DETERMINATION OF EFFECTIVE PROPPANT DISTRIBUTION AFTER FRACTURING USING MULTIPLE GAMMA RAY TRACERS

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A significant application of multiple tracers is their use in tracing different proppant concentration stages and/or types of proppant to determine their effective wellbore distribution at the fracture entrance. Extensive heterogeneous formations with large fracture intervals containing multiple perforated intervals or hydraulic fracture treatments that utilize the limited entry technique provide one of the best opportunities for using multiple tracers to evaluate proppant distribution.

Historically, single isotope tracers (usually Iridium baked or painted onto frac sand) and conventional gamma ray - temperature logs were employed to ascertain fluid and/or propped fracture height at the wellbore.[1] Deviated wellbores or fractures whose azimuth was not vertical caused this analysis technique to yield a lower boundary on fracture height since the full extent of the induced fracture may occur outside the depth of investigation of the scintillation tool being used. Over the last several years, the use of multiple gamma ray tracers in conjunction with advanced gamma ray spectroscopy logging methods has undergone significant evolution and improvement. One of the principal advances is software to differentiate up to four isotopes and their presence inside or outside the wellbore.

Much research has been devoted to the development of radioactive particles which exhibit insignificant tracer washoff and offer superior representation of the transport and placement of the medium they are intended to trace. With the single tracer, after-frac gamma ray log approach, if some or most of the radioactive material "washes off" of the tagged proppant and becomes dissolved in the fracturing fluid, there was little reason to despair. With the recent advances in gamma spectroscopy tracer logging where both particle and soluble tracers are injected simultaneously with the intent of differentiating fluid and proppant placement and distribution, this washoff of radioactive material from the tagged proppant has become the subject of great concern. Certainly, the discrimination of propped and induced fracture height becomes impossible if this washoff is significant. Today, proppant tracers are currently available which exhibit absolutely no radioactive washoff and have virtually the same particle size, density, and crush resistance as the proppants. For the application of studying proppant distribution, superior tracers and advanced gamma spectroscopy logging methods are both needed and required.

How effectively high versus low proppant concentrations are distributed across the gross fracture interval, points of entry at the wellbore, and the effective or ineffective distribution of proppant tail-ins of resin coated proppants, intermediate density proppants or different size proppants is the primary focus of this paper. Examples of actual gamma spectroscopy logs will be used to illustrate how multiple isotopes aid in fracture treatment quality assurance downhole. Examples illustrating multi-tracer evaluations of zone coverage using so-called perfect support fluids, different size and type proppant in single or multiple stages, and proppant settling will be highlighted. Evidence of inconsistent coverage of perforated intervals will also be shown. These examples corroborate the work that has been done showing proppant slurry transport is less than predictable even when today's best fluid technology is used.

Many hydraulic fracture stimulation treatments today involve fracturing with multiple type proppants and/or involve placing high concentrations of proppant across and into predefined intervals of potentially productive reservoirs. Often screenouts occur and a single isotope placed in both liquid and proppant portions of the treatment simply showed that the entire interval was being treated at the time of screenouts. This result was challenged after several treatments involving curable resin coated proppants failed to prevent the non-resin coated proppant from being flowed back. Resin coated proppant is placed within the near wellbore fracture system to lock the non-resin coated proppant in place and prevent it from flowing back. Separate studies showed that this was probably not due to ineffective performance by the resin coated proppant, but rather to the ineffective placement of same over the entire zone that was fractured.[2,3] This non-uniform distribution meant that the portion of the interval where curable resin coated proppant was not placed or did not enter, would not have the protection against flowback, or the higher strength properties of the curable resin coated proppant uniformly distributed. This question raised the issue that distribution problems existed and were not only related to curable resin coated proppants, but could occur with any later stage, or higher concentration proppant stage that would be pumped. The problem was quickly related to proppant transportation in the fracture. Several resin coated treatments were performed where the curable resin coated proppant was tagged with a different isotope from that used on the primary proppant, and it was frequently found that in fact the resin coated (or as the case may be, highest prop concentration) stage was not being pumped into the same portion of the fracture interval as the early proppant. Subsequently, several jobs were traced where multiple isotopes were placed in the proppant stages and proppant entry points and distribution evaluated. Results of these evaluations are included in the case history section of this paper.

In treatments that are single stage or limited entry type fracturing treatments the proppant quantities and the fluid systems for transporting them are designed to incorporate gamma emitting tracers spaced so as to adequately evaluate the uniform or non-uniform distribution of the treatment over the target interval.

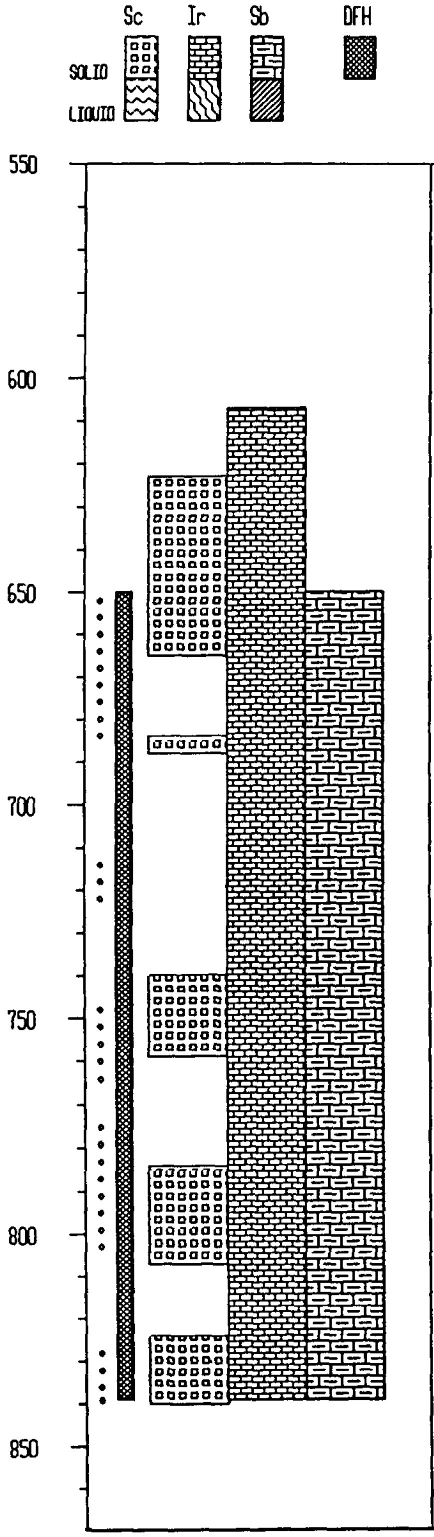
This application of tracers can involve up to four different tracers added to pre-selected portions of the slurry, although the more common method is to use two different tracers in the proppant. The determination of which stages each isotope is to be placed into is made by prior analysis of the fracturing tendency for any particular reservoir. In an area where frequent or numerous screenouts have occurred at some particular concentration point within the treatment, switching to a different isotope should occur just prior to that point, with enough lead volume to anticipate tubular volume pumping lag time. This will allow the different tracer to get distributed well enough to show where that proppant stage was entering the fracture interval, in case a screenout does occur. Multiple gamma ray spectroscopy logs run subsequent to this type of treatment can identify the distribution problem and limits, and efforts can be made to remedy the next stages or future job design. The reasons for poor and inadequate fluid and proppant distribution may then be linked to improper perforation placement or technique, ineffective fracturing fluid rheology or insufficient stages of early proppant concentrations.

Obviously, the larger the interval, number of perforations or size of the treatment, the more beneficial will be the use of multiple tracers for obtaining the information. Usually two tracers are used to document distribution problems by including the first tracer in all but the last stage or in those stages that are deemed to be potential distribution problem candidates. Confirmation of uniform proppant placement and effective fluid rheology necessary for uniform placement can be made by logging the interval via a multiple gamma spectroscopy log and the history of zone coverage mapped to show where various concentrations of slurry entered the interval. This is possible thanks to some tracer material continuing to be deposited or built up over the interval as long as treatment is entering that particular portion of the zone. This is why it is imperative that the entire portion of the proppant laden system be tagged uniformly as possible.

Case Histories

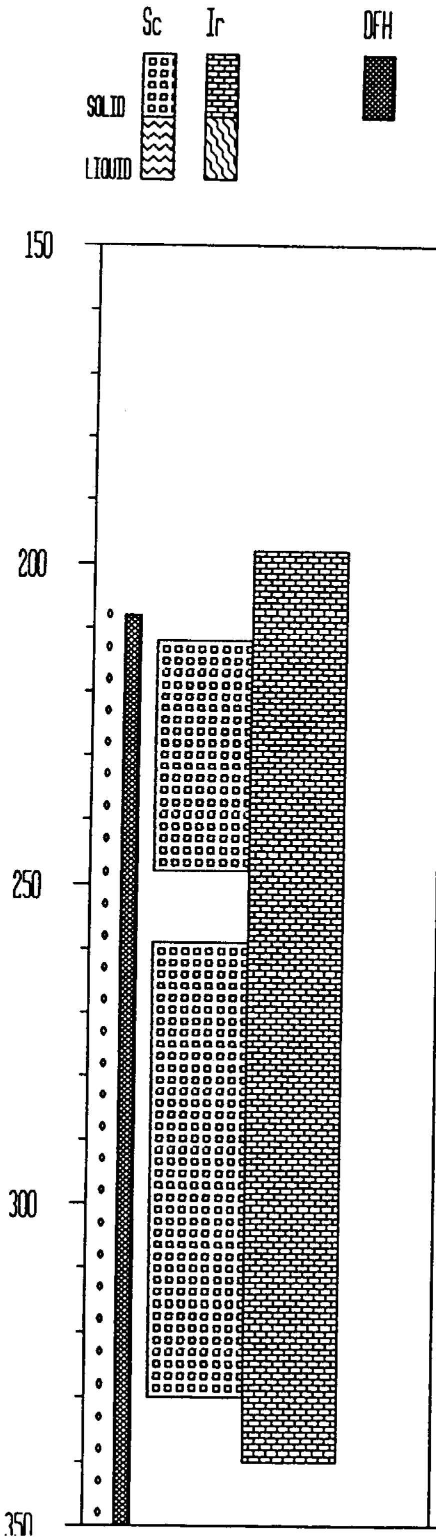
Multi gamma ray spectroscopy logs are run to differentiate the presence and location of gamma emitting tracers. These type logs are presented in a number of different treatment scenarios in straight to slightly deviated wellbores to demonstrate how tracers are used to evaluate effective proppant distribution.

Case History No. 1



ISOTOPES	CASE DESCRIPTION
DFH - DESIGN FRAC HEIGHT Sb (WSL) - Pad Only Ir (ECP) - 1.0 - 5.0 PPG SAND STAGES Sc (ECP) - 6.0 - 7.5 PPG SAND STAGES	Three gamma emitting isotopes were used during a deep, Texas, Devonian stimulation treatment to evaluate fracture parameters, proppant placement and proppant distribution at the wellbore. Gamma spectroscopy shows one induced fracture was created during the treatment and proppant transport was such that the fracture conductivity, near wellbore, is variable. The Iridium traced sand entered the fracture at some point during the 1.0 to 5.0 ppg sand stages. The Scandium traced sand, 6.0 to 7.5 ppg, only entered the intervals shown on the vertical bar graph. The proppant distribution profile clearly shows sections of the induced fracture bridged or screened out at some point during the fracture treatment. The Antimony tracer was pumped in liquid form and only in the pad fluid. It shows that during pad the fracture appears to be confined to the perforated interval. A comparison of the early Antimony to Iridium or Scandium, clearly shows the induced fracture was still growing (upward) at the end of pad. A fracture barrier appears to be present at the bottom of the fracture.

Case History No. 2



ISOTOPES

DFH - Perf Interval

Ir (ECP) - 1.0-13.0 PPG 20/40 SAND

Sc (ECP) - 13.0 PPG RESIN COATED

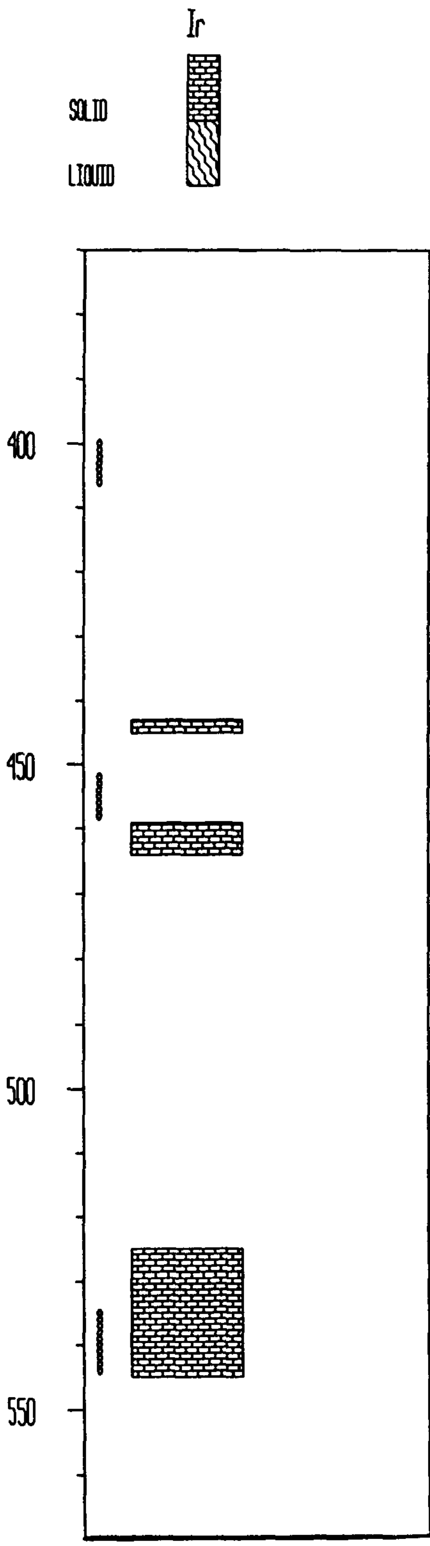
TAGGED SAND

CASE DESCRIPTION

Two gamma emitting isotopes were used during a Van Zandt county, Austin Chalk stimulation treatment to evaluate proppant placement and proppant distribution at the wellbore.

Gamma spectroscopy shows the 20/40 Iridium traced sand entered the induced fracture, if not throughout its entirety, at some point during the 1.0 - 13.0 ppg sand stages. The 13 ppg resin coated sand entered only in the intervals specified on the vertical bar graph. The resulting proppant distribution profile shows that sections of the induced fracture, for whatever reason, bridged or screened off at some point in the fracture treatment and only permitted the 13 ppg resin coated sand to be placed in the sections indicated.

Case History No. 3



ISOTOPES

Ir (ECP) - All Sand

CASE DESCRIPTION

One gamma emitting isotope was used during a South Texas, lower Asche stimulation treatment to evaluate proppant placement at the wellbore.

Gamma spectroscopy shows the Iridium traced proppant never entered and was therefore not placed adjacent the upper perforated interval. The proppant profile for the middle perforated interval shows some proppant trapped above while most settled below the perforations. The lower perforated interval shows proppant distributed across the perforated interval.

Clearly, the well was not successfully fracture treated. Niether the upper or middle perforated intervals have an established, highly conductive pathway connecting the formation to the wellbore.

Summary and Conclusions

1. Multiple gamma emitting tracers can be used to effectively document and record perforated interval coverage by tracing changing proppant concentrations or types during the course of a hydraulic fracturing treatment.

2. By using multiple tracer tagged proppant stages it can be inferred that distribution of those concentrations is either adequate or inadequate, and potential adjustments in fracturing fluid rheology design may be necessary to improve distribution efficiency.

3. Placing a tracer in the tail-in stage qualitatively shows whether or not the tail-in proppant was adequately distributed and placed at the wellbore as intended.

4. Multiple tracers used in both fluids and proppant can provide information as to where within the designed treatment sequence, screenouts are occurring. This allows the design to be re-evaluated to account for and anticipate the problem by running larger pad volumes or changing the volumes and quantities of proppant in respective stages to more effectively permit uniform treatment distribution.

5. Fluid rheology and slurry rheology studies have indicated that proppant transport may vary directly with the type of fluid system pumped within a specific range of temperature, pressure, and rate considerations. Many crosslinked systems used today have been shown to have significant proppant settling rates which promote non-uniform distribution of proppant stages. Specifically, the latter stages tend to enter perforations on top of the previous stages which have formed a concentrated proppant bank toward the bottom of the fracture.

6. Reservoir characteristics, specifically rock strength properties and stresses within and surrounding specific portions of pay intervals are primary controls that may affect how treatments are distributed over intervals identified on gamma ray neutron logs as being potential fracture zones. Gamma spectroscopy logs need to be incorporated into and compared to predictions made by long spaced sonic logs made prior to the treatment.

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References

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