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USE OF GLASS BEADS AS A PROPPING AGENT IN HARD FORMATIONS

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ABSTRACT

Analysis of fracturing techniques in correlation with formation characteristics and past treatments has resulted in the development of a method to increase the flow capacity of artificially created fractures.

Glass beads, a recently developed propping agent, have proved more effective than other rigid or deformable props in all hard formations tested. When placed in a partial monolayer in such formations, they provide a higher fracture flow capacity than any existing prop, and are hard enough to withstand the overburden pressure in any presently produced formation.

Beads can be used as a tail-in following other props, to give a high flow capacity through the critical area immediately around the wellbore. Also, they may be used alone to provide a maximum flow capacity throughout the entire fractured area.

Use of glass beads does not require any additional preparations over conventional fracture treatments. Fracture areas created are calculated in the normal manner. The increased flow capacity is contributed by the hardness, shape, size and placement of the prop.

The first use of beads in the Uintah Basin was in April, 1962, as a prop in the Green River sand. Since then, their use has expanded to other fields and formations. Field results have proved the beads superior to conventional propping agents for hard formations in both new and old wells.

References and illustrations at end of paper.

INTRODUCTION

Since the introduction of hydraulic fracturing as a stimulation treatment, it has been recognized that the full potential is not always realized from this type treatment. Early investigations showed that a large fracture area is required for adequate drainage of a reservoir. More recently, it has been shown that benefits of fracturing, even where large fracture areas are obtained, are frequently limited by low capacity fractures. In order to maintain high well productivity, high conductivity drainage channels are necessary to provide easy access to the wellbore for the reservoir fluids. Special propping agents have now been developed which permit high flow capacity fractures to be placed in nearly any type of formation. The purpose of this paper will be to discuss properties and use of glass beads, a rigid, high-strength propping agent recently developed for use in hard formations.

FLOW CAPACITY

As the fluid pressure within a formation decreases following a fracture treatment, the fracture tends to "heal". In other words, the fracture faces tend to close together and eliminate the drainage channels which have been created.

To prevent complete closure, various materials, or propping agents, are placed within the fracture.

A fracture may be propped in two ways. Until the past few years, high concentrations of propping agents were used in an attempt to completely pack the created fracture. It was thought that a fully packed fracture would have greater resistance to closure and a greater fracture width would be maintained. In this type of propping, fracture flow capacity, or conductivity, has been defined as the product of the fracture width and the permeability of the propping agent.

It has since been found that a sparse distribution of propping agent within a fracture will frequently result in a higher flow capacity than will the full pack. This is due to the fact that the fluid can flow around the sparsely spaced prop more easily than it can flow through the full pack. This method of spacing the prop has been termed "Partial Mono-layer Propping".

EFFECTS OF FORMATION HARDNESS

As a formation attempts to close following a fracture treatment, two things may happen to the propping agent particles. If the formation is soft, the particles will embed in the formation along the faces of the fracture and width of the fracture is reduced. This can be overcome by larger particle size [10-20 or 8-12 mesh particles] and use of deformable props such as rounded walnut shells or aluminum pellets. Since these particles tend to flatten as load is applied, they present a greater bearing area to the faces of the fracture and resist penetration into the formation.

Hard formations may be described as those which resist embedment. Low-strength propping agents, such as sand, will crush or shatter in these formations as overburden load becomes effective following the fracture treatment. Deformable props are useful since they will not shatter; but greatest fracture width and highest conductivity can be obtained through use of a rigid, high-strength propping agent such as glass beads.

SPECIFICATIONS

Glass beads can be defined as vitreous, rigid, spherical bodies, designed as a propping agent for hydraulic fracturing. No formal specifications have been issued, but the following specifications generally are adhered to at the present time:

1. Specific Gravity . . . . . 2.62 gm/cc
2. Size . . . . U.S. Mesh Size [At least 95 per cent must fall within designated mesh size; i.e., 8-12--0.0937 x 0.0661 in. opening--etc.]
3. Sphericity . . . . Min 0.8
   This is determined by the formula:
   $$\text{Sphericity} = \sqrt[3]{\frac{\text{Volume of Sphere}}{\text{Volume of Circumscribing Sphere}}}$$
4. Roundness. . . . . Min. 0.8
   This is determined by the formula:
   $$\text{Roundness} = \frac{\text{Minimum Diameter}}{\text{Maximum Diameter}}$$
5. Compressive Strength . . 100,000 psi
   This is determined by the formula:
   $$\text{psi} = \frac{L_c}{D^2}$$
   Where L_c is the critical load measured in pounds and D^2 is the product of the maximum and minimum diameters of the sphere.

COMPARISON WITH SAND

Laboratory evaluation of glass beads has been previously published[3] and will not be described here. Comparison of some of the properties of beads and sand as propping agents is of interest and is shown in the following table:

TABLE 1

	Glass Beads	Sand
Mesh Size	12-20	10-20
Shape	Nearly Round	Sub-angular
Specific Gravity	2.62	2.6
Compressive Strength	100,000 psi	10,000 psi
Flow Capacity [6,000 psi Overburden]	78 Darcy ft	2.1 Darcy ft
Optimum Concentration	110 lb/1,000 sq ft	200 lb/1,000 sq ft

Comparative flow capacities at 6,000 psi overburden are as shown in Table 2 [see Figs 1, 2 and 3].

PLACEMENT OF PROP

In designing a fracture treatment, the type of prop selected can be used in conjunction with FRAC GUIDE* calculations to determine the size of the treatment. For vertical fractures:

$$\text{Fracture Capacity Ratio} = \frac{K_f W}{K}\sqrt{\frac{40}{S}}$$

where: $K_f W$ = Fracture conductivity in Darcy-ft [K_f = Fracture permeability - Darcys] [W = Fracture width - feet]
K = Effective horizontal permeability, md
S = Well spacing; acres.

If the following well conditions are assumed:

*Dowell Trademark

TABLE 2

Prop	Mesh	Placement	Optimum Concentration	Flow Capacity [Darcy-ft]
Sand	20-40	Packed Fracture	850 lb/1,000 sq ft	0.6
Sand	20-40	Partial Monolayer	150 lb/1,000 sq ft	0.1
Sand	10-20	Partial Monolayer	200 lb/1,000 sq ft	2.1
Beads	12-20	Partial Monolayer	110 lb/1,000 sq ft	78.0

[1] Formation Classification. . .Very hard
[2] Effective Horizontal Perm. [K] . . . . .20 md
[3] Well Depth. . . . . .6,000 ft
[4] Effective Pay Thickness . . .20 ft
[5] Well Spacing. . . . . .40 acres

Then, for a partial monolayer-type of propping using 10-20 mesh sand:

$$\text{Capacity Ratio} = \frac{2.1}{20}\sqrt{\frac{40}{40}}$$

Capacity Ratio = 0.11

For this condition, it can be shown that [see Fig. 4], even if 100 per cent of the spacing area is penetrated by the fracture, the maximum production increase that can be obtained is only a two-fold increase.

However, if a partial monolayer-type of propping with 12-20 glass beads is used, then

$$\text{Capacity Ratio} = \frac{78}{20}\sqrt{\frac{40}{40}}$$

Capacity Ratio = 3.9

For this condition [see Fig. 4], a six-fold production increase can be obtained with only a 33 per cent penetration of the spacing area.

When the desired fracture area for a given treatment has been calculated and the volume and type of fluid to create this area determined, the concentration of propping agent may be determined easily as follows:

Desired Fracture Area. . .	25,000 sq ft
Volume of Fluid Required .	9,000 gal
Optimum Prop Concentration	110 lb/1000 sq ft

In this instance, 2,750 lb of prop would have to be placed in 9,000 gal of fluid, or required concentration is 0.3 lb per gallon.

Normally, this method of placement can be used most beneficially where a partial monolayer in a horizontal fracture is indicated. The concentration generally used in vertical fracturing varies from 1/2 to 1-1/2 lb per gallon, depending on the properties of the fracturing fluid.

FIELD RESULTS

Glass beads were first used in the Uintah Basin in April, 1962, as a propping agent in the Green River sand. Since that time, this use has expanded to three additional formations in four fields. More than 100 treatments using glass beads were performed last year in this area, and results on both new and old wells were better than those obtained with conventional props. Higher initial production and less severe decline has been noted on new wells. Re-frac treatments with beads have shown appreciable increases, while those with conventional propping agents have either failed or resulted in very small increases.

Some comparative results for two of the fields in the Uintah Basin are shown below:

Field A:

Formation Characteristics

Sand Classification	Very Hard
Existing Fractures	Vertical
Bottom-hole Pressure.	1,500 psi
Porosity	12 per cent
Permeability.	50 md
Producing Depth	5,600-5,800 ft

Production Results

Well No.	Completion Date	Prop	Initial Production	Prod. 1-1-63	Prod. 7-1-63	Prod. 12-1-63
2	12-18-62	Beads	612	560	257	164
3	8-4-60	Sand and Walnut Shells	156	90	64	57
4	5-31-61	Sand and Alum. Pellets	210	215	170	129
6	5-22-62	Beads	357	145	70	48
7	8-11-62	Beads	272	387	200	171
10	11-9-62	Beads	445	341	256	179

Field B:

Formation Characteristics

Sand Classification	Very Hard
Existing Fractures	Vertical
Bottom-hole Pressure	800 psi
Porosity	3 per cent
Permeability	8 md
Producing Depth	5,800 ft

Production Results

Well No.	Prod. Before	Treatment Date	Prod. 6-1-63	Prod. 12-1-63
7	10 oil 3 water	9-14-63	135 [10-1-63]	29
8	28	5-1-63	248	160
9	15 oil 23 water	5-29-63	52 oil 109 water	18 oil 29 water
25	32 oil 109 water	7-12-63		45 oil 31 water

Six additional wells have since been fractured in this field as a result of the increases obtained on the above wells.

CONCLUSIONS

Field evaluation has shown high-strength glass beads to be superior to conventional propping agents in hard and very hard formations. Results of their use in the Uintah Basin prove that high flow capacity fractures can be created in such formations, and that favorable production increases can be obtained in both new and old wells.

The use of glass beads is not a solution for all wells, but the more favorable increases obtained in hard formations generally have more than offset any increased cost of the beads over that of conventional propping agents.

ACKNOWLEDGMENTS

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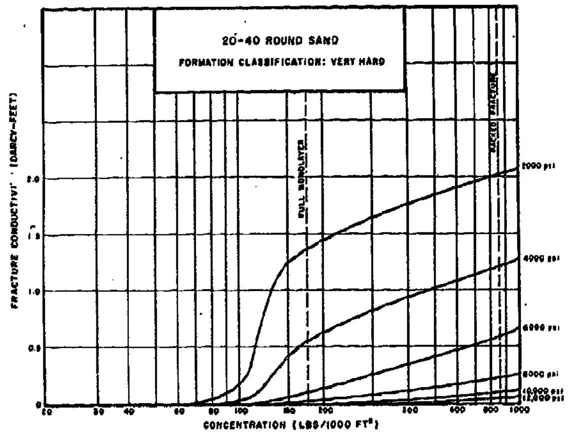

FIG. 1

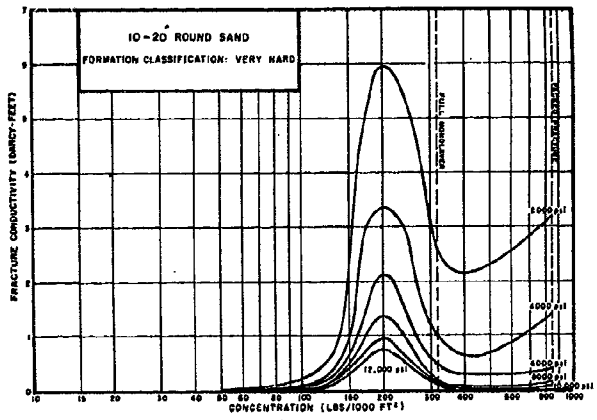

FIG. 2

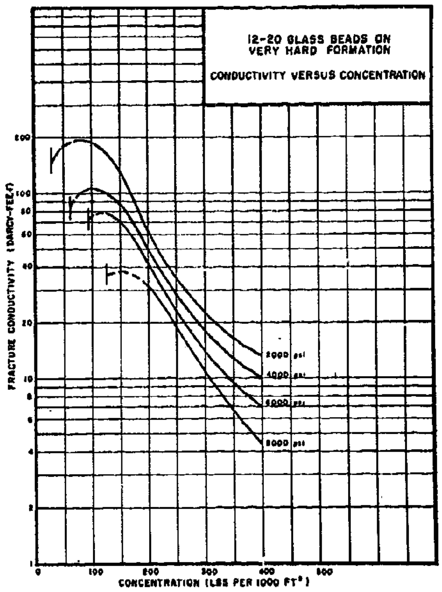

FIG. 3

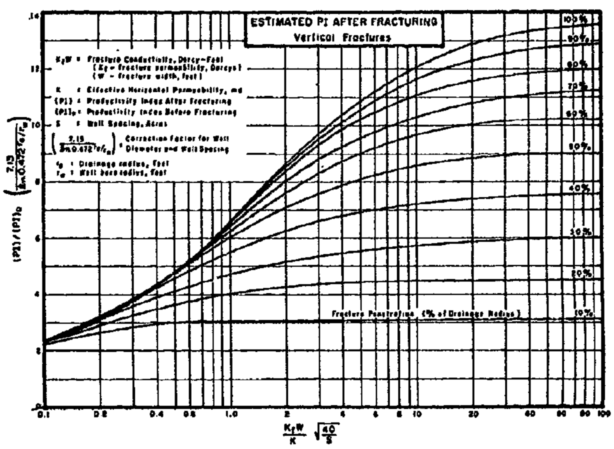

FIG. 4