



Delayed Breakers for Horizontal Well Cleanup

Brad Todd and Ron Powell, Halliburton Energy Services, Inc.

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Abstract

Many high-permeability, soft sandstone formations are completed with horizontal wellbores. In these formations, completions are typically openhole with screens or screens combined with gravel packs. The drill-in fluid filter cake is left in place until after the completion operations are finished.

A need exists for cleanup solutions that have a delayed effect on filter-cake integrity, allowing the cleanup solution to be circulated across the interval before leakoff to the formation becomes a problem. If a sufficient delay is possible, the breaker solution can be placed with a gravel pack. Break times for this situation would range from 4 to 24 hours, depending on the need for fluid-loss control during subsequent pipe trips. Oxidizers (or oxidizers plus a catalyst) used at the lower end of their active temperature range can achieve break-time delays in this range.

Introduction

A horizontal wellbore placed in a high-permeability sandstone formation can have a high production potential, even when completed under less-than-ideal conditions.^{1,2} Horizontal wells can also be used to access remote reserves and to reduce water or gas coning.³ Recently, these types of completions have helped limit the number of wells necessary for economically developing deepwater prospects.^{4,5} However, realizing the full potential of horizontal well completions has been difficult because of mechanical failures and impaired production.¹⁻¹⁶ A critical factor cited in many of the references is the need to uniformly remove the drill-in fluid filter cake from the entire completion interval.^{1-3,10,15}

High-permeability, soft sandstone formations generally require some form of sandface barrier, either for hole stability or for preventing sand production. The majority of earlier completions were performed with stand-alone screens in the open hole. However, the high number of mechanical failures with this type of completion prompted the industry to view gravel packing as a means of improving the overall reliability of the completion.^{4,13} An intact filter cake is necessary for

properly installing sand-control equipment and placing gravel. Once the gravel pack is in place, the filter cake is removed with a post-completion cleanup treatment, which is generally delivered through coiled tubing. A typical treatment consists of an acid, chelating agent, oxidizer or enzyme, or a combination of these materials. When the treatment is properly placed, it can effectively degrade the filter cake. As currently applied, all of these materials can be highly reactive at downhole conditions and difficult to place across the entire interval before high losses are incurred. This problem is especially true for acid and chelating agents used for removing the calcium carbonate bridging particles. Hydrochloric acid reacts with calcium carbonate almost instantaneously, and chelating agents such as EDTA salts can remove the calcium carbonate particles from a filter cake in minutes.

Ideally, the reaction with the filter cake would be delayed

- a minimum of 1 to 2 hours to allow placement of the treatment across the interval,
- 2 to 8 hours to allow the treatment to be included with a gravel pack,
- or 8 to 24 hours to provide a margin of safety and help control fluid loss during subsequent pipe trips.

Delayed Breaks with Oxidizers

To achieve the necessary break delay with oxidizing breakers, use one of the following guidelines:

- Use an oxidizer that has very low activity at the applicable temperature.
- Use an oxidizer combined with a catalyst to extend the oxidizer's useful temperature range.

All oxidizers decompose over time. As an oxidizer decomposes, oxygen, hydrogen peroxide, or free radicals can be produced. For example, when sodium persulfate decomposes, two sulfate radicals are produced. These radicals begin a chain reaction that eventually results in the degradation of a polymer molecule when applied as a gel breaker.

*Halliburton Best Practices Series, *Fracturing Fluid Breakers*, (1995).

The time that is required for reducing the active oxidizer concentration to half the original concentration is referred to as the oxidizers half-life, which varies according to temperature. An oxidizers's half-life at 200°F may only be a matter of minutes, but the half-life value at room temperature could be weeks. The half-life values of various breakers have been previously reported.¹⁷

Although, there is no direct relationship between the half-life value and the break time of a filter cake, the half-life value can be used as a relative indication of how the breaker will behave. For example, sodium persulfate has a half-life of only a few minutes at 200°F, and would certainly be too reactive for use as a delayed breaker. For a delayed break in horizontal well cleanup, a half-life of a few days at the applicable temperature would be advantageous.

It may be tempting to create a delayed break by significantly reducing the oxidizer concentration. However, this practice should be avoided, since small changes in chemistry and test conditions can cause large changes in the break results. The new approach offered here allows the use of moderate breaker loadings that are less susceptible to small formulation changes. In addition, an oxygen scavenger/reducing agent or free radical scavenger could be included in the breaker solution to provide additional control over the break time. Although this technique may seem counterproductive (mixing a reducing agent and an oxidizing agent), it has long been used successfully in fracturing to provide controlled viscosity reduction to fracturing gels.

Testing

Conducting delayed-breaker testing depends on the following:

- repeatable and uniform filter-cakes on which to test
- continuous monitoring and recording of the filtrate rate with time

A computer-controlled dynamic filtration system (DFS) (**Fig. 1**) was adapted for the delayed breaker testing. (More detail on the use of this device for delayed breaker testing will be published in the near future.) This system deposits a filter cake on the internal surface of a cylindrical filter (**Fig. 2**) when a differential pressure is applied. The filter medium is a porous ceramic material, available in several pore sizes (permeability). A shear shaft is centered within the filter and rotated to provide a uniform and known amount of shear across the filter surface. The internal pressure applied to the fluid, the differential pressure applied across the filter, the shear rate, and the temperature are all programmable in up to 20 separate steps for developing and conditioning the filter cake.¹⁸⁻²¹

Performing delayed-breaker testing requires the formation of several filter cakes with the same thickness and properties. The DFS is capable of making the necessary cakes, and its data-acquisition function allows the comparison of the filtrate profile from separate runs. The filtrate profile is the curve of the filtrate versus time during dynamic filtration and cake deposition (**Fig. 3**). When the same drilling fluid recipe is used, the filtrate profile should match. The slope of the curve at the latter part of the test indicates the thickness and permeability of the filter cake when the same viscosity fluid is used under the same differential pressure.

When the filter cake is formed, the excess drilling fluid is removed and the cell is loaded with the breaker solution. The device is reprogrammed with a sequence of timed steps in which the internal pressure, differential pressure, shear, and temperature are applied as required by the application. Until a break occurs, the filtrate rate of the breaker solution through the filter cake is constant. An increase in the filtrate rate indicates a break.

Filter cakes were formed from a typical xanthan/starch/calcium carbonate drill-in fluid. Breaker solutions were prepared in a sodium chloride (NaCl) brine. **Fig. 4** shows the break profile for Oxidizer 1/Catalyst 1 at the various concentrations. These tests were conducted at 132°F for a recent project where a breaker was desired in the gravel-pack carrier fluid. Once a breaker concentration was chosen, the effect of wellbore cooldown during the gravel-pack treatment was investigated (**Fig. 5**). Three tests were performed at 125°F and 132°F, with good agreement in break times. **Fig. 6** shows the results at two of the breaker concentrations in which the effect of pH was tested.

Fig. 7 shows the break profile for Oxidizer 2/Catalyst 2a/Catalyst 2b at 150°F in various concentrations. **Fig. 8** shows the break profile for Oxidizer 2/Catalyst 2b, with and without Catalyst 2a. Although not shown in the figure, no break occurred when both of the catalysts were left out of the breaker solution. The effect of cooldown can be seen in **Fig. 9**.

Fig. 10 shows the break profile for Oxidizer 3 at 180°F in various concentrations. At this temperature, no catalyst was necessary for breaking down the filter cake.

As is evident from these results, using an oxidizer or oxidizer/catalyst with low activity at the applicable temperature can produce delayed breaks useful for drill-in fluid filter-cake cleanup in horizontal wells. Extended breaks longer than those given here are possible when the effects of cooldown, breaker concentration, and catalyst concentration are combined for maximum delay.

Conclusions

- The half-life of an oxidizing breaker can be used for determining the reduced activity at the given temperature.
- Using an oxidizer at the lower end of its active temperature range can result in delayed filter-cake breaks.
- The cooldown period during treatment pumping can provide an additional break delay.
- Catalysts can be used to extend an oxidizer's useful temperature range below those temperatures possible with the breaker alone.

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Figures



Fig. 1- Dynamic filtration system (DFS)

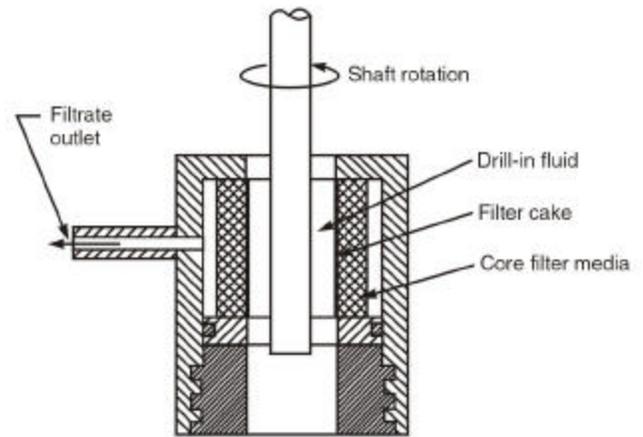


Fig. 2- Core filter media holder.

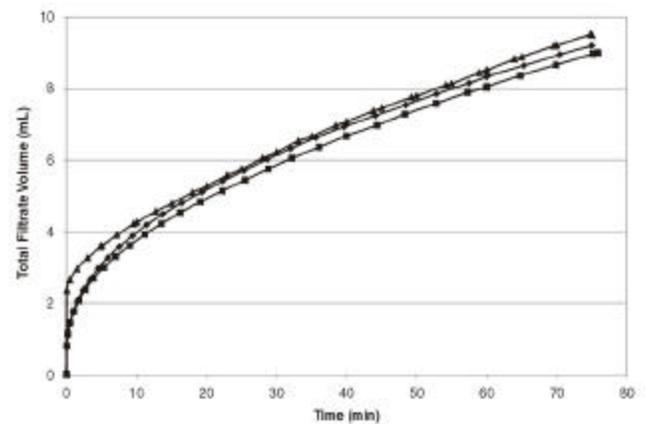


Fig. 3- Total filtration comparison, dynamic cake deposition.

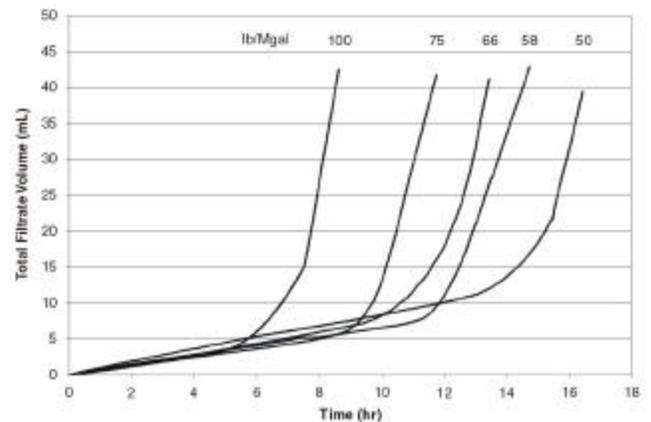


Fig. 4 Filter-cake break time with Oxidizer 1 Catalyst 1 in DFS versus breaker concentration (132°F, 50-psi differential pressure).

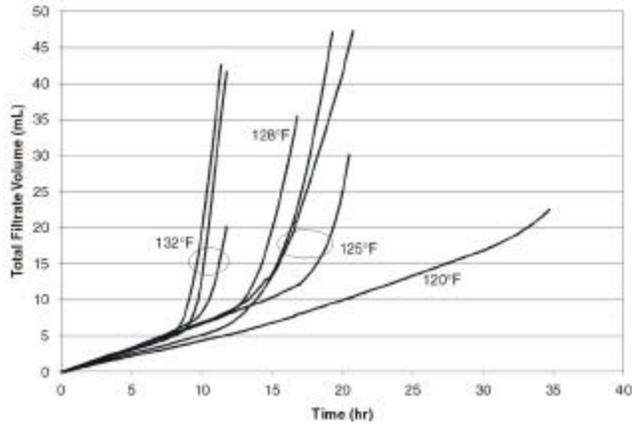


Fig. 5 Filter-cake break time with Oxidizer 1/ Catalyst 1 in DFS versus temperature (50-psi differential pressure).

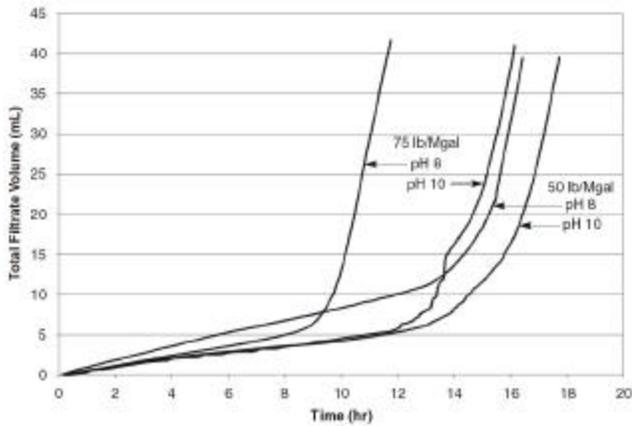


Fig. 6 Filter-cake break time with Oxidizer 1/ Catalyst 1 in DFS versus pH (132°F, 50-psi differential pressure).

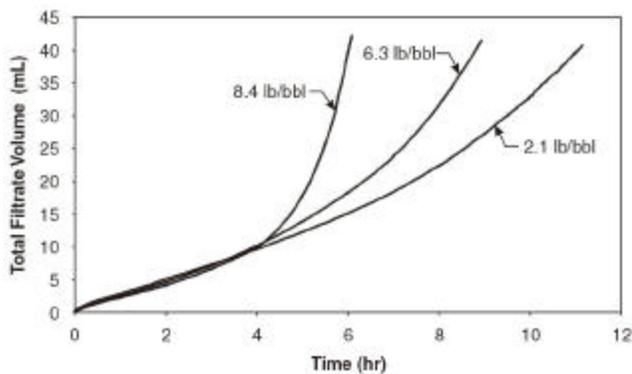


Fig. 7 Filter-cake break time with Oxidizer 2/ Catalyst 2a+2b versus concentration (150°F, 50-psi differential pressure).

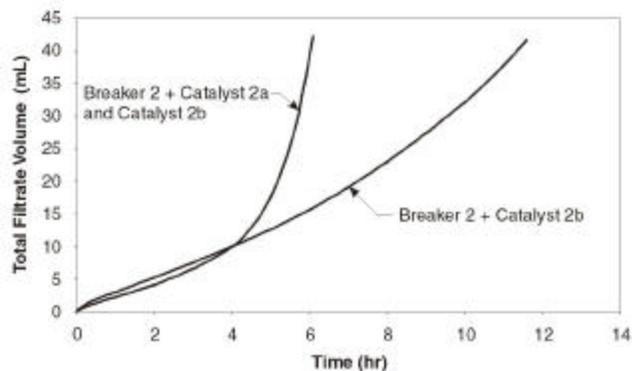


Fig. 8 Filter-cake break time with Oxidizer 2 showing the effect of catalyst (150°F, 50-psi differential pressure).

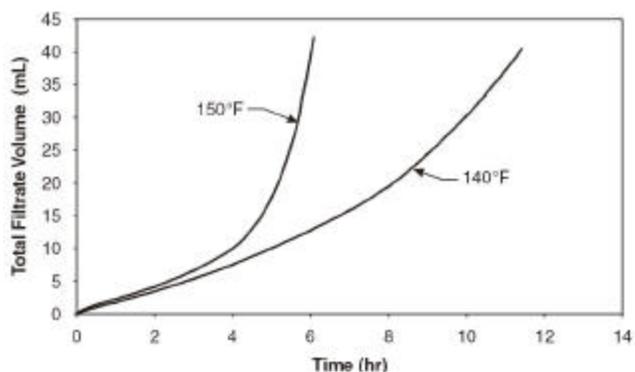


Fig. 9 Filter-cake break time with Oxidizer 2/ Catalyst 2a+2b versus temperature (50-psi differential pressure, 8.4 lb/bbl concentration).

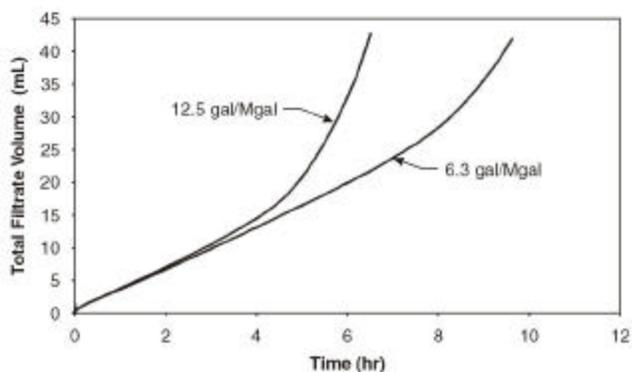


Fig. 10- Filter-cake break time with Oxidizer 3 versus concentration (180°F, 50-psi differential pressure).