simulated Produced fluid	Mineral Oil
Simulated Formation water	10% NaCl Brine
Mud off Parameters	
Overbalance Pressure (psi)	1000
RDF Exposure Time (Hours)	16
Breaker Soaking Parameters	
Soaking Period (days)	4
Proppant carrier fluid	15.0 ppg CaBr <sub>2</sub> /ZnBr <sub>2</sub> Brine
Overbalance Pressure (psi)	500
Breaker Invasion	Yes
Test Results	
% Return	20.8
% Return (after centrifuge)	69.1
Flow initiation Pressure (psi)	1.7

### Case #3-Good cleanup and High Return Permeability

A reversible oil base mud system was proposed for a high temperature gas field development and a chelant-base breaker was designed to dissolve the RDF filtercake while minimizing corrosion post-grave pack operations.

Flowback results are shown on **Table 7** and **Figure 11**.

During the return permeability test, the breaker volume was refreshed to ensure the filtercake reaction with the volume of breaker equivalent to the one used during flowback test breaker soak. Invasion of the breaker into the core was minimized by soaking the breaker without overbalance pressure and with the formation side valve closed.

The return permeability test results show good filtercake removal, and over 100% return to flow with minimal corrosion after a 7-day soak at 280°F (**Table 8** and **Figure 12**).

Table 7- 10 lb. /gal Chelant-Base Breaker Flowback Assessment Results

Flowback Data	
HPHT Filtration	
Aloxite Disk	FAO-05
Temperature (°F)	280
Overbalance (psi)	250
Time (Hours)	16
Total filtrate (mL)	6.8
Breaker Soak	
Proppant size	20/40
Volume of Breaker (mL)	80
Breakthrough time (Hour)	6
Soak time (Days)	6
Flowback Results	
Flow initiation Pressure (psi)	1
Return to Flow at 10 psi (%)	88.4

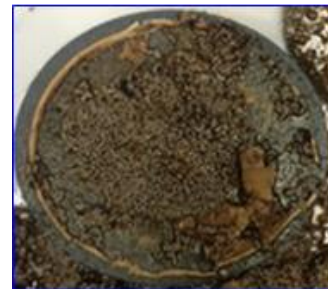


Figure 11- Aloxite disk after 6 days break soak (minimal filtercake residue left on the disk)

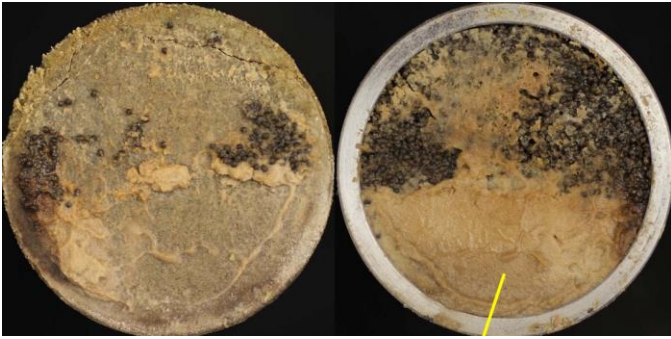


Figure 12- Core plug after return permeability test showing minimal filtercake residue after 7-day breaker soak.

Table 8- 10 lb. /gal Chelant-Base Breaker Return Permeability Results

Test Properties	
Temperature (°F)	280
Net Confining Pressure (psi)	2800
System (pore) Pressure (psi)	500
Core Properties	Berea Core
Diameter (in)	1.50
Formation Fluids Used	
Simulated Produced fluid	Humidified Nitrogen
Simulated Formation water	10% NaCl Brine
Mud off Parameters	
Overbalance Pressure (psi)	250
RDF Exposure Time (Hours)	16
Total Filtrate collected during Mud off Period (mL)	5
Breaker Soaking Parameters	
Soaking Period (days)	7
Proppant carrier fluid	Chelant-base Breaker
Overbalance	0
Breaker Invasion	Minimal
Test Results	
% Return	100+

## Conclusions

A successful breaker evaluation through return permeability testing is a result of both breaker chemistry selection and appropriate testing procedures.

Experience has shown that failure to observe key details may result in unexpected results that require expensive retests or redesign based upon test artifacts.

Return permeability apparatus have limitations on volumes, circulating paths and flow rates. Breaker test volume, soak time and overbalance pressure may have dramatic effects on test results. Careful thought is required to match test conditions to realistic downhole conditions.

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