OPTIMUM USE OF DIVERTING AGENTS IN STIMULATION TREATMENTS

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INTRODUCTION

The importance of properly diverting stimulation treatments was recognized as early as the 1930's. However, each new technique or material developed has carried with it limitations in applicability. It has become evident that a universally effective diverting agent is unlikely. This paper will deal almost exclusively with recent Shell Oil Company experience in the use of "solid" diverting agents in the fracture treatments. The popularity of these materials is a measure of their effectiveness.

EARLY DIVERTING AGENTS

Diverting agents in one form or another have been used since 1936. Insoluble precipitates, gels, and mechanical packers were used throughout the 1930's and 1940's. During the 1950's emulsions, mothballs, rock salt, and ball sealers were used with varying degrees of success, while the 1960's brought development of the limited entry technique, Temp-Trol, Unibeads™, paraformaldehyde, and benzoic acid flakes.[1]

PURPOSE OF DIVERTING AGENTS

While materials and techniques have varied, they generally represent recognition of the fact that an efficient stimulation treatment must contact all potential pay zones in the wellbore with treating fluids. The major requirements of a good diverting agent are (1) diverting fluid entry into zones of progressively lower permeability as injection continues, regardless of the completion technique or the quality of cement seals, (2) compatibility with stimulation fluids under prevailing temperature and pressure conditions, and (3) compatibility with reservoir rock and fluid properties, promoting rapid clean-up without lasting productivity impairment.

The principal well conditions which require emphasis on diversion are (1) thick, heterogeneous pay zones, (2) poor cement jobs, (3) multiple pay zones, (4) open-hole completions and (5) densely perforated intervals.

THE PROCESS OF DIVERTING

Diverting materials mechanically plug flow channels into the treated zone, stopping fluid flow. These passages may be perforations, pores or formation fractures. Upon completion of the treatment, these plugs must be removed or dissolved to maximize production. Most diverting materials are designed to be dissolved by well fluids. Generally, this requires movement of an unsaturated fluid past the blocking material. In the wellbore this will only take place when fluid is produced as leakage through the material. Shell has experienced virtually no clean-up problem in wells when using benzoic acid sufficient to give 50-200 psi surface treating pressure increases. This suggests that the leak-off rate of benzoic acid under these conditions is adequate for effective clean-up.

LABORATORY RESULTS

Quantitative comparisons of leak-off rates for various diverting agents are presented in Table 1. Test results indicate two distinct features must be considered in designing blocking stages. They also indicate that mixtures of the common diverting agents can be more effective than a single agent in many cases.

Four common agents, graded benzoic acid

flakes, graded moth balls, graded rock salt, and Wide-Range Unibeads™ were tested for both leak-off rate and block holding strength (data not shown). These tests show that graded rock salt and moth balls form filter cakes capable of withstanding greater differential pressures than the other agents but rock salt particularly exhibits far higher leak-off rates. This tends to explain a common occurrence in rock salt diverted treatments where a good block is developed but breaks down. It is believed that this is due to the high leak-off rate which tends to dissolve the salt during treatment and weakens the block. According to laboratory test results, this leak-off can be reduced to 10% of the rock salt value by mixing equal parts of benzoic acid and salt. Field results with this mixture have been excellent. The resulting blend has been found to be so much stronger and a more efficient blocking agent with good clean-up properties. Experience also shows that graded materials (exhibiting a wide range of particle sizes) are superior.

The test apparatus consisted of steel cylinders 2.5 in. in diameter and 2.5 ft long, mounted in a vertical position. The top of the cylinder was covered with a cap containing connections to a pressure source. The bottom cap was slotted with one slit 2-in. long and 0.1-in. wide. On the inside of the cap and attached around the slot was a simulated fracture. The fracture tapered from 0.1 in. at the cap to 0.4 in. at top which was 2 in. above the cap.

The cylinder was loaded with gelled water containing the diverting agent. Pressure was applied and the leak-off rate was recorded. Tests which did not dehydrate in 10 min were terminated at that time. The diverting agent was mixed at 1½ lb/gal, pressure applied was 200 psi, and the fluid temperature was 74°F.

GUIDELINES

Effective guidelines for fracture treatment use have been developed from temperature controlled stimulations. Guidelines developed in this manner generally vary with the method of temperature log interpretation. We have used the "fade-out" method which involves running approximately three logs over the zone at 15-min intervals. Not only temperature anomalies but also temperature changes are regarded as significant. (Fig. 1)

TABLE 1*

Diverting Agent % Divert II	Diverting Agent % Rock Salt	Leak-off Rate ml/min
100	0	2.4
75	25	84.0
50	50	567.0
25	75	2400.0
0	100	5400.0
	% Unibeads	
100	0	2.4
75	25	5.0
50	50	3.7
25	75	5.5
0	100	253.0
	% Moth Balls	
100	0	2.4
75	25	1.5
50	50	0.4
25	75	0.3
0	100	0.1
% Unibeads	% Rock Salt	
100	0	253.0
75	25	1600.0
50	50	2400.0
25	75	3150.0
0	100	5400.0
% Moth Ball	% Rock Salt	
100	0	0.1
75	25	4.6
50	50	40.0
25	75	2640.0
0	100	5400.0
% Moth Ball	Unibeads	
100	0	0.1
75	25	0.6
50	50	0.3
25	75	1.5
0	100	253.0

* Courtesy of Byron Jackson Company

Using this interpretation method, accurate and reflectable information was acquired which led to a workable guideline in the Jordan University Unit San Andres formation, (Table 2).

No guideline can be universally effective; therefore, the Jordan University Unit data primarily served as a basis for construction of

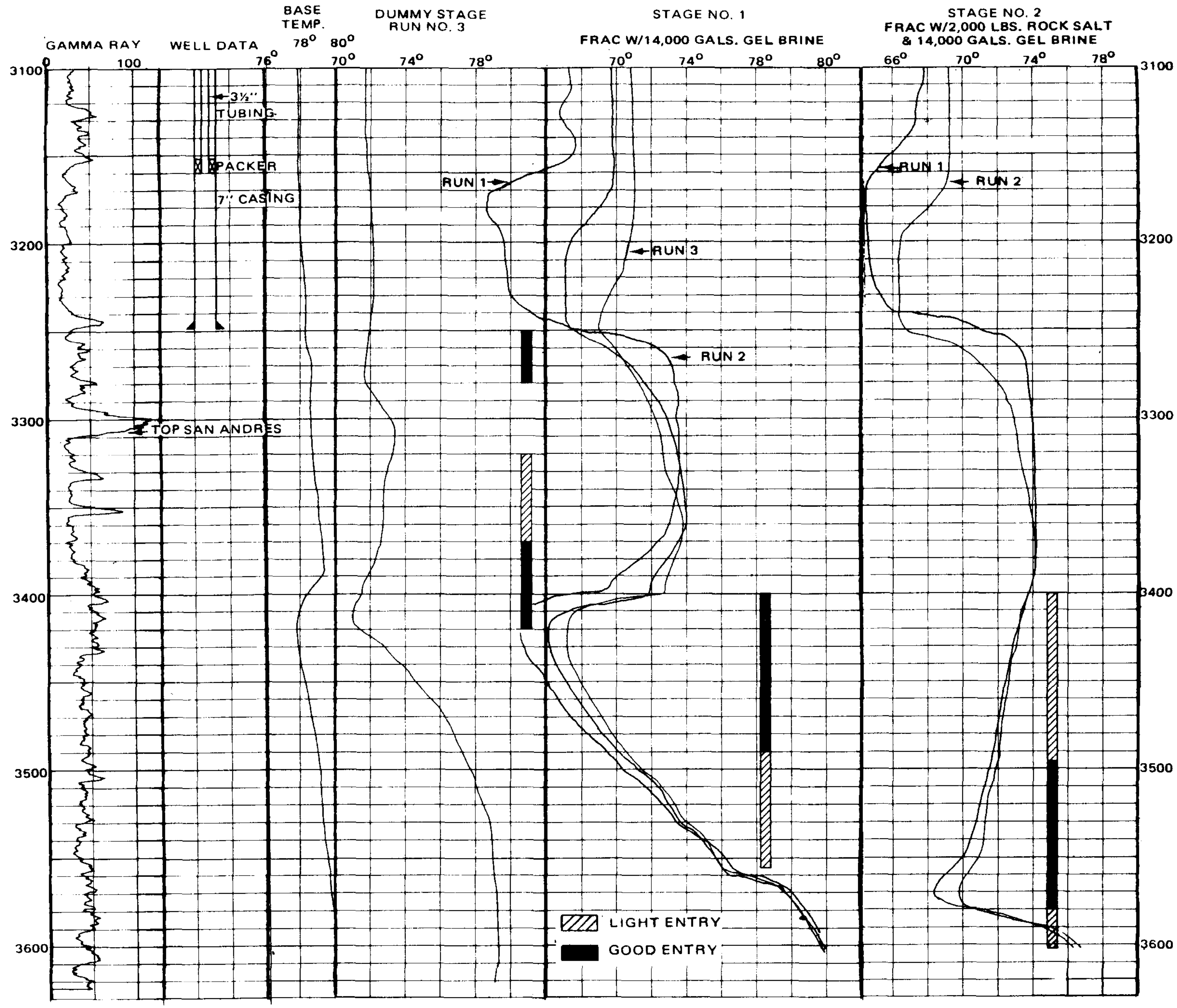

FIG. 1—JORDAN UNIVERSITY UNIT WELL NO. 421, STIMULATION ANALYSIS

TABLE 2

Materials	Lb/ft of Fracture Height
Graded Rock Salt	18 lb/ft
Moth Balls	14 lb/ft
Unibeads	6 lb/ft
Benzoic Acid	8 lb/ft

guidelines in other fields. All of the formations treated by Shell's Mid-Continent Division in the past four years have required less diverting agent per foot than the Jordan University Unit. However, we found that in the Jordan San Andres, 80% of guideline volume would give a block sufficient for diverting without serious breakdown of the material in place. Also we found that up to 120% of guideline volume could be used without overblocking to the extent that impairment (slow clean-up and blocking-out of zones desired to be treated) resulted.

This range of 80-120% provided enough flexibility to apply the basic Jordan Unit guideline to other fields. Knowing that (1) most zones require less diverting agent than the Jordan University Unit, (2) the range 80-120% of guideline volume is workable, and (3) overblocking may cause adverse effects, the lower limit (80%) is used in fields and formations where we have not established other reference data, (Table 3). This 80% guideline is used for the first stage of diverting material and a temperature survey is run. The amount of material is then altered for subsequent stages based on performance indicated by the temperature survey. Production results to date have been excellent, (Fig. 2).

There appears to be little correlation between fracture gradient and diverting guidelines from one field to another. However, variance in fracture gradient from well to well in the same field can be an indicator that diverting volume guidelines must be altered. Therefore, a good average of the fracture gradient is needed. It appears that if a fracture gradient exceeds the field average by 15% or more, the amount of diverting agent should be reduced. This application is particularly advisable in zones that have been squeeze-cemented. The diverting volume has sometimes been successfully decreased by 50% in this case.

The diverting material is generally pumped in a carrier fluid mixed 1 lb to 1½ lb/gal at treating rates. If the material is pumped at higher concentrations, bridging seems to occur in or near the wellbore and is very susceptible to breakdown on following stages. If the material is pumped at lower concentrations, there appears to be little or no diverting action. The diverting materials should be pumped at treating rates so that the formation fractures are open and can be bridged.

DIVERTING MATRIX ACID TREATMENTS

Because they are difficult to interpret for matrix acid jobs (and of questionable validity), temperature evaluation surveys are seldom used to size diverting stages. We have used a procedure based on the fracture treating guideline for that field or formation.

Net pay is obtained from a porosity log and multiplied by the fracture treatment guideline for the formation. This volume of diverting agent is divided into equal stages and pumped in a spacer between the acid stages. The spacer is not gelled because this method invariably leads to an excess of diverting agent at some time during the treatment. If carried in an ungelled spacer, most of the excess blocking agent should fall out before causing a premature diversion from the next zone treated.

Some of the better acid treatments have pressure increases of 50-100 psi per stage. These increases are difficult to see on a treating pressure log. A good indication that changes should be made in the diverting agent volume is the amount of fill in the well due to diverting agent fall-out. In general, there should be a small amount of fill. A large amount of fill occurring from diverting materials indicates that smaller stages or lower guidelines are required.

CONCLUSIONS

The proper use and sizing of diverting agent stages can lead to more effective stimulation. Test results indicate both fluid leak-off rate and block strength to be of great importance to diverting material performance. The use of temperature evaluation logs has made possible the development of quantitative guidelines applicable to most West Texas carbonate reservoirs.

REFERENCE

1. Harrison, N.W.: Diverting Agents - History and Application, *Jour. Petr. Tech.*, May, 1972.

TABLE 3

Materials	Lb/ft of Fracture Height
Graded Rock Salt	14.4 lb/ft or 14.5 lb/ft
Moth Balls	11.2 lb/ft or 11.0 lb/ft
Unibeads	4.8 lb/ft or 5.0 lb/ft
Benzoic Acid	6.4 lb/ft or 6.5 lb/ft

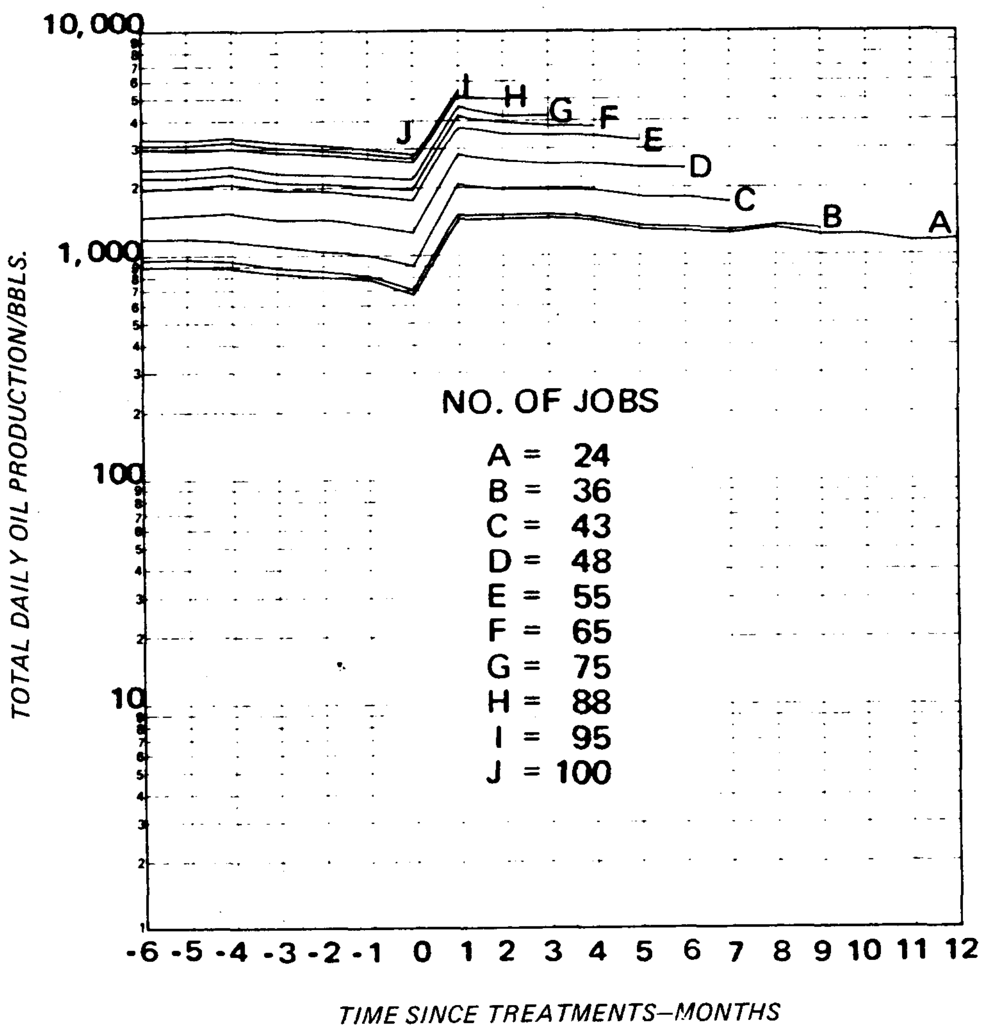

Fig. 2—MID-CONTINENT DIVISION
TREATMENTS WITH DIVERTING AGENTS
1969-1971