THE DESIGN OF HYDRAULIC FRACTURING TREATMENT FOR DEEP, HOT WELLS

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INTRODUCTION

The search for oil and gas has led to the exploration of deeper, hotter, and tighter formations. Producing zones which would have been considered non-commercial a few years ago are being stimulated to produce commercial quantities of hydrocarbons. This paper deals with the design of fracturing treatments in this type of reservoir.

PENETRATION

The first consideration is the desired penetration. Deeper penetration requires more efficient fluids from the point of view of both fluid efficiency and prop transport efficiency. The standard definition of fluid efficiency is created volume divided by the fluid volume pumped.

$$\text{Fluid Efficiency} = \frac{\text{Created Volume}}{\text{Pumped Volume}} \times 100$$

There are a number of methods that can be used to increase fluid efficiency. In the past, fluid-loss additives have been added to decrease fluid leakoff. This practice is not particularly good in very tight formations and will not be considered here. Addition of higher concentrations of gelling agent is a good way to increase fluid efficiency. This technique is ideal for viscosity-controlled fluids, i.e. cellulose-based fluids.[1] Crosslinking of the polysaccharide-base gelling agents increases the efficiency of these gels dramatically, as illustrated in Figure 1. The addition of small quantities of oil to these crosslinked fluids results in a *dramatic* increase in their fluid efficiency.

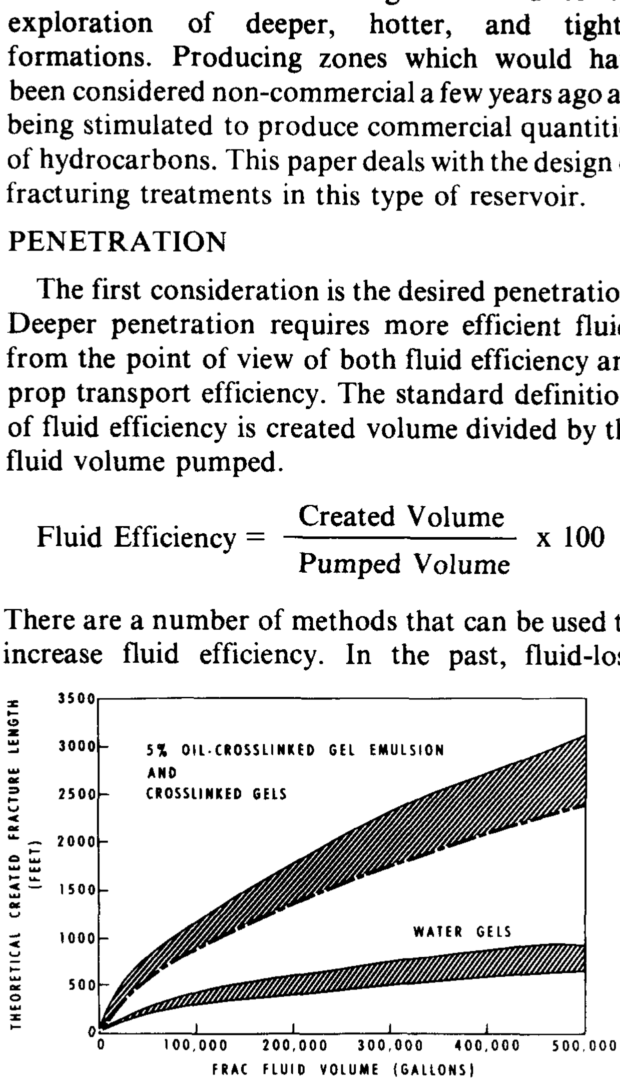

FIG. 1—COMPARISON OF EFFICIENCY OF NORMAL AND CROSSLINKED WATER GELS.

TEMPERATURE

In high-temperature formations the effect of temperature on the fluid must be taken into account. Interestingly enough, the crosslinked polysaccharide and the crosslinked polysaccharide 5-percent oil emulsions maintain their fluid efficiency at higher temperatures even though there is some loss in viscosty. This means that at temperatures above 250°F where most fracturing fluids lose a significant portion of their viscosity, fluid-loss efficiency is affected to a lesser extent in these fluids (an important factor in depth of penetration).

Since efficient fluids create more fracture volume per gallon of fluid pumped, it should be obvious that a more expensive, efficient fluid can be more cost effective than a cheaper, less-efficient fluid.

PROP TRANSPORT

Another consideration in fracture design is prop transport. Fracture orientation with respect to the producing interval and cool down of the fracture by the frac fluid are important factors here.

In the initial planning stages, it is important to consider expected zone coverage. Confining a frac job to a specific zone is difficult, and care must be taken to place as much of the propping agent as possible in the most productive part of a zone. There are four possible places that a fracture can go in relation to the zone.

(1) The fluid will stay in zone (Figure 2a).
(2) The fluid will frac down out of zone (Figure 2b).
(3) The fluid will frac up out of zone (Figure 2c).
(4) The fluid will frac both up and down out of zone (Figure 2d).

The last case is a general case of fracturing a long string of intermittent short zones. The particular type of zone coverage desired will determine the type of fluid pump, the rate, and the concentration of propping agent. For example, if a long zone is to be covered with maximum penetration of propping agent, a high-viscosity fluid and a high concentration of propping agent is desirable.

The importance of leaving propping agent in the

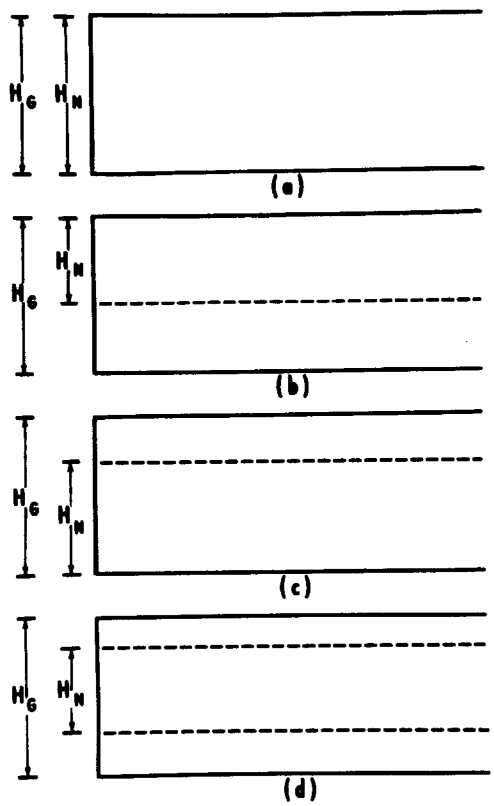

FIG. 2—FRACTURE PLACEMENT WITH RESPECT TO PRODUCING INTERVAL.

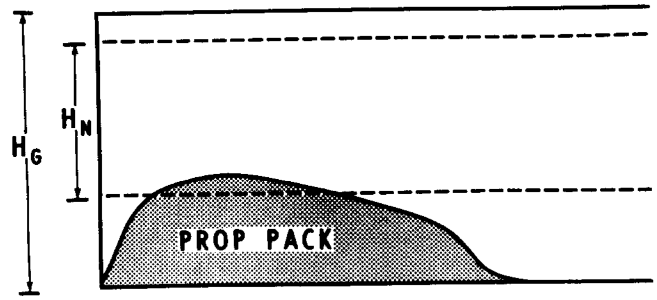

FIG. 3—PROP PACK THAT RESULTS FROM FRACTURING DOWN OUT OF ZONE.

producing interval cannot be overstressed. If a fracture grows out of a zone, there is a good chance that a situation similar to that depicted in Figure 3 can occur. In most cases, it is important to pump the highest concentration of propping agent possible to ensure good zone coverage of the prop.

In some areas, it has been difficult to pump high concentrations of propping agent without a screenout. Through a field experimental program coupled with laboratory work, it has been determined that excessive fluid loss through a network of hairline fractures is responsible for the screenout problem. A unique method that has proved effective in a number of areas throughout the country has been developed to solve this problem. The addition of 100-mesh sand to the pad has allowed much higher propping agent concentrations to be used following the pad and has resulted in significantly better treatment results.

COOL DOWN

An excellent example of the cooling effect of the frac fluid on the fracture may be found in Figure 4. In this case, the lines on the curve that project outward from the plane of the paper respresent increments of pumping time. The whole plot may be termed a cool-down profile of time, temperature, and penetration surface. The effect of the cool down must be taken into account in design of the prop transport. Typically, a pad fluid precedes the prop-laden fluid into the well. In the treatment of deep, hot wells, it is necessary to increase the volume of the pad: for example, in a 100,000-gallon treatment in a well with a BHST of less than 200°F, it might be necessary to use a 10,000 to 20,000 gallon pad, while in a well with a BHST greater than 200°F a pad of 25,000 to 35,000 gallons or greater might be

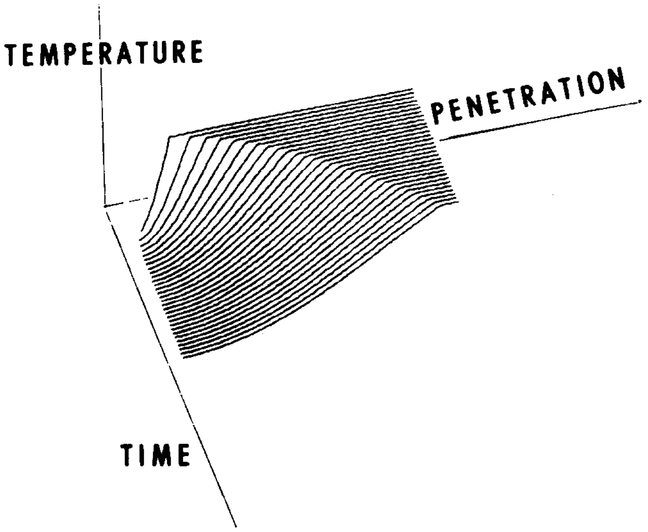

FIG. 4—TEMPERATURE PROFILE FOR A 280°F WELL DURING A 300,000 GAL. TREATMENT.

required. This pad serves two functions: it establishes leak-off control, and it cools the fracture down.

The leak-off control is necessary for good fluid efficiency and the cool down is necessary for good viscosity maintenance. To maximize prop-transport it is necessary to maintain the viscosity above 20 cps. Crosslinked gels with or without 5-percent oil will meet this criterian at temperatures below 230°F. Figure 4 shows that through a large portion of a treatment, the prop-carrying fluid will be below this temperature even in a well with a BHST of 280°F.

CONCLUSIONS

In conclusion, it is necessary to plan the treatment of deep, hot wells carefully. A good treatment design will take into account the desired penetration of the fluid, the efficiency of the fluid, prop-transport characteristics of the fluid, and cool down of the fracture by the fluid. In general, high-viscosity, efficient fluids carrying high prop concentrations give the best results in deep wells.