A PRACTICAL METHOD OF MONITORING STIMULATION FLUID ENTRY INTO POTENTIAL PRODUCING ZONES

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INTRODUCTION

Agnew[1] has proposed that temperature be utilized as a method for obtaining knowledge of the portion of a reservoir which has actually been stimulated. This particular method of evaluating frac and acid treatments has been utilized for several years. Additional evidence for the use of radioactive materials with temperature has recently led to the utilization of techniques involving the use of RA materials in conjunction with temperature, which lends a more quantitative perspective to treatment design and interpretation. This is particularly true when the combined techniques are used in conjunction with selective staging of fracturing and acidizing treatments.

THEORY AND PROCEDURES

Since the theory of temperature has been fairly well established over the years, discussion will be confined to the use of RA materials and how their interpretation can lend a more complete diagnosis of fluid entry points. One of the primary objections to using RA materials has been the cost. To date, this objection has been virtually eliminated because of the development of better diagnostic equipment for use down hole, which allows a smaller quantity of RA material to be placed onto propping agents or to be placed in fracturing fluids. More sophisticated chemical procedures in processing RA material also reduce the cost to a point where an objection is no longer raised. To date, over 100 logs of the type outlined here have been run, all of which have added foundation to this theory. Before the frac or acid treatments, a base temperature log and a base gamma ray log are run. The temperature panel should be set on 1-3° per inch, depending on the existing bottomhole temperature and the surface temperature. This consideration is extremely important because, when the temperature differential is as low as 10°, interpretation becomes extremely difficult, if not impossible. A gamma ray base is run at the same time as a temperature base with the sensitivity of the recorder between 70 and 135, depending on the type of tools being run. Because of the increased sensitivity which allows for better depth of investigation, scintillation tools are preferred. At this point, the first dummy stage is run. The RA material is placed in 2000 gal. (the preferred volume) of fluid; many successful logs, however, have been run with less fluid. The combination logging tool is run after the dummy stage. If the temperature differential is not too great, a temperature anomaly should exist. Whether it is a cold-breaking log or hot-breaking log will depend entirely on surface conditions. Start logging temperature down the hole, using a collar locator as a depth reference and logging the gamma ray up. As the tool passes the treated zone, the RA indicators will register or record in counts per second. It has been found that the higher counts per second reading over a given interval is usually accompanied by a radical break in temperature. This has been true approximately 85 percent of the time. Next, overlay the two logs, using the collar locator as a depth reference to see if they complement one another. If the dummy stage entered the formation at the desired interval, proceed directly to the first stage of frac. If not, pump a solid diverting material, then another 2000-gal dummy stage, and go through the same logging procedures as with the first dummy stage. At this point, a change in the location of the

RA material and the temperature anomaly and a decrease in counts per second in the intervals of the first logs are sought. Next, overlay the log using the collar locator as a depth reference. The main stages of frac are evaluated in the same manner.

INTERPRETATION AND PRESENTATION OF ACTUAL LOGS

Interpretation of temperature logs has always been difficult. In recent years there have been several good papers written on some of the factors that affect temperature logging. These articles are applicable whether a temperature log is run during or after a frac or acid operation, or on an injection well in waterflood. Significant papers referring to temperature logging are by Steffensen and Smith[2,3] on Joule Thomson heating or cooling effects and Agnew's paper[1] for evaluating a fracturing treatment with temperature surveys. With these two papers in mind, details will be eliminated regarding temperature interpretation in the logs presented in this paper. Elaboration on the RA materials installed and how they react under frac and acid conditions will be the primary topic.

First, there are a few facts which must be considered when dealing with RA material. One is residual contamination. The procedure calls for tagging all of the propping agent installed in the well to be logged. This is the *only* way one can assume pen heights or an increase in counts per second to be proportional to fluid entry. In this tagging process, however, flush procedures are critical. Enough flush must be available to displace the tubing or casing plus at least 5-10 bbl additional fluid to properly clean the wellbore area. There will be residual contamination left in the wellbore, especially around packers and certain types of collars, which is the primary reason the sensitivity is turned down on the logging equipment. The low gain on the instrument will effectively screen out "low-counts-per-second" contributed by background radiation and residual (wellbore) contamination. At the same time, the large fluid entry points will still have a "high-counts-per-second" increase and temperature anomaly. To interpret a gamma ray log of this type, the first question generally raised is, "How far into the formation is the logging tool able to see the RA material?" Some preliminary testing has shown depth of investigation to be approximately 18 in. It is very difficult to be more specific because of the general nature of RA material. A portion of all the propping agent used in a frac operation is tagged, thus we have to treat the entire amount of propping agent as the source of RA emission.

Figure 1 represents a RA log that was run several days after a stimulation operation. This particular log has several interesting points. The top of RA material is shown approximately 350 ft above the highest perforated interval. This is definitely channelling behind the casing. This point of the interpretation is shown because of the location of the packer, which offers additional shielding to the gamma ray emitting material on the propping agent. It was concluded that the channel existed between the cement and the formation because of a gamma ray neutron log, indicating the "high-counts-per-second" interval corresponded with the zones of high porosity, and a cement bond log, reflecting poor bonding onto the formation. This particular well had a pump-in tracer, as well as a temperature log, run prior to the stimulation operation to determine the evidence of a possible channel. The logs were inconclusive; therefore, a stimulation operation of 60,000 lb of 20/40 mesh sand was run. Two things were learned from this; (1) that the channel did exist, and (2) the height of the channel.

The benefit of this type log is that it can be run several days (and up to three months) after a treatment to obtain the definitive results as shown.

Following is a discussion of a multistage frac job involving logging between each stage, with emphasis on controlling the placement of frac materials.

On Log 2A-1 (Fig. 2), the LTD is 4505 ft; the perforated interval is 54 ft; the bottomhole temperature is 88°; and the packer is set at 4212 ft. The fluid in the hole is water. A base temperature and a base gamma ray were run to establish any radical breaks.

In relationship to Log 2A-1, the only abnormal deflection was indicated on base gamma ray at 4450 ft. There is a high-counts-per-second indication at this point. The procedure calls for review of the gamma ray neutron log to see if the "hot spot" is part of the original formation or if it is a buildup caused by injection water. Whatever the cause, it is important to make an allowance for this deflection in subsequent logs.

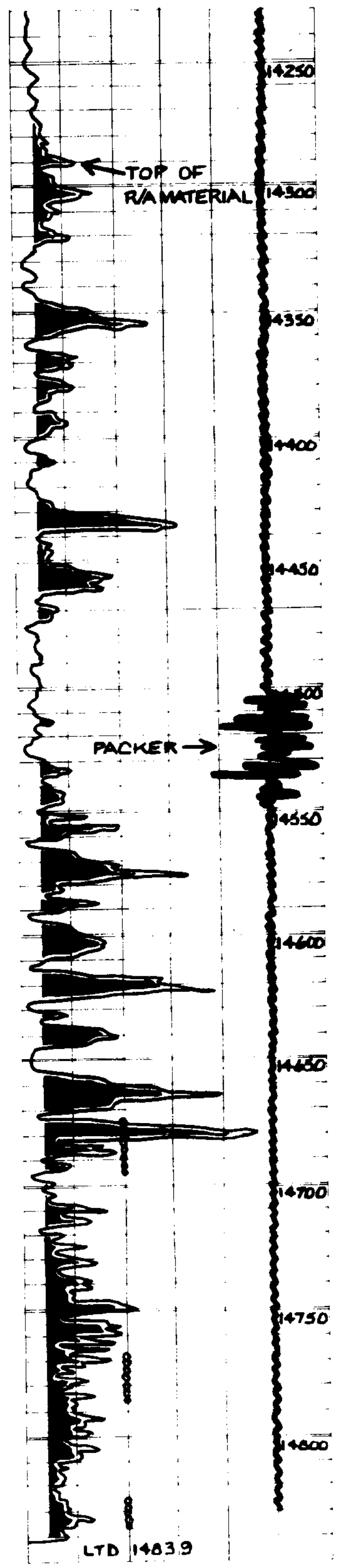

FIGURE 1

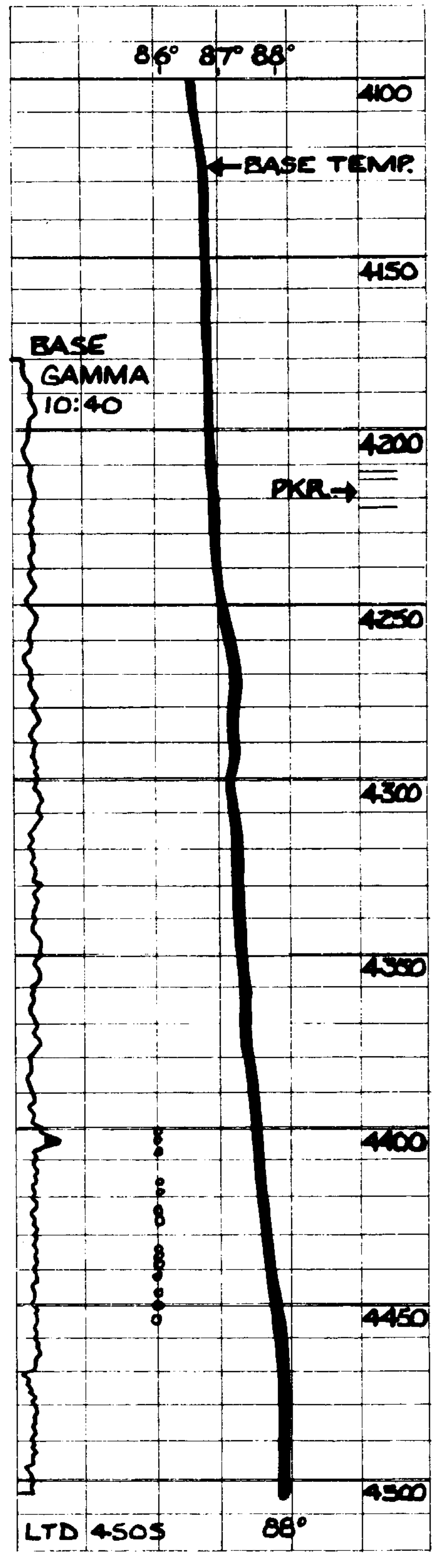

FIG. 2—LOG 2A-1

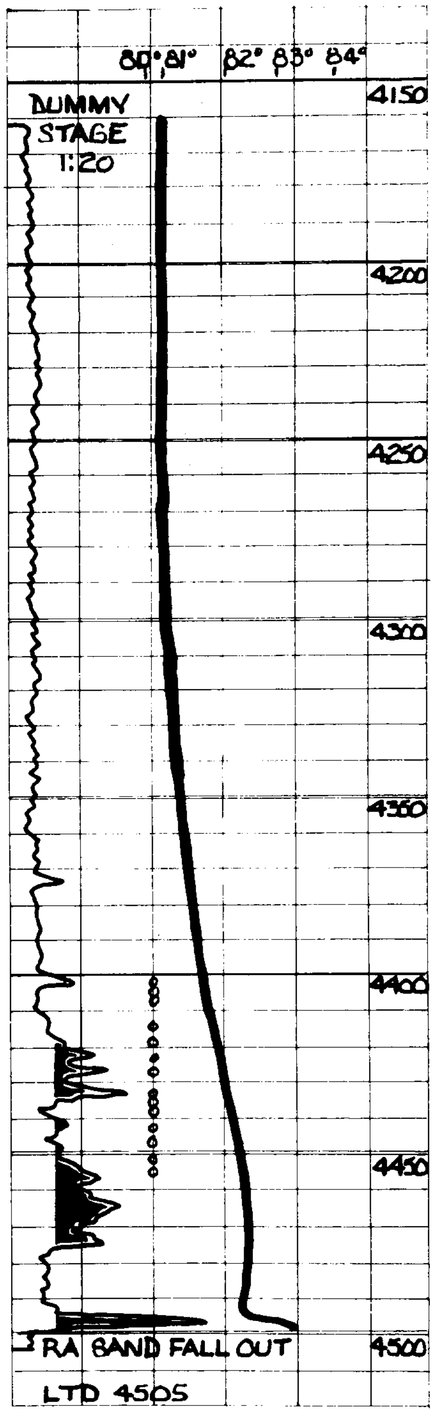

FIG. 3—LOG 2A-2

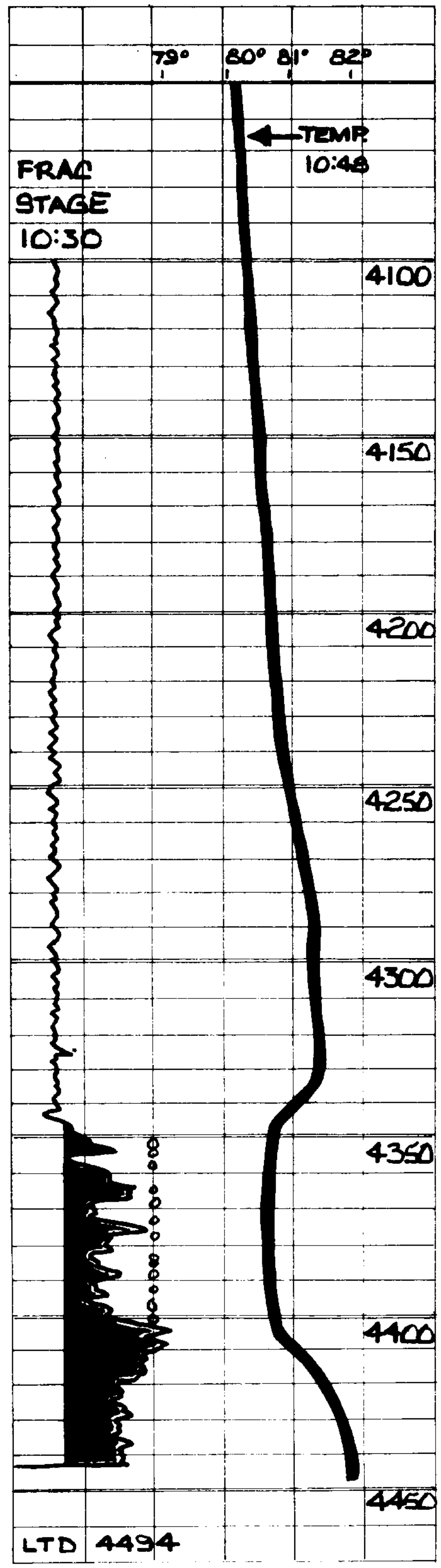

FIG. 4—LOG 2B-1

The next step is to establish the points of entry of the treating fluids by utilizing the dummy stage technique. This particular run (Fig. 3) indicated that the "hot spot" at 4405 ft still exists. The point of entry begins at 4420 ft and continues to 4468 ft. Down to the bottom of the well, starting at 4500 ft, we have a large pen deflection which is caused by RA sand fallout and is common to RA tagging procedures. In this particular log, the fallout can be disregarded because of the corresponding temperature interpretation which supports the theory that no fluids were pumped out the bottom.

One of the most important reasons for running the gamma ray and temperature together is to counter objections about RA sand fallout. The total volume pumped was 2000 gal. which indicates the point of entry at 4420 ft, using the temperature as a diagnostic procedure. This would indicate the bottom of the entry to be 4497 ft. One consideration is that the temperature anomalies are created by fluid and some of the anomalies do not indicate where the propping agent has entered. This is a plus for running both types of logs.

Moving on to Log 2B-1, (Fig. 4), it is found that the fluid entries were in the zone. No evidence of upward channelling existed, which was the primary concern. The next step is to proceed with the next frac stage. First, notice that the bottom of the well is clean. The LTD has been reduced to 4494 ft because of fallout. The RA material indicated a channel down of 16 to 20 ft, which was indicated on the preceding run, and that the entire stage stayed well in zone, with no evidence of upward channelling. The temperature supports the RA interpretation.

Log 3-A, (Fig. 5), which was run in Yoakum County, Texas, in the Prentice Field, shows a temperature that is not clear by itself. Again, by utilizing a RA tag, the total interpretation is made much clearer.

Another consideration is the ability to pump blocking materials and to evaluate the effects of blocking materials. Also, if balls are dropped, one can see the effects of a diverting technique by repeating the log procedure. This logging technique has become valuable in the West Texas area because of its ease of interpretation. This takes the pressure off of the wireline operator and company personnel where accurate, on-the-spot interpretations are needed.

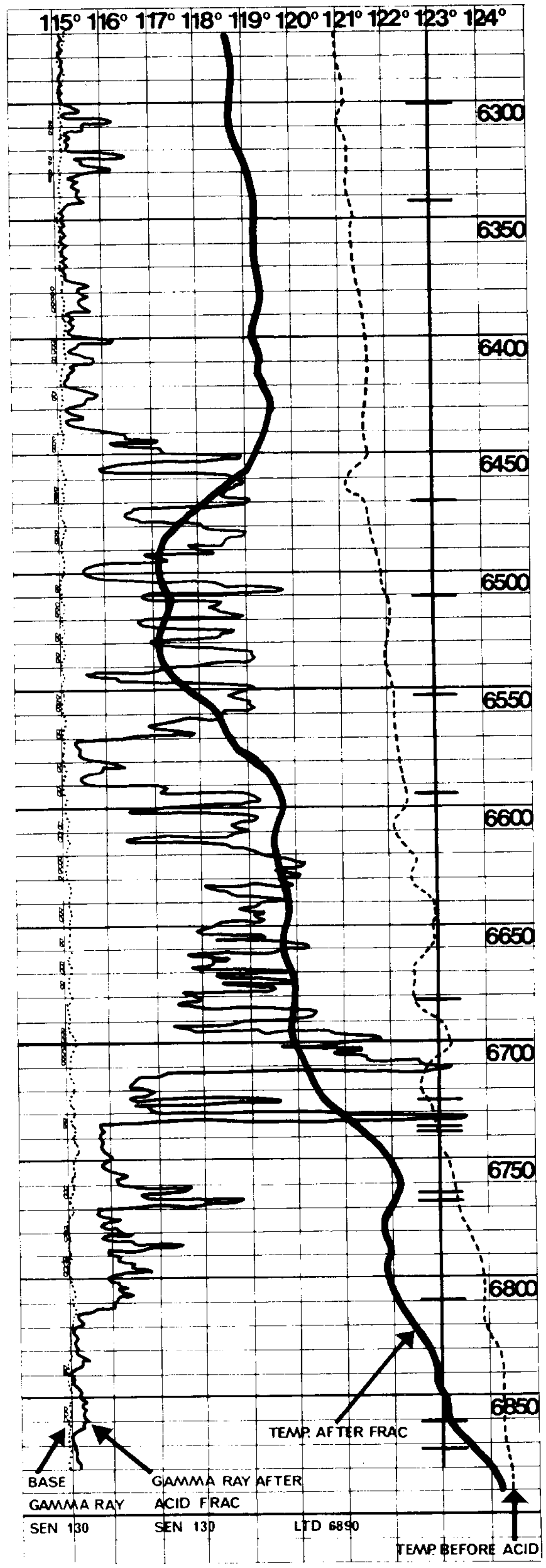

FIG. 5—LOG 3A

CONCLUSION

From the foregoing discussion, it can be concluded that acid and fracture evaluation through the use of temperature and RA surveys run before, during and after a stimulation operation can provide valuable diagnostic information which can reliably locate treated zones. This is not a cure-all, nor is it intended to be presented as such. It is, however, a valuable asset to stimulation operations.

REFERENCES

1. Agnew, B.G.: Evaluation of Fracture Treatments with Temperature Surveys. SPE 1287 presented at SPE Annual Fall Mtg., Denver, Col., Oct. 3-6, 1965.
2. Smith, R.C. and Steffensen, R.J.: Improved Interpretation Guidelines for Temperature Profiles in Water Injection Wells. SPE 4649 presented at SPE 48th Annual Fall Mtg., Las Vegas, Nev., Sept. 30-Oct. 3, 1973.
3. Steffensen, R.J. and Smith, R.C.: The Importance of Joule-Thomson Heating (or Cooling) in Temperature Log Interpretation. SPE 4636 presented at SPE 48th Annual Fall Mtg., Las Vegas, Nev., Sept. 30-Oct. 3, 1973.

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