SPE-189900-MS

Diversion Optimization in New Well Completions

C. W. Senters, M. D. Johnson, R. S. Leonard, C. R. Ramos, C. L. Squires, T. M. Wood, and R. A. Woodroof,
ProTechnics Division of Core Laboratories LP

This paper was prepared for presentation at the SPE Hydraulic Fracturing Technology Conference & Exhibition held in The Woodlands, Texas, USA, 23-25 January 2018.

Abstract

Completion optimization continues to be a priority for many operators. The process of adding diverter to hydraulic fracturing treatments remains one of the fastest growing techniques to gain operational efficiency while maintaining the desired reservoir contact during the treatment. Case studies in this paper are utilized to illustrate the effects of diversion on the overall completion program.

Evaluating diversion effectiveness and relating it back to overall completion effectiveness remains a challenge with surface pressure data alone. Diagnostics in the form of proppant tracing are applied to evaluate the near-wellbore coverage of the stage with the use of diversion. These stages are also evaluated based on the shift in treatment as a result of the diversion. Unique proppant tracers are utilized before and after diverter drops to evaluate changes in the treatment over time.

The results of diversion based on the overall stage coverage and the role that the diverter played in obtaining this coverage is presented in several case studies. Examples include data from projects that utilize different types of diverting techniques. The overall completion effectiveness based on missed clusters is illustrated in the case studies presented in this paper. Diversion cleanup and fracture interference while using diversion is evaluated using chemical tracers. Diversion will be discussed in an interwell communication case history.

In addition to the evaluation of diversion, baseline examples are included without diverter material. These baseline examples are sometimes referred to as "ghost stages." The diagnostic approach to this compilation of case histories compares the results of over 20 wells using completion diagnostics. All of the stages evaluated are summarized for perforation efficiency and diversion effectiveness.

Introduction

This paper is a continuation of SPE 187045, "Diversion – Be Careful What You Ask For," however, this paper will incorporate additional case histories involving: ghost stages, perforation pods, PLA diversion, novel applications of diverter, and inter-well communication (Senters, et al. 2017). The previous paper goes into detail regarding the basic concepts and established products/techniques for diversion. This paper will present detailed descriptions of some of the newer diversion products/techniques that were not included in the previous paper, and their descriptions will be included with their associated case histories. The diagnostic technologies described in this paper utilize unique proppant and chemical tracers to evaluate near-wellbore diversion. Detailed descriptions of those technologies and the associated analytical procedures employed are also described in the previous paper (Senters, et al. 2015).

The diversion effectiveness of these newer technologies are compared in the case histories presented in this paper. A more extensive diverter dataset is also included in the appendix, with details regarding cluster treatment effectiveness and diversion effectiveness for each stage of the included wells. Work is on-going to compare the effectiveness of additional diversion products/techniques as they become available.

Case Histories

Case History 1: Ghost Stages

When studying diversion effectiveness the method of deploying the diverter should be considered. It is operationally desirable to slow surface treating rates to allow for the diverter slug to be deployed. Once the slug of diverter has entered the well, rate is typically increased to save time while the diverter is traveling to the perforation clusters. At a predetermined distance/volume prior to diverter reaching the perforation clusters, the pump rate is reduced to avoid sharp increases in pressure as the diverter is seated. Pressure is monitored as the diverter seats and rate is once again increased. During this process of rate-cycling, diversion of the fracturing treatment could be taking place in lieu of any diverter material. Some of the possible reasons for changes in the treatment distribution during rate-cycling include: flushing the well and NWB area with clean fluid, stress relaxation in the fracture network, deactivating clusters from low pumping rates, downhole pressure changes from lowered pipe and perforation friction and other abrupt fluctuations in the steady state equilibrium of injection. For these reasons it is recommended to run ghost stages in the evaluation of diversion effectiveness. A ghost stage is a stage in which the rate-cycling of deploying diverter is duplicated. Essentially, the ghost stage is the exact same as a stage pumping diverter with the exception of pumping the diverter material. Although these stages can be tedious, they can be insightful when applying diverter to new well completions. Comparison of diversion during ghost stages to stages with diverter can help account for the effect of the rate-cycling that takes place during diversion. (Kiel, 1977)

Well G1 traced three ghost stages in which diverter material was not deployed. The first of these ghost stages appears in Figure 1. In this example, the treatment shifted after the rate-cycling within the stage. Two of the under-stimulated clusters were stimulated as a result.

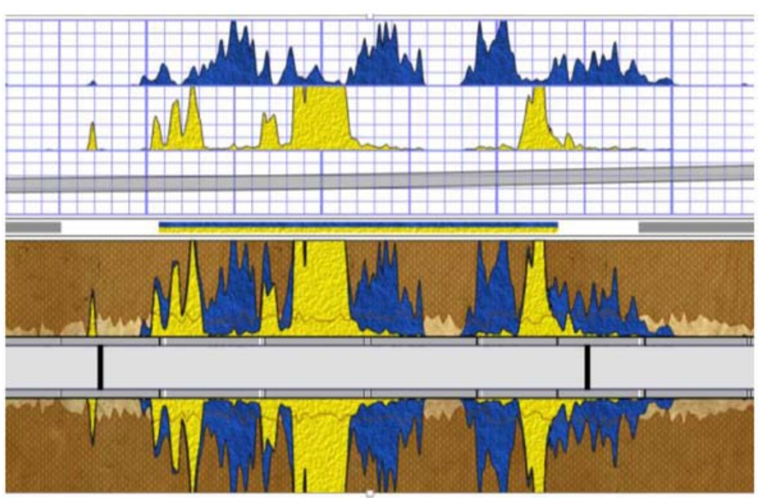


Figure 1—Well G1 ghost stage 1

Figure 2 shows stage two of well G1 that was traced with two ghost drops within the stage. Diversion of the stage progressed to the middle cluster within the stage by the end of the treatment.

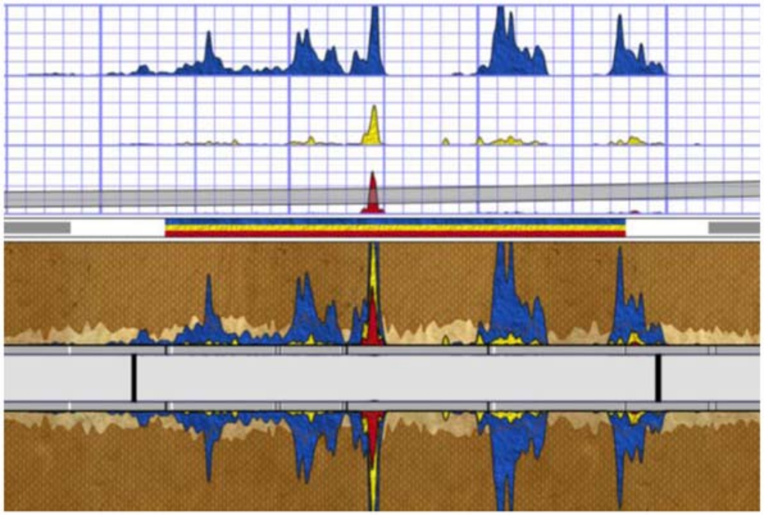


Figure 2—Well G1 Ghost Stage 2

Figure 3 is a portion of the spectral gamma ray log showing stage three of well G1. This ghost stage shows a heel bias after the second ghost drop. The toe-most cluster is usually the most difficult cluster to treat in a horizontal well and it appears to be opened up after the first ghost drop.

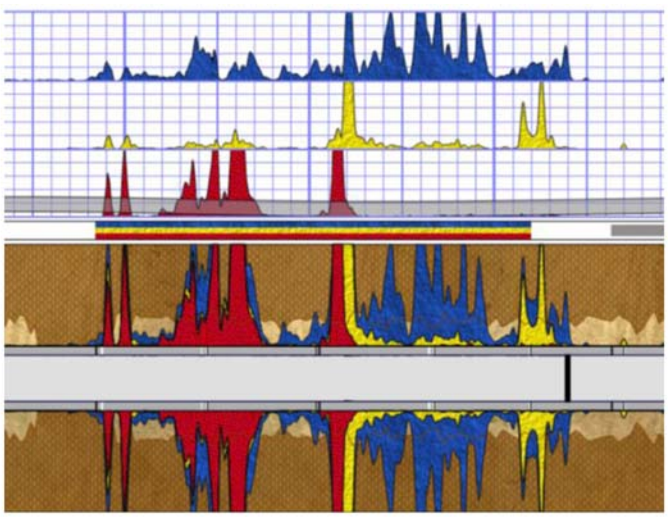


Figure 3—Well G1 Ghost Stage 3

Well G2 also contained a ghost stage that was evaluated for diversion. Figure 4 is a spectral gamma ray log of the ghost stage 1 in well G2. The stage diverted away from the heel-most two clusters as a result of the rate-cycling. The two heel clusters were under-stimulated during the initial portion of the treatment prior to the rate-cycling.

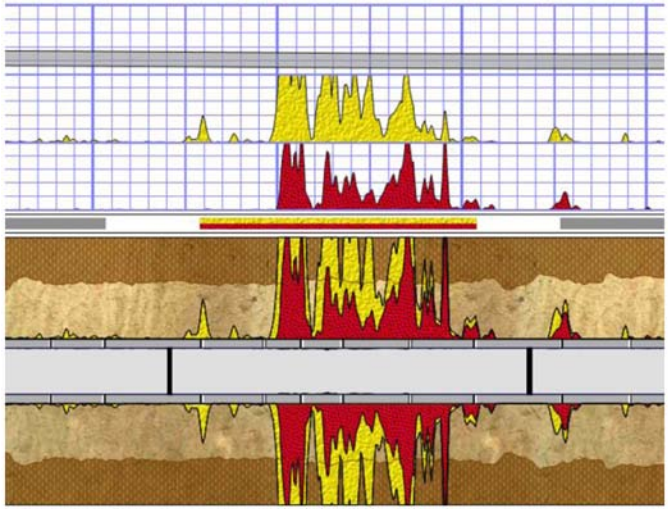


Figure 4—Well G2 ghost stage 1

Case History 2: Diverting with PLA in plug and perf completions

PLA diversion was significantly discussed in SPE-187045 and SPE-184828 (Weddle, et al. 2017).

PLA Diversion Well 1:

The first case utilized PLA to divert a treatment consisting of two separate stimulation designs. Each design segment of the treatment included its own pad and sand ramp of comparable size. PLA was utilized after the first ramp. Two wells were evaluated to test the cluster coverage and diversion effectiveness for a different number of clusters.

Well M1 was completed with 10 clusters per stage and was traced in two segments each representing a unique sand ramp. The sand ramp utilized Scandium and is illustrated by the yellow color. The second utilized Iridium and is shown as red. The diversion analysis tool will assign a full bar at each cluster that was fully stimulated, half for an under-stimulated cluster and for clusters that did not show any tracer there is none. Figure 5 represents the diversion analysis of several stages within well M1.

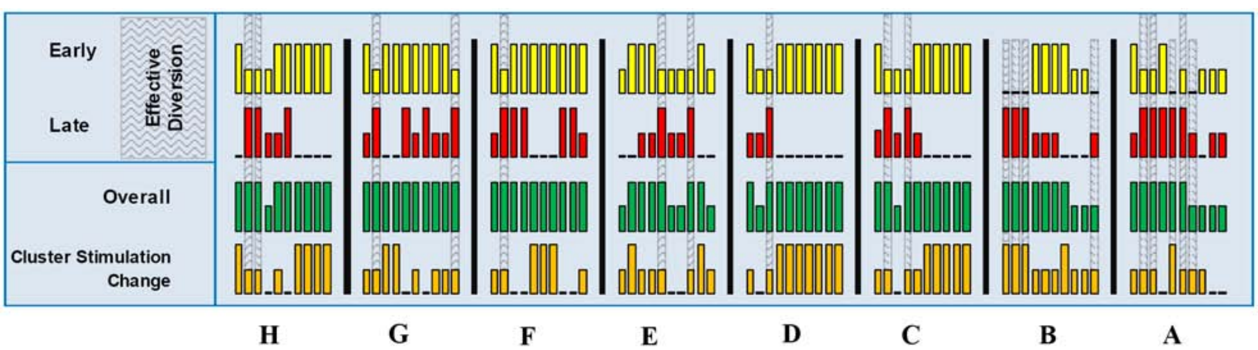


Figure 5—Diversion analysis of well M1

The diversion analysis is a tool to evaluate the effects of diversion and overall treatment coverage for near-wellbore treatment distribution. For diversion evaluation stages are typically traced with a unique proppant tracer before and after the diverter. The diversion analysis is a summary of the results of the spectral gamma ray log when multiple proppant tracers are utilized. The top rows on the diversion analysis represent an evaluation of the coverage at a specific cluster within a stage. Each portion of the treatment contains bars corresponding to the unique proppant tracer that was injected. A full bar represents a stimulated cluster, a half bar represents an under-stimulated cluster and the absence of a bar is a cluster that was not contacted by that portion of the stimulation treatment. The multiple segments of the treatment are combined to show the overall cluster coverage across all portions of the treatment for a stage and are represented by the green bars. The changes in treatment profile as a result of the diversion (both effective and ineffective) are represented by the orange bars.

The overall coverage of each cluster of well M1 is represented by the green bars. Changes in stimulation treatment are in orange and represent any change in treatment (both effective and ineffective diversion). All of the stages within Well M1 show at least some positive diversion affects. Stages A and B have clusters that initially were not being stimulated that started taking sand after diversion was pumped. Stage B had the most effective diversion results with the 3 heel-most clusters not getting stimulated until after diversion was pumped. One other item to note is that the number of total clusters being stimulated after diversion decreased by approximately one-third, to a total of 50 clusters and an overall perf cluster efficiency of 47%.

PLA Diversion Well 2:

Well M2 utilized diversion in a similar way as well M1 and was completed with five clusters per stage vs 10 clusters per stage in M1. Figure 6 represents the diversion analysis for well M2. All 15 of the traced stages show some change in treatment coverage using PLA diversion; however, four of the stages are not effectively diverting into new rock. Also, this five cluster per stage design had all clusters initially being stimulated with at least some proppant prior to diversion and a better initial perf cluster efficiency of 82%. After the diversion drop the perf cluster efficiency decreased to 78%.

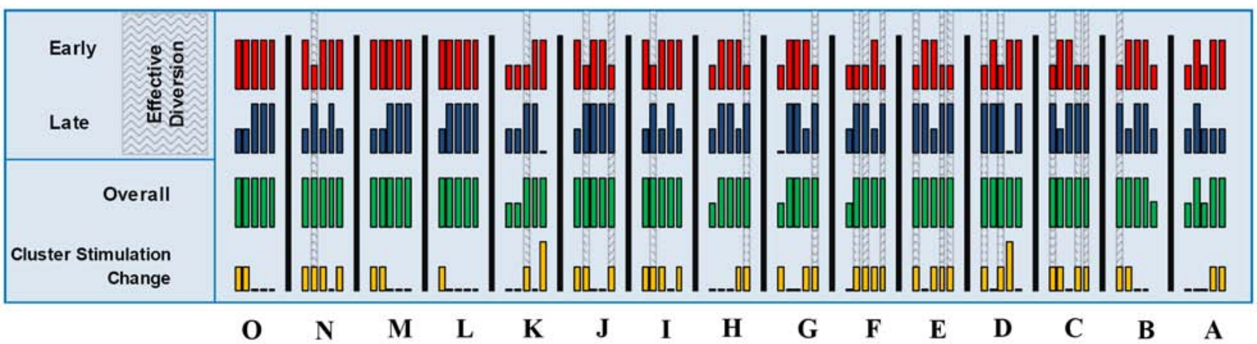


Figure 6—Diversion analysis of well M2

The complete results of the all of the PLA wells included in the paper are located in the Table A.1 within the appendix. The overall results of the PLA diversion technique compared to other methods can be found within the results section of this paper. Both of the wells within this study include examples of effective diversion. Examples of effective diversion that are also heavily reducing the treatment interval are evident within many of these wells. Prior to diversion projects, a list of goals should be agreed upon. Some examples of these goals are:

"Leave no cluster untreated"
"Combine stages to reduce cost"
"Control inter-well communication"
"Mitigate the risk of low treatment coverage."

This is only a small snapshot of the possible goals of a diversion project. The goal of the project can determine the optimization of the stage volumes, cluster design, and finally the diversion program. Optimization of these programs can result in effective diversion that achieves all of the goals for the project.

Case History 3: Diverting Using Perforation Pods

The type and amount of material can make a difference in effective diversion as observed via surface pressure response as well as diagnostically. The next case study evaluates the use of perforation pods for diversion in new well completions. Pods are especially designed to isolate an individual perforation and designed for a range of hole sizes. This technology is being utilized on new well completions to improve stimulation distribution across multi-cluster plug-and-perf treatments.

In each of the cases within this case history, the treatment design was broken into multiple segments with diversion being utilized between each of the segments. The wells were new well completions and no other type of diversion was utilized.

Proppant tracer is utilized to detect near wellbore diversion. The technology utilizes unique tracers throughout the sand laden fluid. Upon completion of the treatment, the well is logged for the presence of the tracers. The area of investigation is calibrated within 25 inches of the wellbore. Evaluation of the wells in this paper will classify treatment at each of the clusters as either stimulated, un-stimulated or under-stimulated.

Pod Diversion Well 1

This horizontal well landed in the Middle Bakken Shale (MB-1H) was a 50-stage open hole, plug-and-perf (OH-PnP) completion, utilizing the pods as a diverting agent on select stages. Two main objectives were evaluated: first, the effectiveness of the perforation pods as a diverting agent, and second the possibility of cost savings by combining two stages into one and utilizing pods to aid in the stimulation effectiveness. The standard treatment consisted of four sweeps pumped between five proppant ramps. In order to study the first objective, one drop of pods was included after the third sweep, after approximately half of the total proppant had been pumped. Proppant tracers were switched during this pod drop to determine any differences in the pre/post proppant placement. In order to evaluate the second objective, two standard treatments were pumped with a drop of the pods in the middle, swapping proppant tracers following the pod drop. Additionally, on the last combined stage for this well, two pod drops were utilized by splitting the stimulation treatment into thirds, while alternating proppant tracers. A total of over 700 perforation pods were launched, with an average of 42 pods per drop. The 50 stages were stimulated with ~5500 bbl per stage of slickwater and an extra 150 bbl of crosslinked gel sweeps after the pod drops. Stages were pumped at a maximum rate of 80 bpm, lowering that rate by at least 15 bpm for the pod drops. Although it varied, each stage had an average length of 227 ft from plug to plug with five perforation clusters, three shots per foot, and 120° phasing at an average cluster spacing of 42 ft. Figure 7 shows the spectral gamma ray log for this well as well as a graphical representation of some of the stimulation treatment parameters for the individual and combined stages.

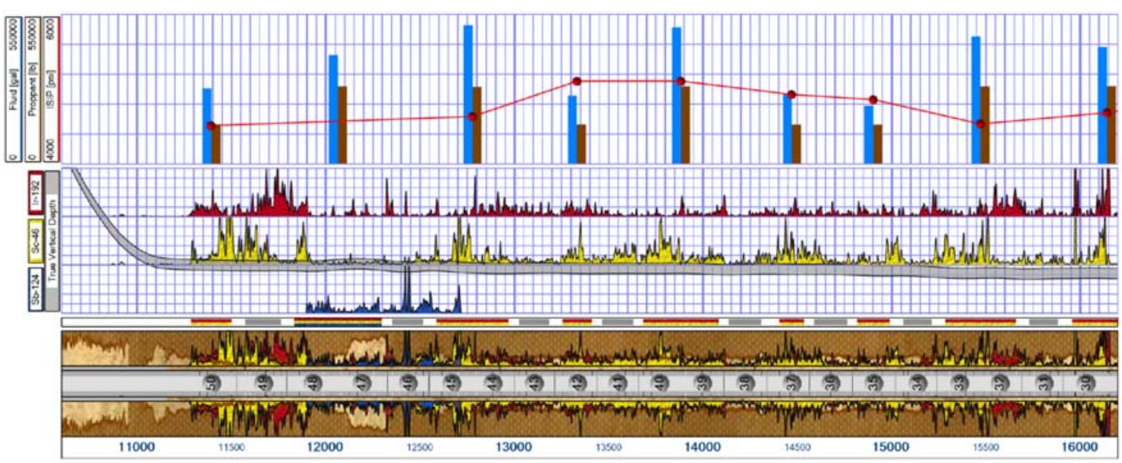


Figure 7—Spectral gamma ray log for MB-1H Well.

Ultimately, 13 stages with 69 clusters were traced. Analysis of the spectral gamma ray log showed a cluster efficiency of 88% (61/69), and a near-wellbore lateral coverage of 2,812 ft, out of the possible 3,069 ft of wellbore-traced length or 92% coverage. The early sand, pre-diverter, left 22 clusters under-stimulated, and 17 unstimulated. While the late sand, post-diverter, indicated effective diversion by under stimulating five new clusters and fully stimulating nine more previously unstimulated. Moreover, the late sand fully stimulated 15 more clusters previously under-stimulated. On the combined stage lengths, diversion stimulated one new cluster previously not touched and one more cluster previously under stimulated during the last third of that treatment. Overall, 55 clusters were stimulated, 12 clusters were under-stimulated, and two clusters appeared to have taken no stimulation. Figure 8 shows these results as described above in the diversion analysis.

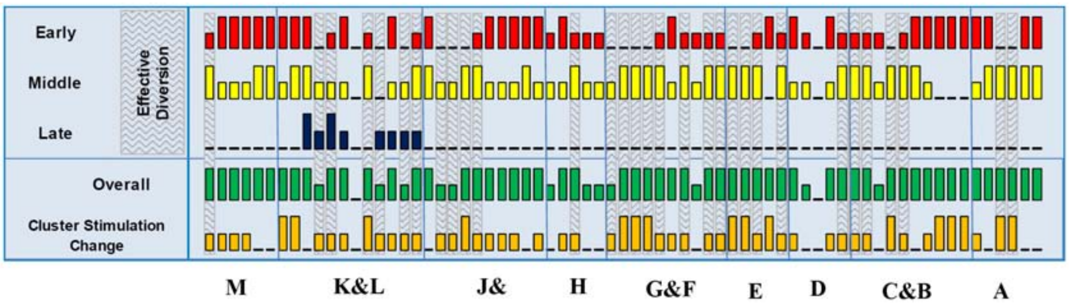


Figure 8—Diversion analysis for well MB-1H

In total, 52-clusters showed some degree of diversion. Out of these 52 instances, 31 were deemed to be effective diversion as was defined previously in the paper. Every traced stage in this well showed at least one instance of effective diversion shown in Figure 8.

Pod Diversion Well 2

This horizontal well landed in the Three Forks formation (TF-1H) was divided into 50 stages in an OH-PnP completion design. This study had similar objectives to the MB-1H case, but on the underlying Three Forks formation. Similarly, the cluster spacing was kept constant at ~43 ft, with the difference that the stages were shorter having only 4 clusters per stage measuring ~180 ft from plug to plug. A total of more than 200 pods were pumped with an average of 20 pods per drop. The stimulation design for this well was structured in the same manner as in MB-1H, and it also included some combined stages. Figure 9 shows the spectral gamma ray log for this lateral, as well as a graphical representation of the stimulation treatment parameters for the individual and combined stages.

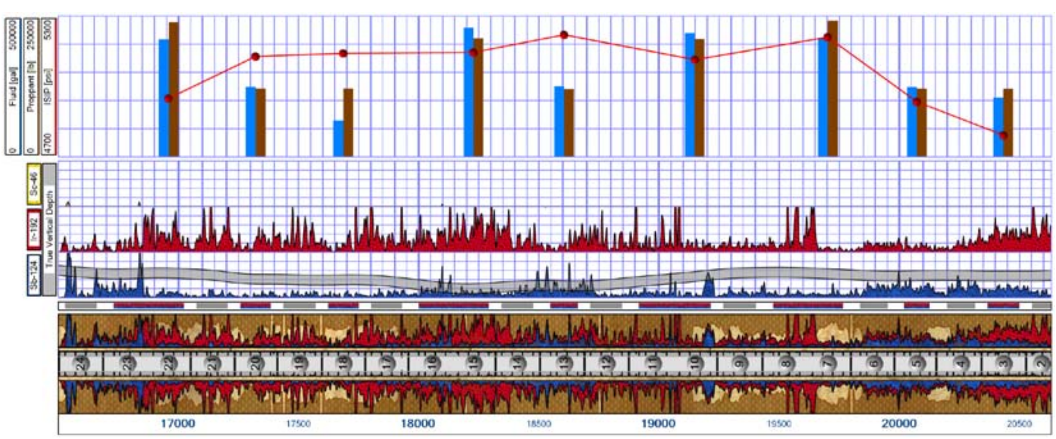


Figure 9—Spectral gamma ray log for TF-1H Well

The spectral gamma ray log showed an overall cluster stimulation efficiency of 95% (49.5/52), and a near-wellbore treated coverage of 100%. The early sand, pre-diverter, left 11 clusters under-stimulated, and only four unstimulated. The late sand, post-diverter, treated these previously unstimulated clusters. In addition, the late sand fully stimulated eight more clusters previously under-stimulated. Overall 47 clusters were stimulated, 5 were under-stimulated, and none showed an absence of proppant placement. Figure 10 shows the results in the diversion analysis for well TF-1H. This horizontal Three Forks well had 33 instances of cluster stimulation change, out of which only 12 were deemed to be effective. These results are largely due to the high cluster stimulation efficiency accomplished by the early sand prior to deploying pods.

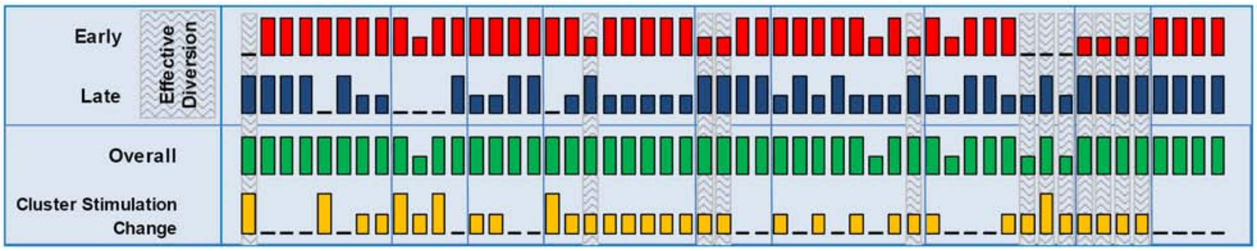


Figure 10—Diversion analysis summary for well TF-1H

Pod Diversion Well 3:

Figure 11 represents the diversion analysis for well Q1. One pod diverter drop was employed between the first and second segments of the treatment. Diversion took place in 10 of the 15 stages that were evaluated on well Q1. Of the 10 stages that had some form of diversion, only half of these stages had one or more instances of effective diversion. Although not all diversion was effective, the tendency to divert to a small percentage of clusters or towards the heel half of the stage (heel-bias) did not take place on this well.

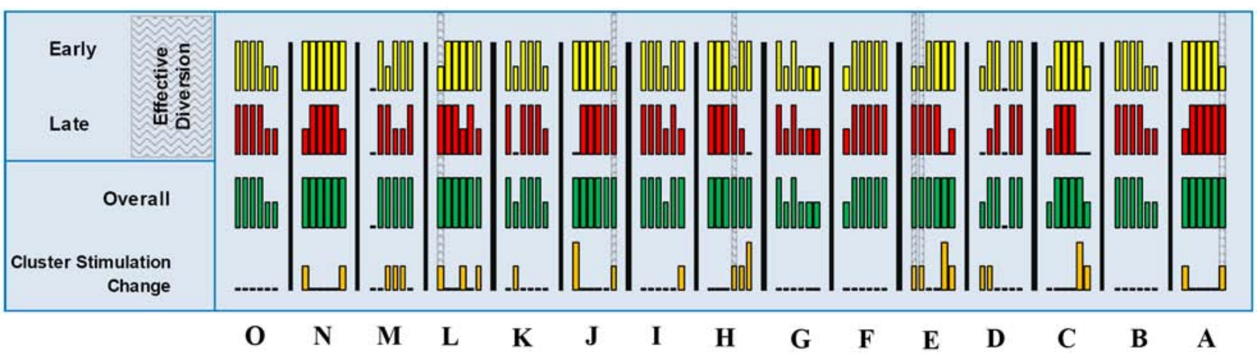


Figure 11—Diversion analysis of well Q1

Pod Diversion Well 4

As discussed earlier in the paper, pods are designed to seal a certain range of perforation hole sizes. In horizontal wells, the perforating guns tend to be off center in the wellbore on the lower side of the wellbore. The plug and setting tool can help keep the guns centralized, but there will likely still be some of the charges that are closer to the bottom of the wellbore. This effect can result in uneven perforation sizes. Charges are available to account for the positioning of the perforating tool string in horizontal pump-down perforating operations. The charges allow for consistent hole size regardless of the position of the tool string.

When perforations are within the size range for the working diameter of the pod, effective isolation of perforations during the treatment can be achieved. Wells P2 and P3 utilized perforation technology that enabled more consistent hole size in horizontal well perforating.

Well P2 utilized a 14-cluster perforation design and pod diversion. In each of the traced stages within the well, new clusters were opened that were either unstimulated or under-stimulated during the previous portion of the treatment. The diversion did limit the treatment interval in two of the stages with one of those stages showing a heel-bias. On the stage showing the heel-bias, the heel was under-stimulated during the initial portion of the treatment. Figure 12 shows the diversion analysis of well P2. The overall coverage improved for each of the three stages evaluated. In stage A three of the previously under-stimulated heel clusters were stimulated after diversion; however, this stage had a bias towards the heel after diversion.

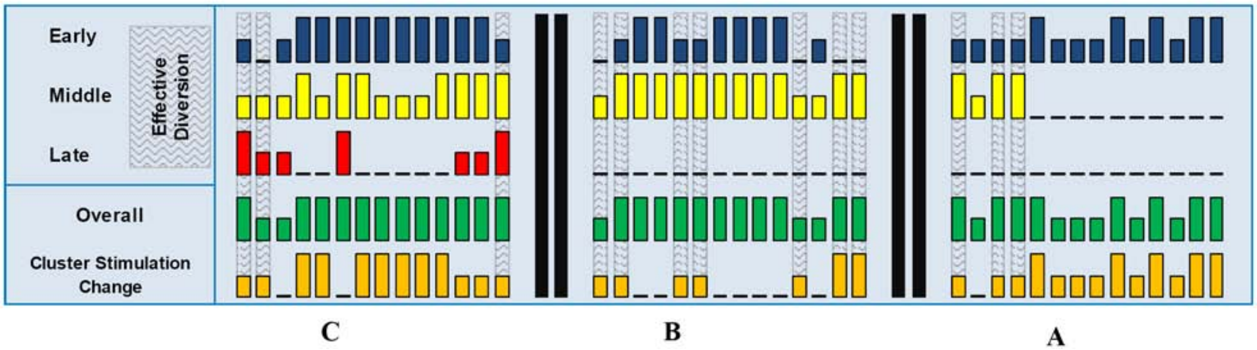


Figure 12—Diversion analysis for well P2

The diversion analysis of well P3 is shown in Figure 13. Well P3 utilized pod diversion on a nine-cluster per stage design. Each of the three stages showed diversion in which at least one of the under-stimulated or unstimulated clusters was improved. The third cluster from the heel of stage C remained unstimulated throughout the treatment.

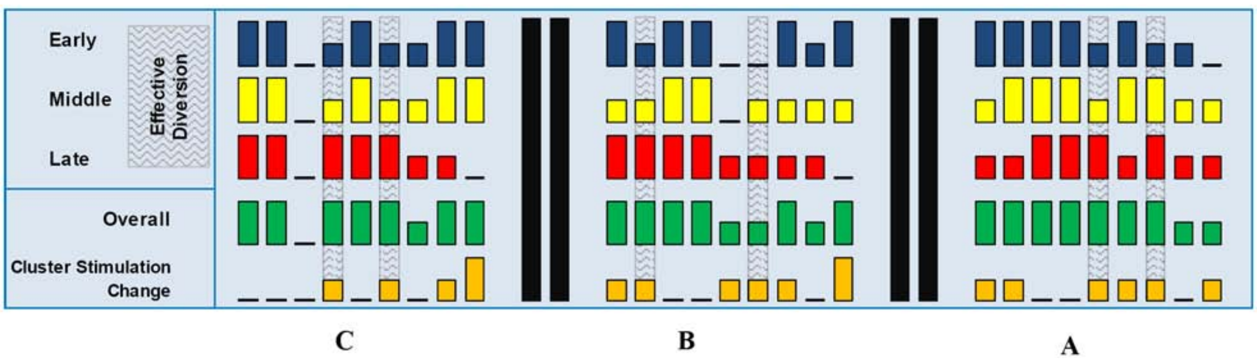


Figure 13—Diversion analysis for well P3

Well P7 utilized pods to stimulate six clusters per stage in a new horizontal completion. Pods were deployed between the two segments of the treatment. The segments were traced utilizing Iridium (red) prior to diversion and Antimony (blue) after diversion. Figure 14 is the diversion analysis for well P7. Most of the stages show some treatment within the stage as a result of diversion. The stages that did not show much change in the distribution of the treatment had a high percentage of clusters treated prior to the diversion drop.

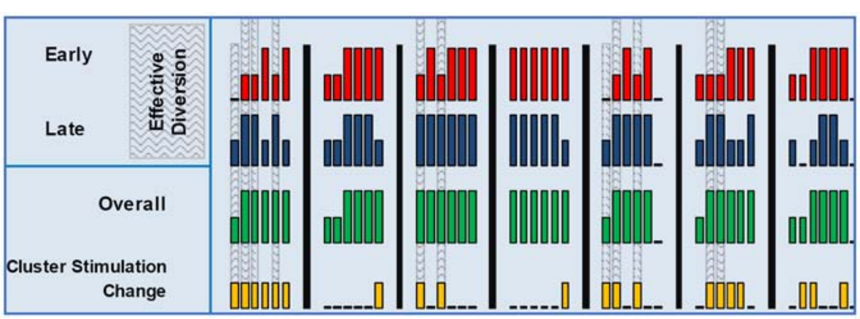


Figure 14—Diversion analysis for well P7

Case History 4: Novel completion approaches on new wells utilizing diversion

Case Histories one through three focus on diversion material used during plug perf treatments on new well completions. In all of those examples, the annular isolation on the outside of the casing in the horizontal wellbore is cement. This case history will look at applications of diverter in uncemented wells as well as the use of diversion as an internal isolation method in lieu of bridge plugs.

Well 1: Uncemented Completions

Diversion in new well completions often relates to cemented plug-and-perf applications, but that is not always the case. Uncemented wells (sometimes referred to as "open-hole" completions) offer the same opportunity of treatment optimization through the use of diversion. Diversion can be utilized to vary the treatment distribution across the open-hole section of the lateral or attempt to combine stages in uncemented plug-and-perf completions. The uncemented completions in this paper utilize open-hole packers for annular isolation of the treatment in lieu of cement.

Well O1 was completed using plug and perf in casing with packers as an annular isolation. The diversion analysis is shown in Figure 15. The number of clusters was varied in the well. Pods were used as a diversion material and two drops were utilized for all but one of the stages. Each of the stages show change in the treatment between diversion drops. In all of the stages, the previously unstimulated or under-stimulated clusters were accessed as a result of the diversion.

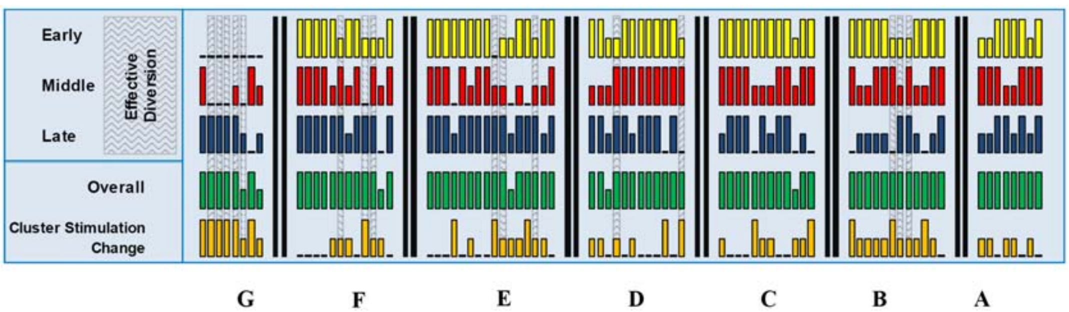


Figure 15—Diversion analysis for well O1

Overall perf efficiency for well O1 is 96%. The resulting change in stimulation profile that took place for each of the stages allowed for at least one of the previously under-stimulated or unstimulated clusters to be stimulated prior to the completion of the stage. After the second pod drop on stage B, the treatment was restricted to stimulating 3 of the 12 clusters and shows that another 3 of the clusters were not contacted at all during this portion of the treatment. The diversion allowed for a change in the treatment profile after the 2nd drop but also restricted the treatment.

Well 2: Use of Particulate Diverters instead of Plugs

In addition to application of diversion technology to uncemented completions, another novel use of diversion is the elimination of plugs in a plug and perf completion. This case study evaluates several approaches to plug-less completions.

A Marcellus operator was using particulate diversion to minimize the number of plugs placed in a well. Two different diversion methods were tested in the well. Proppant tracers were used to determine which method worked most effectively.

Perf Then Divert:

Perforations were shot for the current stage immediately after completion of the prior stage. Plugs were not set in between the current and prior stages. Diversion was employed at the beginning of the current stage in order to seal off the prior stage's clusters and to use the resulting pressure increase to break open the new perforations for the current stage. Figure 16 and Figure 17 below show the results of the perf then divert stages.

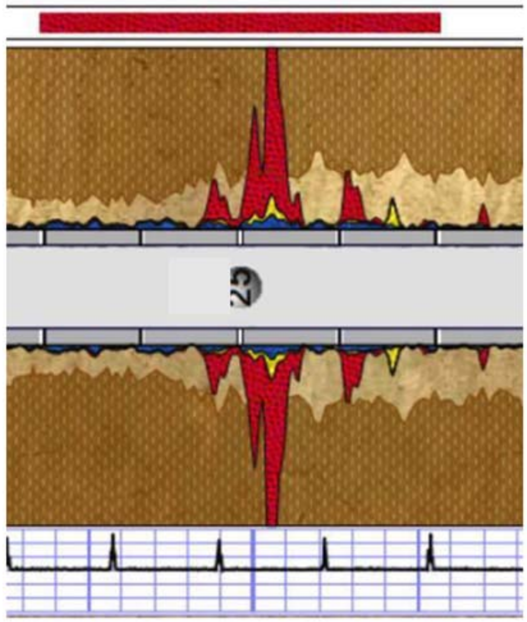


Figure 16—Poor Cluster Stimulation

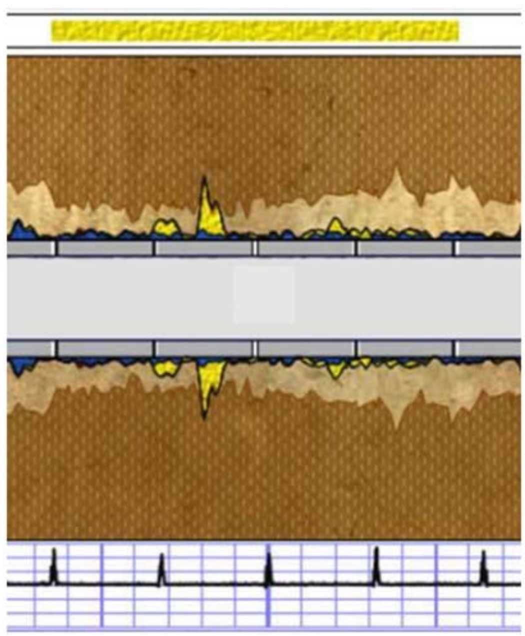


Figure 17—Poor Cluster Stimulation

Divert Then Perf:

Diversion was employed at the end of the prior stage in order to seal off open perforations. Pumping pressure was allowed to increase as the diversion sealed off the prior stage's perforations. Once pressure was high enough to only allow enough rate to pump down perforating guns, the current stage's clusters were shot. Then the current stage was completed. No plugs were set between stages. Figure 18 and Figure 19 below show the results of the divert then perf stages.

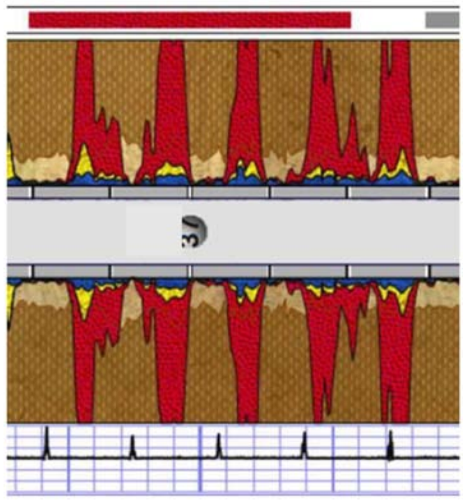


Figure 18—Stimulated Clusters

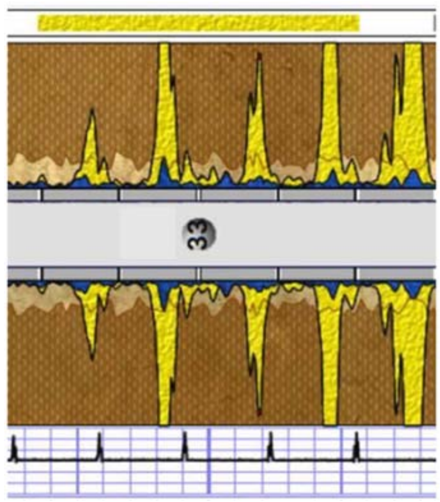


Figure 19—Stimulated Clusters

When comparing the two methods with the proppant tracer log, it was evident that ‘divert-then-perf’ was more successful than the ‘perf-then-divert’ method. When the diverter was used in the perf-then-divert stages it is likely that the diversion was sealing off both old and new clusters, resulting in the poor cluster stimulation shown in figure 16 and 17. Additionally, the diagnostics showed that diversion can be used to successfully stimulate clusters when plugs are minimized or eliminated.

Well 3: Evaluation of Perforation Pods for Stage Isolation versus Conventional or Dissolvable Plugs

Pods have been extensively used as a diversion method to improve cluster stimulation coverage across a fracture treatment stage. However, a less utilized application of the pods is for stage isolation in replacement of plugs in plug-and-perf completions.

An operator in the Mid-Continent designed a study to evaluate the effectiveness of pods in isolating the current stage from the previous completed stage in a horizontal completion. These two stages are defined as the "test pair" in this case history. Proppant tracers and spectral gamma ray imaging were utilized in this evaluation. Conventional plugs, pods and dissolvable plugs were tested in this wellbore (Fripp, 2017).

In order to compare the pods isolation effectiveness, some of the test pairs used conventional plugs. The spectral gamma ray log analysis across a test pair using a conventional plug provides a baseline evaluation for a successful stage isolation. In this formation, longitudinal fracture growth is possible and less than adequate behind pipe cement isolation can be an issue concerning fracture energy containment to the target stage. Either scenario can be identified with the spectral gamma ray log but can make the detection of a stage isolation (plug or pods) leak or failure more difficult.

Diagnostics Design and Analysis Approach:

As mentioned earlier, proppant tracers and spectral gamma ray imaging diagnostics were deployed in this evaluation. A single proppant tracer was pumped in each current stage after pumping the pods or setting a plug. The spectral gamma ray log was utilized to evaluate treatment coverage and containment of the current stage, but especially the detection of this tracer across the previous stage. The presence of tracer would indicate an isolation leak or complete isolation failure. In addition to the traditional spectral gamma ray log analysis, a secondary evaluation was conducted by measuring the tracer counts across the current stage (traced) and the previous stage (not traced). Tracer counts are not a quantitative measurement of fracture development. However, when the tracer profile is primarily a response to tracer placed outside the wellbore in the fracture network, the tracer count profile can be useful in a qualitative evaluation of stage isolation.

All test stages were identical hybrid fracture treatments with five clusters per stage at 20 ft spacing.

Conventional Plug Tests:

After completion of the previous stage, a conventional plug was set prior to perforating and fracture treating the current stage. A single proppant tracer was pumped in the current stage. Figure 20 and Figure 21 represent two of the stage test pairs using conventional plugs.

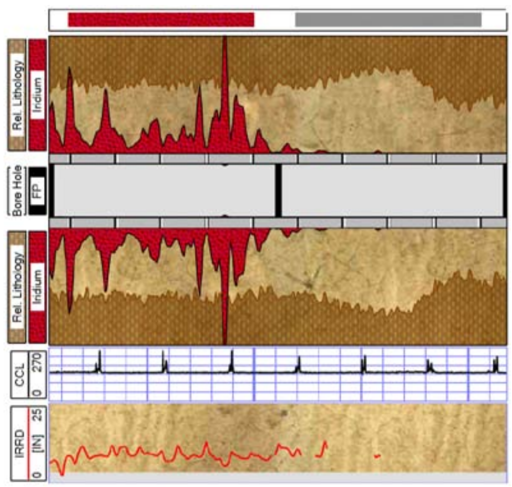


Figure 20—Conventional plug test 1

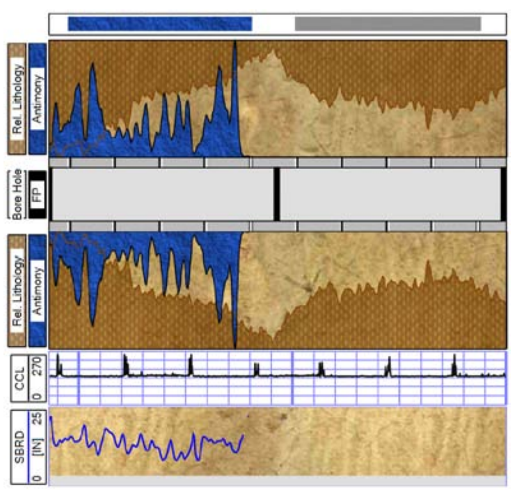


Figure 21—Conventional plug test 2

Figure 20 shows good cluster coverage and containment across the current traced stage (Figure 20: identified with the red flag, iridium tracer, on the log) with very minor tracer across the heel-half of the previous stage (Figure 20: gray flag, not traced), identified as minor longitudinal growth in the toe direction. Minor longitudinal growth was also detected in the heel direction away from the toe-most cluster of the current stage. The tracer counts across the previous stage account for less than 0.5% of the total tracer counts for the test pair. This minor longitudinal growth did not interfere with the evaluation of the plug isolation effectiveness. There is no evidence that the plug leaked or failed. Hence, the conventional plug is isolating effectively.

Figure 21 shows good cluster coverage and containment across the current traced stage (blue flag, antimony tracer) with no tracer detected across the previous stage (gray flag). The conventional plug is isolating effectively. These two test pairs established a baseline for pod effectiveness. Also, it appears that the cement is providing adequate behind pipe isolation and fracture longitudinal growth is minimal.

Perforation Pod Tests:

After completion of the previous stage, pods were pumped to seal off the open perforations across the previous stage. Then the current stage was perforated and fracture treated. A single proppant tracer was pumped in the current stage. Figures 22-24 represent the stage test pairs using pods for stage isolation.

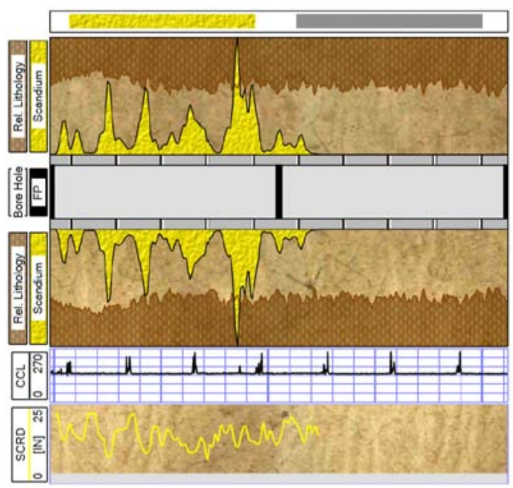


Figure 22—Pod test 1

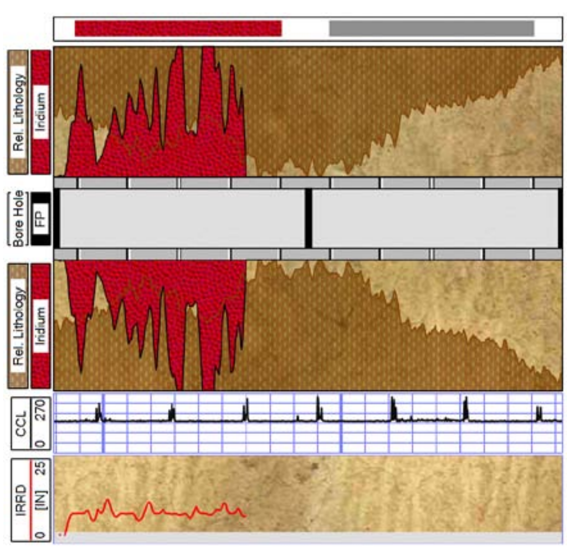


Figure 23—Pod test 2

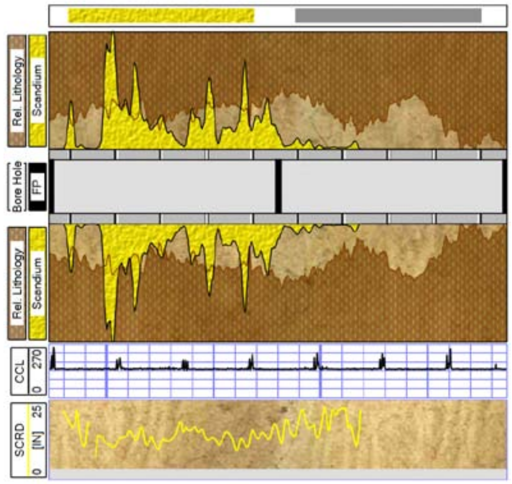


Figure 24—Pod test 3

Figure 22 shows good cluster coverage and containment across the current traced stage (yellow flag, scandium tracer) with very minor tracer across the heel-most cluster of the previous stage (gray flag). The tracer counts across the previous stage account for about 1.0% of the total tracer counts for the test pair. Also, the tracer profile is connected between the stages, so the minor coverage across the heel side of the previous stage is minor longitudinal growth. The pods are isolating effectively.

Figure 23 shows no tracer across the toe-most cluster of the current traced stage (red flag). The gamma ray shows a possible lithology change that may have impacted the frac treatment coverage. The treatment is well contained across the current traced stage with no tracer detected across the previous stage (gray flag). The pods are isolating effectively.

Figure 24 shows good cluster coverage and containment across the current traced stage (yellow flag) with very minor tracer across the heel-most clusters of the previous stage (gray flag). The tracer counts across the previous stage account for about 2.5% of the total tracer counts for the test pair. Also, the tracer profile is connected between the stages, so the minor coverage across the heel side of the previous stage represents minor longitudinal growth. The pods are isolating effectively.

Dissolvable Plug Test:

After completion of the previous stage, a dissolvable plug was set prior to perforating and fracture treating the current stage. Figure 25 represents the spectral gamma ray log of this single test pair.

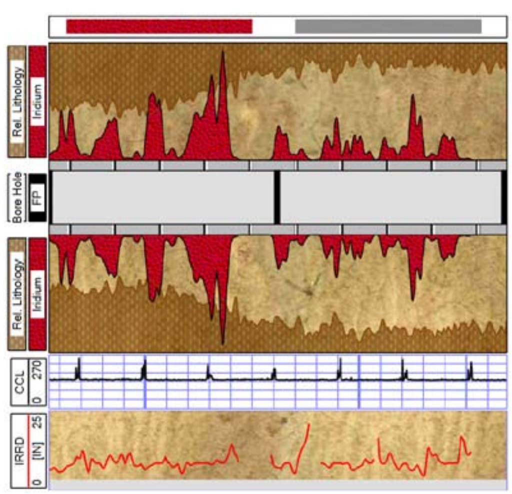


Figure 25—Dissolvable plug test

Figure 25 shows good cluster coverage except for the toe-most cluster of the current stage (red flag). Containment across the current traced stage is poor due to the large amount of tracer detected across the previous stage (gray flag). The tracer peaks across the previous stage correlate to the cluster locations indicating restimulation of the previous stage's clusters. The tracer counts across this stage account for about 31% of the total tracer counts for the test pair. This high tracer count percentage compared to the zero to 2.5% range for conventional plugs and pods identifies a complete isolation failure. The dissolvable plug is not isolating effectively.

In conclusion, the pods performed favorably in this limited evaluation. Based on the spectral gamma ray log analysis, the pods and conventional plugs both isolated the previous stage from the current fracture treatment. However, the dissolvable plug showed a complete isolation failure, which did provide a spectral gamma ray baseline for a failure.

Case History 5: Diversion Effects on Interwell Communication

Diversion can affect interwell communication. In cases of effective diversion, interwell communication can be managed by impeding the growth of dominant fractures and reducing their corresponding half-length. On the other hand, ineffective diversion can focus the treatment on fractures that were previously stimulated and increase the amount of communication. Chemical tracing is used to quantify the effects of interwell communication.

Two pads were evaluated for interwell communication with the use of PLA diversion. Each pad utilized fluid diagnostics to evaluate interwell communication.

Well Pad W:

Well W1 is an example of diversion being utilized to effectively mitigate communication with an offset well W2. Well W1 was traced with 17 unique water soluble tracers in 11 different stages. Six of those stages utilized two tracers to evaluate the effectiveness of diversion. One fluid tracer was pumped in the first half of the job and then a second fluid tracer was pumped after diverter was injected. The two bar charts (Table 1 and Table 2) show percent frac fluid recoveries for the traced well W1, along with the percent frac fluid communication to the offset well W2.

Table 1—Percent of tracer recovered in treatment well

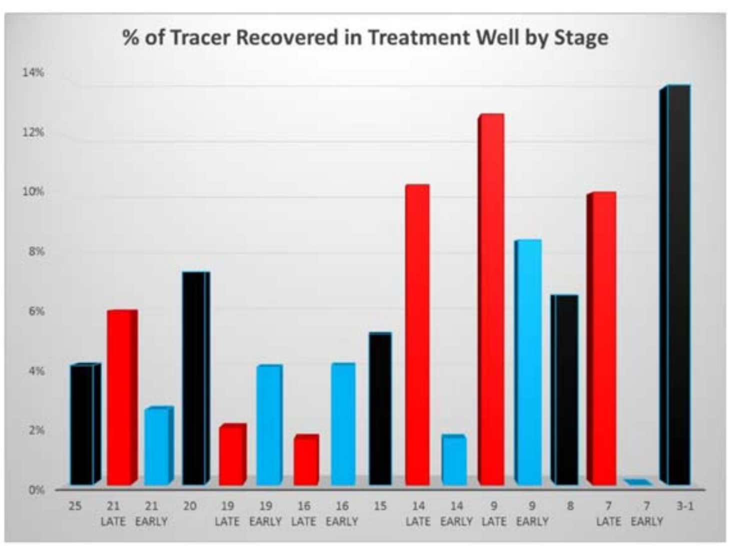
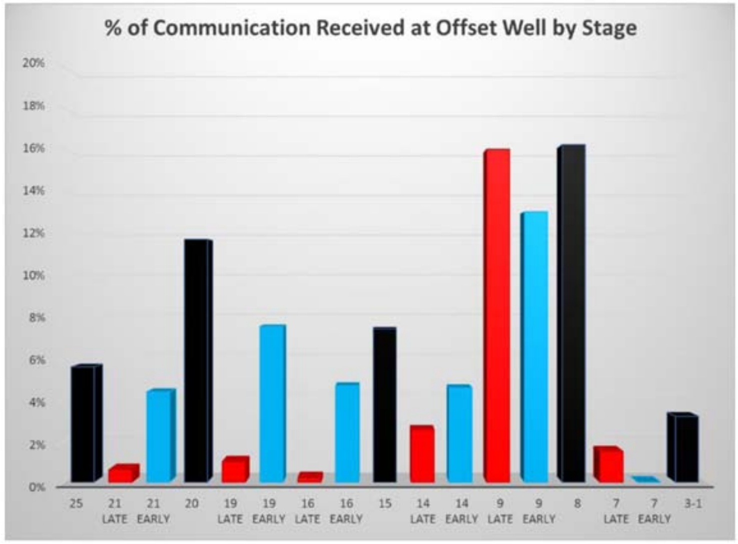


Table 2—Percent of tracer recovered from offset well



The red bars in Table 1 show late frac fluid recovery in the treatment well W5. In stages 7,9,14 & 21 the late recoveries are significantly greater than early recoveries. In Table 2 the blue bars indicate early frac fluid recovery in the offset well W2. In stages 14, 16, 19 & 21 of well W2 significantly less communication was observed, after diverter was pumped. Overall, there was a 50% reduction in communication to the W2 well after diverter was pumped. Additionally, there was a 36% increase in frac fluid recoveries at the W1 traced well. The stages that did not run diverter represented by the black bars (Stages 8, 15, 20 & 21) all showed more communication than the adjacent diverter stages.

Well Pad Y:

Wells on Pad Y were stimulated using PLA diversion. The wells were traced with unique chemical tracers, and well Y2 utilized proppant tracers before and after the diversion. Well Y2 was completed using a five-cluster limited entry design. Figure 26 shows the diversion analysis of well Y2. Changes in the treatment profile occurred in each of the four stages traced. Stages A and D had 5/5 clusters stimulated during the initial part of the treatment, thus any diversion taking place near-wellbore would be ineffective at increasing cluster coverage. Stage B had effective diversion which enabled the toe cluster to be stimulated. Stage C had a post diversion heel-bias.

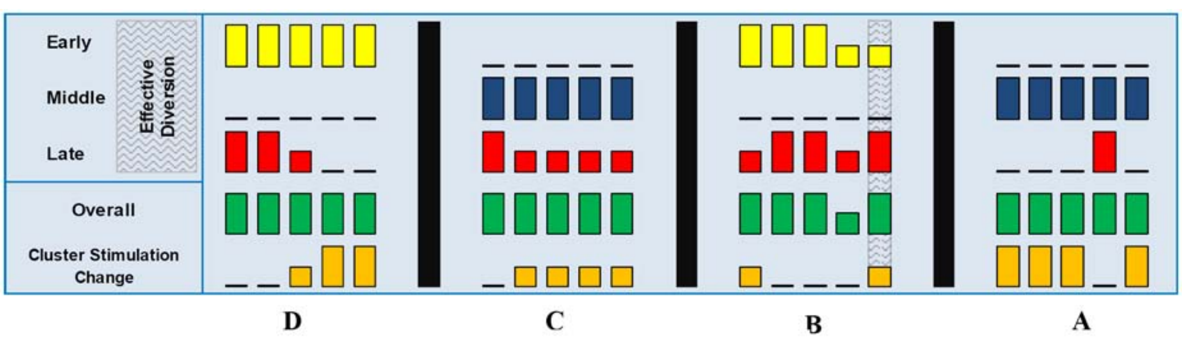


Figure 26—Diversion analysis for Y2

Figure 27 shows a summary of the water tracer recovery for the treatment well Y2 for each segment of the treatment (early and late). Five of the fifteen stages are showing a lagging recovery of the early treatment fluid when compared to the late fluid recovery. Because this is observed over several weeks of recovery, this is indicative of early fluid "trapped" within the stage. On stages where late fluid dominated the cleanup throughout the entire sampling period, there could be undissolved diverter material left within the fracture. Future tests should include control stages similar to the "ghost stages" discussed early in the paper. Comparison of these "ghost stages" to diverter stages can further confirm ineffective diverter clean-up.

15 Late	15 Early	13 Late	13 Early	12 Late	12 Early	11 Late	11 Early	10 Late	10 Early	9 Late	9 Early	8 Late	8 Early
CFT 10350	CFT 10300	CFT 4000	CFT 10650	CFT 10250	CFT 10400	CFT 3900	CFT 10750	CFT 10450	CFT 10100	CFT 2800	CFT 10200	CFT 3700	CFT 1400
0%	0%	2%	1%	0%	0%	1%	5%	6%	4%	3%	6%	1%	2%
1%	1%	7%	3%	1%	1%	2%	5%	8%	4%	3%	6%	2%	2%
1%	1%	7%	3%	1%	1%	2%	4%	6%	4%	3%	6%	1%	2%
2%	1%	7%	3%	1%	1%	2%	5%	7%	4%	3%	6%	2%	2%
3%	2%	8%	3%	1%	2%	2%	4%	7%	4%	3%	6%	1%	2%
7%	4%	9%	4%	2%	2%	3%	3%	6%	3%	3%	5%	2%	2%
7%	4%	8%	4%	2%	2%	3%	3%	6%	3%	2%	5%	2%	2%
6%	4%	7%	4%	2%	3%	2%	3%	7%	2%	3%	6%	2%	2%
5%	4%	6%	3%	2%	2%	2%	3%	7%	2%	3%	5%	2%	2%
5%	4%	6%	3%	2%	2%	2%	3%	7%	3%	3%	5%	2%	2%
5%	3%	6%	3%	2%	2%	3%	3%	7%	3%	3%	5%	2%	2%
5%	3%	6%	3%	2%	2%	3%	3%	7%	3%	3%	5%	2%	2%
4%	3%	6%	3%	2%	2%	2%	3%	7%	3%	3%	5%	2%	2%
7.5	5.0	11.3	5.3	2.8	3.5	4.1	5.3	11.4	4.8	4.7	8.8	3.0	3.6

7 Late	7 Early	6 Late	6 Early	5 Late	5 Early	4 Late	4 Early	3 Late	3 Early	2 Late	2 Early	1 Late	1 Early
CFT 2300	CFT 2900	CFT 3000	CFT 2500	CFT 2400	CFT 1500	CFT 2100	CFT 1600	CFT 2200	CFT 1900	CFT 2000	CFT 10500	CFT 1700	CFT 1300
4%	5%	2%	5%	7%	4%	3%	2%	8%	11%	5%	4%	7%	4%
4%	4%	2%	4%	6%	3%	2%	2%	6%	7%	3%	3%	6%	4%
4%	4%	2%	4%	5%	3%	2%	2%	6%	7%	3%	3%	6%	4%
4%	4%	1%	4%	5%	3%	2%	2%	5%	7%	3%	3%	6%	4%
5%	4%	2%	4%	5%	3%	2%	2%	5%	6%	3%	3%	6%	3%
4%	5%	2%	4%	5%	3%	2%	2%	3%	4%	2%	3%	5%	3%
4%	5%	1%	4%	5%	3%	2%	2%	3%	5%	2%	2%	6%	4%
4%	5%	1%	2%	4%	2%	2%	2%	4%	5%	2%	2%	8%	5%
4%	4%	1%	4%	4%	2%	2%	2%	4%	6%	2%	2%	8%	5%
4%	4%	1%	1%	4%	2%	3%	2%	4%	6%	2%	2%	9%	6%
4%	4%	1%	4%	4%	2%	2%	2%	4%	6%	2%	3%	9%	5%
4%	4%	1%	4%	4%	2%	2%	2%	4%	5%	2%	2%	9%	6%
4%	4%	1%	4%	4%	2%	2%	2%	3%	5%	2%	2%	10%	6%
7.0	7.0	2.2	5.9	7.0	4.0	3.8	3.4	6.6	9.2	3.7	4.2	12.7	7.8

Figure 27—Chemical Tracer Recovery for Well Y2

The communication matrix is a way of evaluating interwell communication with chemical tracers. The time-weighted average of the treatment well recoveries are shown in gray cells within the matrix. Offset communication of these wells is shown in the cells on each side of the treatment well recovery. The offset well recoveries are shaded based on the extent of communication from the treatment well to the offset wells. The categories of communication within the matrix include significant, moderate and minimal communication. Significant communication for this project occurs when offset well recoveries exceed 50% of the treatment well recovery. Moderate communication is from 10%-49%, and minimal communication is considered when the offset well recoveries are present but show less than 10% of the treatment well recovery over the same time period.

Figure 28 represents the interwell communication matrix. The pre and post diversion segments of the treatment were each traced with a unique tracer for well Y2. The interwell communication for stages that showed ineffective diversion did not show a significant difference in the early and late fluid communication. There were several instances in which early communication was more significant than late communication. This could be the result of failing to close off fractures that were taking the majority of the treatment and allowing the early fluid to be "pushed" out further as a result. There were several cases in which significant communication was observed during both portions of the treatment. The amount of interwell communication for this pad was less than what is commonly observed in the area. These project results indicated that diversion in conjunction with job size may have helped to mitigate interwell communication. Instances of significant late fluid communication in the absence of early communication were not observed. If this type of communication did take place, it could have been the result of over-diverting to a small post-diversion treatment interval.

Frac Fluid Communication Matrix		Stages	Y 4	Y 3	Y 2	Y 1
Traced Well	Y - 4	3-1	53.6	4.5	8.1	
	Y - 3	1-3		102.3	27.8	0.6
	Y -2	1 E	0.5	11.9	7.4	
		1 L	0.0	9.5	12.7	
		2 E	4.2	4.7	6.0	3.0
		2 L		0.3	6.0	
		3 E	0.0	1.1	14.2	
		3 L		1.1	11.2	0.1
		4 E	3.0	1.4	4.0	3.3
		4 L	4.3	1.8	4.9	5.6
		5 E	0.3	0.3	6.3	1.1
		5 L	0.3	0.9	11.1	3.9
		6 E	0.5		9.1	0.6
		6 L			3.3	
		7 E	5.3	0.1	8.5	3.3
		7 L			9.1	0.9
		8 E			4.1	0.4
		8 L			3.2	
		9 E			12.7	0.3
		9 L			6.2	
		10 E		0.5	8.2	
		10 L		0.3	14.7	0.1
		11 E			9.4	
		11 L			4.3	0.0
		12 E			2.8	0.4
		12 L			2.1	0.2
		13 E			5.9	
		13 L			15.2	1.3
		15 E			2.5	14.7
		15 L			3.8	11.6
	Y - 1	3-1	0.1			45.7

Figure 28—Communication matrix for pad Y

Results

The results for all of the wells evaluated are detailed in Table A.1 in the appendix. The stages are categorized by the type of diverting method used. Coverage is evaluated based on the number of stimulated clusters per stage. Diversion is listed as "yes" when changes in the treatment occur from one portion of the stage to another. Effective diversion occurs when previously unstimulated or under-stimulated clusters improve as a result of the diversion.

Table 3 is a summary of the data included in Table A.1 in the appendix. The data are organized by type of diversion. The number of clusters evaluated for pod diversion was less than for PLA diversion. Perforation efficiency for the two diversion types is very close with PLA showing an average of 88% and 89% for pods. Diversion took place 89% of the time for PLA diversion while the pods diverted 97% of the time. Of this diversion, the PLA wells had effective diversion of 59% while the pods had effective diversion 70% of the time. The pod diversion is a relatively new technology and many of the wells evaluated using PLA were earlier in the lifecycle of diversion. Significant optimization of diversion through completion diagnostics could have taken place during this time.

Table 3—PLA vs. Pods

PLA	Clusters	Perf Efficiency (%)	Diversion?	Effective Diversion?
Stimulated Clusters	1069			
Total Clusters	1220	87.6%	88.7%	59.3%
Pods				
Stimulated Clusters	448.5			
Total Clusters	504	89.0%	97.0%	70.1%

Tables 4 and 5 organize the data in Table A.1 by the number of clusters in each stage. Table 4 shows the results of the PLA diversion by cluster and Table 5 is for pod diversion. The PLA diversion for the range of four to 10 clusters per stage was effective less often by roughly 30%. The pod diversion for stages containing 4-6 clusters had effective diversion 61% of the time, and when the number of clusters per stage increased beyond 6, this number increased by roughly 20%. The data clearly show that diversion is more effective with a higher number of clusters per stage.

Table 4—PLA by clusters per stage

PLA Diversion Summary by Clusters per Stage				
Clusters/Stage	Clusters Evaluated	Perf Efficiency	Diversion	Effective Diversion
4 - 6	69	90%	88%	55%
7 - 10	53	90%	87%	53%
> 10	28	82%	93%	82%

Table 5—Pods by clusters per stage

Pod Diversion Analysis by Clusters/Stage				
Clusters/Stage	Clusters Evaluated	Perf Efficiency	Diversion	Effective Diversion
4-6	38	92%	97%	61%
7-10	16	87%	100%	81%
> 10	13	87%	92%	85%

Conclusions and Recommendations

One of the most interesting observations from the diversion data is that no matter what type of diversion is used, it does have a very high probability of changing the treatment distribution. In the 222 total stages in the table, only 20 stages showed no diversion at all. The other 200 stages did show diversion, but effective diversion was less common. In many cases diversion did open new clusters, but it came at the expense of reducing the total number of clusters treated during the later portion of the treatment.

One recommendation may be to delay diversion drops nearer the end of the treatment instead of dividing them based on equal treatment volumes. This would allow for the majority of the treatment to be distributed into the clusters that initially accept treatment, which is typically greater than 50% of clusters. If the diversion works properly, the few remaining clusters that were not initially treated are treated with a more proportionate volume. Also, if the diversion does not work properly, it will mitigate the risk of treating only a few clusters post-diversion with high volumes.

Through the analysis of the wells in this study, the following conclusions have been drawn:

- Diversion effectiveness continues to be inconsistent from stage to stage
- Diversion can be detrimental when perforation efficiencies are initially high
- Diversion is more effective with a higher number of clusters per stage
- Perforation pods appear to be a viable replacement for conventional plugs for stage fracture treatment isolation

- Conventional plugs may be replaced with proper diversion techniques
- Diverters can be utilized to mitigate offset well communication
- Rate-cycling is a possible alternative to chemical diversion
- Ghost stages should be considered to evaluate rate-cycling
- Open-hole plug-and-perf completions can benefit from pod diversion
- Completion diagnostics should be used to optimize diversion strategies.

Acknowledgments

The authors wish to thank Core Laboratories LP for permission to present this paper. They also wish to thank Katie Karadimas for her contributions to the paper.

Nomenclature

Barrels per minute:	bpm
Cemented plug and perf:	CPnP
Estimated ultimate recovery:	EUR
Equivalent hole diameter:	EHD
Open-hole plug-and-perf:	OH-PnP
Polylactic acid:	PLA
Pounds per square inch:	psi
Shots per foot:	spf

References

Fripp, M., & Walton, Z. (2017, March 6). *Fully Dissolvable Frac Plug Using Dissolvable Elastomeric Elements*. Society of Petroleum Engineers. doi:10.2118/183752-MS

Kiel, O. M. (1977, January 1). *The Kiel Process Reservoir Stimulation By Dendritic Fracturing*. Society of Petroleum Engineers.

Senters, C. W., Leonard, R. S., Ramos, C. R., Wood, T. M., & Woodroof, R. A. (2017, October 9). *Diversion - Be Careful What You Ask For*. Society of Petroleum Engineers. doi:10.2118/187045-MS

Senters, C. W., Warren, M. N., Squires, C. L., Woodroof, R. A., & Leonard, R. S. (2015, September 28). *Reducing Costs and Optimizing Drilling and Completion Efficiencies in Unconventional Plays Using Completion Diagnostics*. Society of Petroleum Engineers. doi:10.2118/174844-MS

Weddle, P., Griffin, L., & Pearson, C. M. (2017, January 24). *Mining the Bakken: Driving Cluster Efficiency Higher Using Particulate Diverters*. Society of Petroleum Engineers. doi:10.2118/184828-MS

Appendix

Table A.1—Diversion results by stage

Well	Stage (s)	Diversion Type	# of Stimulated	# of Clusters	Diversion	Effective
B1	1	PLA	4.0	7.0	Yes	No
B1	2	PLA	5.0	7.0	Yes	No
B1	3	PLA	5.0	5.0	Yes	No
B1	4	PLA	4.0	5.0	Yes	No
B1	5	Pods	5.0	5.0	Yes	Yes
B1	6	Pods	4.5	5.0	Yes	Yes
B1	7	Pods	6.0	7.0	Yes	No
B1	8	Pods	4.0	7.0	Yes	No
B1	9	PLA	4.0	5.0	Yes	Yes
B1	10	PLA	5.0	5.0	Yes	Yes
CM1	1	Pods	5.0	5.0	Yes	Yes
CM1	2	Pods	4.5	5.0	Yes	Yes
CM1	3	Pods	5.0	5.0	Yes	No
CM1	4	Pods	4.5	5.0	Yes	Yes

CM1	5	Pods	5.0	5.0	Yes	No
CM1	6	Pods	5.0	5.0	Yes	No
CM1	7	Pods	4.5	5.0	Yes	Yes
CM1	8	Pods	5.5	6.0	Yes	Yes
CM1	9	Pods	5.0	5.0	Yes	No
CM1	10	Pods	5.0	5.0	Yes	Yes
CM1	11	Pods	4.5	5.0	Yes	Yes
CM1	12	Pods	5.0	5.0	Yes	No
CM1	13	Pods	6.0	6.0	Yes	Yes
CM1	14	Pods	4.5	5.0	Yes	No
CM1	15	Pods	4.5	5.0	Yes	No
CM1	16	Pods	5.0	5.0	Yes	Yes
CM1	17	Pods	5.0	5.0	Yes	No
CM1	18	Pods	6.0	6.0	Yes	No
CM1	19	Pods	4.5	5.0	Yes	No
CM1	20	Pods	2.5	5.0	Yes	No
CM1	21	Pods	3.0	5.0	Yes	No
CM1	22	Pods	4.0	7.0	Yes	Yes
CM1	23	Pods	3.0	5.0	Yes	Yes
CM1	24	Pods	5.0	5.0	Yes	Yes
CM1	25	Pods	6.0	6.0	Yes	Yes
CM1	26	Pods	5.0	5.0	Yes	Yes
CM1	27	Pods	5.0	5.0	Yes	Yes
EF1	1	PLA	9.0	10.0	Yes	No
EF1	2	None	9.0	10.0	Yes	No
EF1	3	None	9.5	10.0	Yes	No
EF1	4	PLA	9.0	10.0	Yes	Yes
EF1	5	PLA	9.0	10.0	No	N/A
EF1	6	PLA	9.5	10.0	Yes	Yes
EF1	7	None	9.0	10.0	No	N/A
EF1	8	PLA	8.5	10.0	No	N/A
EF1	9	PLA	9.5	10.0	No	N/A
EF1	10	PLA	10.0	10.0	Yes	Yes
EF1	11	PLA	10.0	10.0	Yes	Yes
EF1	12	PLA	8.5	10.0	Yes	No
EF1	13	PLA	9.0	10.0	Yes	No
EF2	2	PLA	6.5	7.0	Yes	No
EF2	4	PLA	6.0	6.0	Yes	Yes
EF2	6	PLA	5.0	6.0	Yes	Yes
EF2	8	PLA	6.0	7.0	No	No
EF2	10	PLA	5.5	6.0	No	No
EF2	12	PLA	7.0	7.0	Yes	Yes
EF2	14	PLA	8.0	8.0	No	No
EF2	16	PLA	6.0	6.0	No	No

EF2	18	PLA	4.5	5.0	Yes	Yes
EF2	20	PLA	4.5	5.0	No	No
EF2	22	PLA	6.5	7.0	No	No
EF2	24	PLA	6.0	6.0	No	No
EF2	26	PLA	9.0	10.0	Yes	Yes
EF2	28	PLA	5.5	7.0	No	No
EW1	26	PLA	12.5	14.0	Yes	Yes
EW1	28	PLA	12.5	14.0	Yes	No
EW1	30	PLA	9.0	14.0	Yes	Yes
H1	1	PLA	5.0	5.0	No	N/A
H1	2	PLA	5.0	5.0	No	N/A
H1	3	PLA	5.0	5.0	Yes	Yes
H2	1	PLA	9.5	10.0	Yes	Yes
H2	2	PLA	9.0	10.0	Yes	No
H2	3	PLA	8.0	10.0	Yes	Yes
LHMB1	4	PLA	12.0	15.0	Yes	Yes
LHMB1	6	PLA	13.5	15.0	Yes	Yes
LHMB1	8	PLA	12.5	15.0	Yes	Yes
LHMB1	10	PLA	10.5	15.0	Yes	Yes
LHMB1	12	PLA	9.5	10.0	Yes	Yes
LHMB1	14	PLA	9.0	10.0	Yes	Yes
LHMB1	16	PLA	7.5	8.0	Yes	Yes
LHMB1	18	PLA	7.5	8.0	Yes	Yes
LHMB1	20	PLA	11.0	15.0	Yes	Yes
LHMB1	22	PLA	14.0	15.0	Yes	Yes
LHMB1	24	PLA	13.5	15.0	Yes	Yes
LHMB1	26	PLA	14.0	15.0	Yes	Yes
LHMB1	28	PLA	13.5	15.0	Yes	Yes
LHMB1	30	PLA	13.0	15.0	Yes	Yes
LHMB1	32	PLA	12.0	15.0	Yes	Yes
LHMB1	34	PLA	11.5	15.0	Yes	Yes
M1	1	PLA	8.0	10.0	Yes	Yes
M1	2	PLA	8.5	10.0	Yes	Yes
M1	3	PLA	9.5	10.0	Yes	Yes
M1	4	PLA	9.5	10.0	Yes	Yes
M1	5	PLA	8.0	10.0	Yes	Yes
M1	6	PLA	10.0	10.0	Yes	Yes
M1	7	PLA	10.0	10.0	Yes	Yes
M1	8	PLA	9.5	10.0	Yes	Yes
M2	1	PLA	4.0	5.0	Yes	No
M2	2	PLA	4.5	5.0	Yes	Yes
M2	3	PLA	5.0	5.0	Yes	Yes
M2	4	PLA	5.0	5.0	Yes	Yes
M2	5	PLA	5.0	5.0	Yes	Yes

M2	6	PLA	4.5	5.0	Yes	Yes
M2	7	PLA	4.5	5.0	Yes	Yes
M2	8	PLA	4.5	5.0	Yes	Yes
M2	9	PLA	5.0	5.0	Yes	Yes
M2	10	PLA	5.0	5.0	Yes	Yes
M2	11	PLA	4.0	5.0	Yes	Yes
M2	12	PLA	5.0	5.0	Yes	No
M2	13	PLA	5.0	5.0	Yes	No
M2	14	PLA	5.0	5.0	Yes	Yes
M2	15	PLA	5.0	5.0	Yes	No
MB-1H	30	Pods	6.0	6.0	Yes	Yes
MB-1H	33-32	Pods	9.5	10.0	Yes	Yes
MB-1H	35	Pods	3.5	5.0	Yes	Yes
MB-1H	37	Pods	5.0	5.0	Yes	Yes
MB-1H	40-39	Pods	9.0	10.0	Yes	Yes
MB-1H	42	Pods	3.5	5.0	Yes	Yes
MB-1H	45-44	Pods/DVA (150lbs)	9.0	10.0	Yes	Yes
MB-1H	48-47	Pods	9.5	12.0	Yes	Yes
MB-1H	50	Pods	6.0	6.0	Yes	Yes
NU1	16	PLA	3.0	4.0	Yes	Yes
NU1	17	PLA	4.0	4.0	Yes	Yes
NU1	18	PLA	4.0	4.0	Yes	Yes
NU1	20	PLA	4.0	4.0	No	No
NW2	2	PLA	8.0	8.0	Yes	No
NW2	4	PLA	7.0	8.0	Yes	No
NW2	6	PLA	7.0	8.0	Yes	No
NW2	8	PLA	7.0	8.0	Yes	Yes
NW2	10	PLA	8.0	8.0	Yes	No
NW2	12	PLA	7.5	8.0	Yes	No
NW2	14	PLA	7.5	8.0	Yes	Yes
NW2	16	PLA	7.5	8.0	Yes	No
NW2	18	PLA	8.0	8.0	Yes	Yes
NW2	20	PLA	3.0	4.0	No	No
O1	1	Pods	8.0	8.0	Yes	Yes
O1	7	Pods	7.0	8.0	Yes	Yes
O1	2	Pods	12.0	12.0	Yes	Yes
O1	3	Pods	11.5	12.0	Yes	Yes
O1	4	Pods	11.5	12.0	Yes	Yes
O1	6	Pods	11.5	12.0	Yes	Yes
O1	5	Pods	15.5	16.0	Yes	Yes
P1	1	PLA	9.5	10.0	Yes	Yes
P1	2	PLA	9.0	10.0	Yes	Yes
P2	1	PLA	10.0	10.0	Yes	Yes
P2	2	PLA	7.5	10.0	Yes	No

P2	3	PLA	5.0	5.0	Yes	Yes
P3	1	Pods	11.0	14.0	Yes	Yes
P3	2	Pods	12.5	14.0	Yes	Yes
P3	3	Pods	13.0	14.0	Yes	Yes
P4	1	Pods	9.0	9.0	Yes	Yes
P4	2	Pods	7.0	9.0	Yes	No
P4	3	Pods	8.5	9.0	Yes	Yes
P5	1	Pods	8.0	9.0	Yes	Yes
P5	2	Pods	7.5	9.0	Yes	Yes
P5	3	Pods	7.5	9.0	Yes	Yes
PB3	1	PLA	7.0	7.0	Yes	Yes
PB3	2	PLA	7.0	7.0	Yes	No
PB3	3	PLA	6.0	7.0	Yes	No
PB3	4	PLA	12.0	12.0	Yes	Yes
PB3	5	PLA	10.0	12.0	Yes	No
PB3	6	PLA	9.0	12.0	Yes	Yes
PB3	7	PLA	12.0	12.0	Yes	Yes
PB4	1	PLA	10.0	12.0	Yes	Yes
PB4	2	PLA	8.5	12.0	Yes	Yes
PB4	3	PLA	2.0	12.0	No	No
PB4	4	PLA	8.0	12.0	Yes	Yes
PB4	5	PLA	17.0	18.0	No	No
PB4	6	PLA	17.5	18.0	Yes	Yes
PB4	7	Pods	8.5	12.0	Yes	No
PB4	8	Pods	10.0	12.0	No	No
PB4	9	Pods	15.0	18.0	Yes	Yes
PB4	10	Pods	13.5	18.0	Yes	Yes
TF-1H	3	Pods	4.0	4.0	No	N/A
TF-1H	5	Pods	4.0	4.0	Yes	Yes
TF-1H	8-7	Pods	6.5	8.0	Yes	Yes
TF-1H	13	Pods	4.0	4.0	Yes	Yes
TF-1H	18	Pods	4.0	4.0	Yes	No
TF-1H	20	Pods	3.5	4.0	Yes	No
TF-1H	11-10	Pods	7.5	8.0	Yes	Yes
TF-1H	16-15	Pods	8.0	8.0	Yes	Yes
TF-1H	23-22	Pods/DVA (150lbs)	8.0	8.0	Yes	Yes
WBT1	3	PLA	5.0	6.0	Yes	Yes
WBT1	6	PLA	6.0	6.0	Yes	No
WBT1	9	PLA	6.0	6.0	Yes	Yes
WBT1	12	PLA	5.5	6.0	Yes	Yes
WBT1	15	PLA	5.0	6.0	Yes	No
WBT1	18	PLA	6.0	6.0	Yes	Yes
WBT1	21	PLA	5.0	6.0	Yes	Yes
WBT1	24	PLA	5.5	6.0	Yes	No

WBT1	27	PLA	6.0	6.0	Yes	No
WBT1	30	PLA	6.0	6.0	Yes	No
WBT1	33	PLA	6.0	6.0	Yes	Yes
WBT1	36	PLA	5.5	6.0	Yes	Yes
WBT1	39	PLA	6.0	6.0	Yes	Yes
WC3	2	PLA	3.5	6.0	Yes	No
WC3	4	PLA	6.0	6.0	Yes	Yes
WC3	5	PLA	6.0	9.0	Yes	Yes
WC3	7	PLA	4.0	6.0	Yes	No
WC3	9	PLA	11.5	12.0	Yes	Yes
WC3	17	PLA	6.0	6.0	Yes	No
WC3	11	PLA	3.0	5.0	Yes	Yes
WC3	19	PLA	7.0	9.0	Yes	No
WC3	21	PLA	5.0	6.0	Yes	No
WC3	23	PLA	9.5	12.0	Yes	Yes
WC3	25	PLA	4.5	5.0	Yes	No
WC3	29	PLA	6.0	6.0	Yes	No
WC3	31	PLA	9.0	9.0	Yes	No
WC3	33	PLA	6.0	6.0	Yes	No
WC3	35	PLA	10.5	12.0	Yes	No
WCS2	4	PLA	3.0	6.0	Yes	No
WCS2	7	PLA	4.5	6.0	Yes	Yes
WCS2	10	PLA	5.0	6.0	Yes	No
WCS2	13	PLA	5.5	6.0	Yes	Yes
WCS2	16	PLA	4.5	6.0	Yes	No
WCS2	18	PLA	4.5	6.0	Yes	No
WCS2	21	PLA	4.5	6.0	Yes	Yes
WCS2	24	PLA	5.5	6.0	Yes	No
WCS2	27	PLA	5.0	6.0	Yes	Yes
WCS2	30	PLA	5.0	6.0	Yes	Yes
WCS2	32	PLA	4.5	6.0	Yes	Yes
WCS2	35	PLA	5.0	6.0	Yes	Yes