CRITERIA FOR SCALE INHIBITOR APPLICATIONS IN HYDRAULIC FRACTURING TREATMENTS

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As the price of energy and services increases, even greater attention will be focused on all aspects of scale deposition. The detrimental impact of scale deposition continues to compel the industry to develop new technologies and innovations in scale control and prevention. One area where this has been especially challenging is in hydraulic fracturing treatments. As well completions and fracturing treatments increase in cost, size, and complexity, the demand for cost effective scale control has increased accordingly. Potential scale deposition problems need to be evaluated and strategies for prevention and control need to be planned before the well is completed and stimulated. Previous papers have addressed new products, technologies, and applications, but few have provided a process for scale inhibitor design in hydraulic fracturing treatments. This paper will attempt to provide criterion for planning and design of these scale inhibitor applications by addressing inhibitor selection, placement, loading, and experience.

INTRODUCTION

The use and need for scale inhibitors in hydraulic fracturing treatments have increased with oil industry activity. Technological advances in scale inhibitors and applications have eliminated some of the detrimental effects caused by scale inhibitors added to fracture systems in the past. These advances have made these applications more economically viable and advantageous over scale inhibitor squeeze treatments, continuous treatments, and other scale inhibitor applications. There are obvious advantages of adding scale inhibitor into fracturing treatments, such as scale prevention throughout the fracture, reduction of well intervention, better control of inhibitor placement, and increased oil production.

All new technologies and new applications require a period of time to test, implement, and evaluate their performance and viability. Such is the case with scale inhibitor applications in hydraulic fracturing treatments. With time and experience, more studies and information will become available to help establish industry guidelines and standards for these inhibitor applications. This paper is an initial attempt to provide criterion for planning and design of these scale inhibitor applications by addressing inhibitor selection, placement, loading, and experience.

SCALE INHIBITOR SELECTION

There are a variety of scale inhibitors traditionally used in the oilfield for the prevention of scale. In general, scale inhibitors are classified into three groups; phosphoric acid esters, phosphonates, or polymers. These inhibitors can be applied in various forms such as liquids, solids, encapsulated liquids, impregnated proppants and impregnated substrates. When selecting an inhibitor to be applied in a hydraulic fracturing treatment, it is critical that specific criteria be met for that specific frac design. The following will list the most common criteria for product selection with a brief explanation and considerations.

Frac System Compatibility

The first and most important step in the selection process is to determine what inhibitors will be compatible with the frac fluids to be used to fracture the well. Whether it is slick water frac fluids, cross-linked gel frac fluids, or any other frac fluid system, very few scale inhibitors will be compatible. Although some inhibitors may initially appear to be compatible with a frac system, details of the frac system and job design must be thoroughly examined to ensure that the product is compatible with all fluids to be used at all pump rates and pump stages. It should also be noted that some scale inhibitors have proven to be beneficial to certain frac systems because of the poor water quality of the frac water.

Water Compatibility

Another criteria, is the scale inhibitor compatibility with the formation water. Some scale inhibitors can be limited by the physical and mineral characteristics of the water to be treated. Many scale inhibitors are limited by the composition of water such as water hardness, iron levels, and total dissolved solids in the water. Also, the TDS of the water can be a key factor in the dissolution rate of solid or encapsulated inhibitors.

Formation Temperature

The formation temperature can limit the choices of scale inhibitors. Usually, high formation temperatures (greater than 280^{o}F) can only be treated with polymer inhibitors. Just like the TDS of the water, temperature can be a key factor in the dissolution rate of solid or encapsulated inhibitors.

Scale Inhibitor Longevity

The last phase of the selection process will be to evaluate the inhibitors based on a desired longevity and cost effectiveness. The life or longevity of the scale inhibitor will be determined by inhibitor placement, quantity of inhibitor, minimum effective concentration of inhibitor, reservoir conditions, and water production of the well.

SCALE INHIBITOR PLACEMENT

The design of the scale inhibitor placement in the frac job is critical to achieve the effectiveness and duration of the inhibition treatment. The scale inhibitor must be present in the water before the scale precipitation or deposition begins. This section will list several placement methods and give a brief explanation and considerations of each technique.

Spearhead or BullHead

The conventional spearhead or bullhead method is applied by placing a liquid scale inhibitor into a pre-pad ahead of the frac fluid and can be repeated and applied to multiple intervals if necessary. This technique is a non-selective process that allows very little control of placement and provides very little inhibition, if any, into the fracture and proppant pack. Most of the scale inhibitor will be lost to the immediate formation face due to fluid leak-off. This method is not effective if scale deposition is occurring in the fracture. The inhibitor is also susceptible to very high initial rates of return and thus a shorter duration or life. Another concern with this method is compatibility problems with the frac fluids. It is not always the case that separating incompatible scale inhibitors with a pad of fluid will prevent any detrimental effects to the frac system. On the contrary, it is not uncommon for frac jobs to be adversely affected using this technique.

Scale Inhibitor Placement Throughout the Frac Fluid (Liquid Inhibitor)

This method is applied by pumping a liquid scale inhibitor at a designed concentration continuously or "on the fly" with the frac fluid. This technique provides scale protection over the full fracture and proppant pack. Usually the inhibitor will have a high initial rate of return and quickly drop off to a relatively steady return rate much like a scale squeeze. This method usually requires a polymer scale inhibitor, which can cause concerns with monitoring of the scale inhibitor residuals. Scale inhibitor residuals from polymers can be difficult to accurately measure in low concentrations, but generally have a very low minimum effective concentration. This makes it extremely difficult to determine when the product has dropped below the minimum effective concentration and reached the end of its life.

Scale Inhibitor Placement Throughout the Proppant Pack (Solid Inhibitor)

Solid scale inhibitors come in various forms such as solid particles of inhibitor, impregnated proppant, or impregnated substrates. This method is applied by adding solid scale inhibitor at a designed concentration to the proppant as it is pumped. This technique also provides scale protection over the full fracture and proppant pack. This design and technique is frequently used to increase the longevity of scale inhibition or is the only means of maintaining compatibility between the inhibitor and a particular frac system. This method tends to be the easiest to monitor the scale residuals over an extended period of time.

Backloading of Scale Inhibitor

This technique is generally used when scale deposition is only occurring in the near well bore, pump, or tubulars. In this application, the scale inhibitor (liquid or solid) is applied with the frac fluid or proppant at a designed concentration in the last stages of the frac for each pay interval. This is mostly used on wells with multiple completions. Multiple completions present a variety of problems and concerns in scale prevention. It is impossible to determine water production from each zone and often times different zones produce at different time intervals. This creates a major concern with the monitoring and evaluation of the scale inhibitor treatment.

SCALE INHIBITOR LOADING

The design of the scale inhibitor loading or concentration is also critical to achieving the desired effectiveness and duration of the scale inhibition treatment. This section will present the main criteria for scale inhibitor loading and give a brief explanation and considerations for each.

Compatibility

As mentioned in the scale inhibitor selection process, each loading or concentration of the selected inhibitor must be reviewed to ensure that there is no compatibility issue at any time during the fracturing process. The solid scale inhibitor loading should be evaluated based on frac fluid volume and proppant volume.

Equipment

Equipment availability should also be considered in the design process. Some inhibitors such as solid materials may require special pumping equipment to apply the scale inhibitor properly.

Scale Inhibitor Longevity

The longevity of the scale inhibitor application is directly related to the quantity of scale inhibitor placed in the fracturing treatment and the water production of the well. Estimating and planning for a specific range of water production will be necessary to determine the inhibitor loading. It appears that the best long-term scale inhibition is achieved with solid scale inhibitor applications. Each scale inhibitor and application will have its own "point of diminishing return", that is the point where the cost exceeds the economic benefit. At this time, only job experience and case studies can help determine guidelines for optimum loading.

EXPERIENCE

Since there is very little published data and design criteria for scale inhibition design for hydraulic fracturing treatments; lab research, industry guidelines, job experience and case studies were used to establish design criterion outlined in this paper. After two years of monitoring and evaluating performance of various designs, this design process has proven to be beneficial to improving performance and new application designs. Because of the number of different fracturing systems and fracturing designs, not all criterion and considerations could be mentioned in this paper.

CONCLUSIONS AND RECOMMENDATIONS

1. Scale inhibitor applications in hydraulic fracturing treatments should be designed to provide effective scale prevention without any detrimental effects to the fracturing system or the fracturing process.
2. The scale inhibitor selected should be compatible with the frac system, formation water, and stable under reservoir conditions.
3. Scale inhibitor placement should be designed to address scaling potential and provide minimum effective concentrations of the scale inhibitor for a specific time frame.
4. Scale inhibitor loading should maintain compatibility with frac system and provide minimum effective concentrations of the scale inhibitor for a specific time frame.
5. Specific design criteria should be followed to minimize potential problems and establish benchmarks for future designs.
6. Monitoring of scale inhibitor and well performance is essential to improving design and developing new applications.

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