# AN IMPROVED RADIOACTIVE TAGGING SYSTEM FOR STIMULATION EVALUATION

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## ABSTRACT

*In the past, in wells that were candidates for fracturing or acidizing treatments, it was found that the use of temperature and radioactive materials were very benficial in evaluating where the fluid and propping agents, if any, were located in the formation. Both of these methods had their drawbacks. This paper deals with overcoming some of the problems associated with radioactive material only. An automatic system has been designed for pumping fluid into the frac line (pressure side) using an ion exchange resin as the isotope carrier to improve evaluation of the fluid and/or proppant-laden fluid moving into the zone. Also, this procedure eliminates some downhole contamination problems which have caused difficulty in interpreting staged stimulation work.*

## INTRODUCTION

The combination of radioactive material and temperature for evaluating frac and acid treatments has been utilized very successfully in the past three years in and around the Permian Basin Area. This technique has been performed over 750 times to date and its use is growing rapidly. A paper written by Moon and Smith covers the theory, as well as field procedures.[1] Because of the increased use of radioactive material, and its occasional misuse, improved tagging and handling procedures now have been implemented. This paper describes one method now being used.

## THEORY AND PROCEDURES

A method has been devised of logging and treating wells utilizing a macroreticular ion exchange resin as a carrier for radioactive material having a half-life of 150 days or less. The resin is injected into the pressure side of the frac line to the well for accurate logging of fluid flow into the formation or zone of interest. The resin preferably falls into one of the following groups: sulfonic carboxylic, quarternary ammonium, or polystyrene polyamine in aqueous or non-aqueous solutions. The resin's size should be between 0.1 to 1.00 mm or 10 to 400 mesh, and it should withstand temperatures up to 350° F. A high-pressure pump such as a low-volume piston pump injects the ion exchange resin, previously reacted with a radioactive material, into the pressure side of the frac line to the well. The resin readily mixes with the frac fluid/proppant slurry, providing a homogeneous solution which flows into the well and out through perforations into the producing formation. The solution, therefore, affords accurate readings when the well is logged.

In utilizing the staged-stimulation method of fracturing or acidizing a well, a log is first made of the well after it has been shut-in for approximately 24 hours. This provides a base gamma-ray log reading. A 2,000 gallon dummy solution such as water or a gel-water is pumped into the frac line and the ion exchange resin is injected simultaneously into the frac line. A log is then run which will show where fluid entry occurs along the zone. Depending on the results, it may be desirable to plug certain zones of flow temporarily by using rock salt or various other temporary plugging materials. This could allow a more effective utilization of the treatment to selectively stimulate production. After the appropriate fluid entry points are determined and the undesired zones plugged, the main fracture-treating fluid is pumped into the well, and the radioactive resin is pumped simultaneously into the line to tag the material. A log is then run after the material has been pumped. If deemed necessary, a second fracturing solution may be pumped into the well with a second log to determine the results of the fracturing solution.

A primary objective of the ion exchange resin is to provide a carrier having a low specific gravity for introducing radioactive material into the well, yet having physical characteristics similar to those of sand. This allows the material to behave like sand when in place in the formation, but have the specific gravity of the treating fluid. Another objective of the ion exchange resin is to provide a spongelike carrier for radioactive material which is readily adapted for pumping into the pressure side of the frac line into the well with standard pumping equipment. A still further objective of the resin is to provide a method of tagging a well with a minimum amount of equipment contamination, plus a maximum amount of control over the operation.

The following ion exchange resins have been successfully tested, but other resins may be used as well.

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|---|---|
| CAT-400 | Styrene-DVB |
| CAT-50 | Methacrylic Acid-DVB |
| CAT-93 | Styrene-DVB |
| CAT-94 | Styrene-DVB |

The CAT-400 is a gel-type ion exchange resin which is a strongly basic anion exchanger of a quarternary ammonium functional group. Because of the unique characteristics of the resin material when mixed with water, the resin can be pumped as if it were a fluid. The resin flows like a fluid and mixes easily with other solutions and fluids.

Isotopes having a half-life of 300 to 500 days require the well to be shut-in for several days to a few weeks to allow radioactivity in the well to reduce to a safe level. By using a short half-life of 150 days or less, the well can be allowed to flow sooner. This also reduces possible field contamination which would render other wells, such as offset wells, unloggable. The following is a partial list of isotopes which are generally available.

| | |
|---|---|
| Scandium | Sc 46 |
| Iridum | Ir 192 |
| Iodine | I 131 |
| Thulium | Tm 125 |
| Zirconium/Niobium | Zr/Nb 95 |
| Cermium | Ce 141 |

A combination which has been found to work reasonably well is the CAT-400 ion exchange resin and Iridium or Iodine. The resin and radioactive isotope are mixed at the well site and given ample time to chemically react. The mixture is then mixed with a quantity of refined lubricating oil of a nondetergent type, such as 30 weight non-detergent oil, which lubricates the pump and seals the radioactive material within the ion exchange resin to prevent it from exchanging with other materials in the well. The radioactive material and ion exchange resin are then ready to be pumped into the well.

The amount of radioactive isotope pumped into the frac line equals 0.7 to 1.0 microcuries of the isotope per pound or gallon of treating solution pumped by pumps into the well. Thus, one must consider the pumping rates of both pumps to determine the quantities of tagging agent needed to tag the treating solution to assure that the requirement of 0.7 to 1.0 microcuries per pound or gallon is met.

The first procedure in the process of treating the well is to determine the level of base radiation which is naturally occurring within the well. A scintillation counting tool should be used to determine the gamma-ray radiation level of the well. In addition, a temperature sensing device is used in conjunction with the scintillation counting tool to make a temperature log. (This allows one run for both logs.) Typically, a log-type recorder records the level of radiation at the depth of the tool within the well. The location of perforation is known. There are several methods of determining the depth of the tool within the well, but a collar locator is generally used as a depth reference tool. Also, a gamma-ray correlation log, taken off the open-hole log, can be used.

## INTERPRETATION AND PRESENTATION OF ACTUAL LOGS WHERE IMPROVED TAGGING METHODS WERE USED

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 a waterflood. Significant papers referring to temperature logging are by Steffensen and Smith on Joule Thompson heating or cooling effects and Agnew's paper on evaluating a fracturing treatment with temperature surveys.[2,3] With these two papers in mind, details regarding temperature interpretation in the logs presented in this paper will be eliminated. The temperature, however, will be reflected on the logs presented.

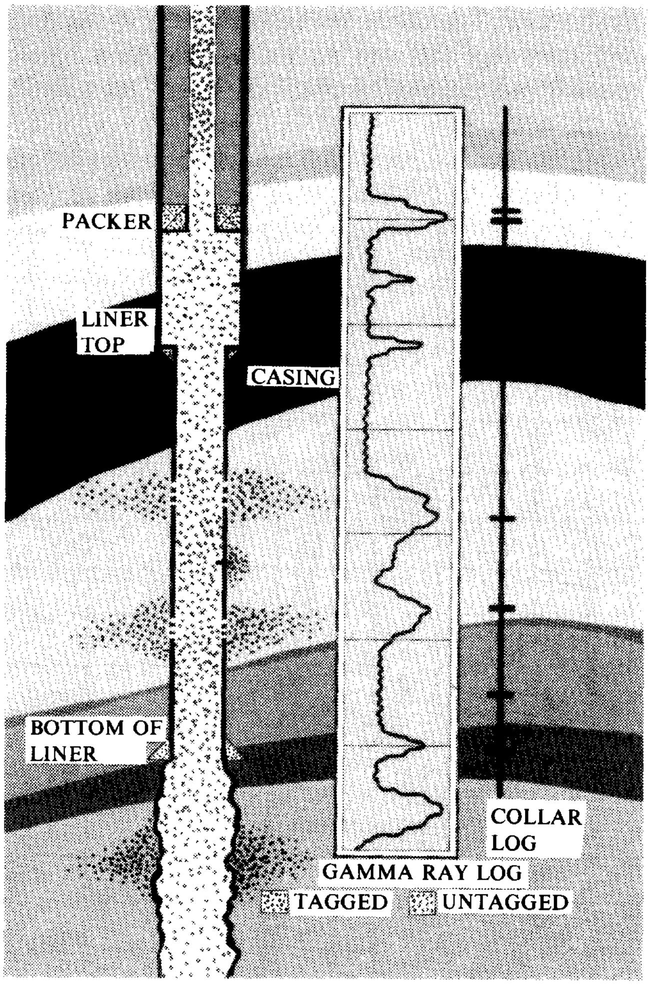


FIGURE 1—RADIOACTIVE CONTAMINATION OF WELLBORE

Discussion of radioactive material and how it is used will now be the primary topic. There are a few facts that must be considered when dealing with radioactive material. Residual radioactive contamination of the wellbore and equipment is minor in most cases, as far as surface equipment is concerned. When the contamination is located in the wellbore, it can be a problem and will affect the interpretation of the log. Figure No. 1 shows an energy increase where this wellbore hardware is located and, of course, an energy increase over the treated zones. This contamination problem was created by an improperly designed flushing program. The pressure-mechanical tagging system has eliminated most of this type of contamination. The mechanical apparatus allows a designated amount of radioactive material to be pumped into the treating fluids, which insures balance in energy readings throughout the entire operation. This balance is also checked by a sensing device placed on the wellhead which is capable of rendering radioactive-material-level readings through the frac lines. Improper flushing is not always the fault of the chemical company. It is mainly related to mechanical considerations. Because of the different designs involved in acid and frac pumping equipment, the time required for equipment decontamination (regarding radioactive contamination) will vary as much as 3 to 10 minutes. Of course, this is a "lifetime" in the fracturing and acidizing operation. Nevertheless, radioactive material ends up in the flush and creates an interpretation problem.

The mechanical tagging system has eliminated

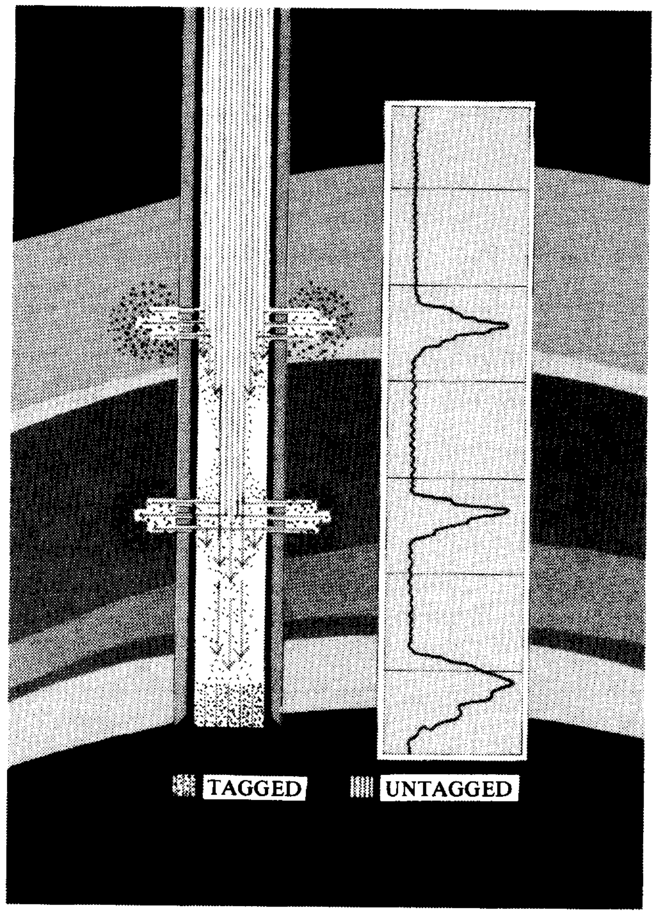


FIGURE 2—RADIOACTIVE MATERIAL PRECIPITATING TO WELL BOTTOM

clean-up time altogether, and when the device is shut down, radioactive material stops going into the frac line immediately. As a result, wellbore contamination has been all but completely eliminated.

Figure No. 2 shows one of the other problems that the ion exchange resin has eliminated. That is, radioactive tag material precipitating to the bottom of the well during the frac or acid treatment. In the past, frac sand was used, and radioactive material was baked onto its surface. This tagged sand then was sprinkled into the blender during the frac operation, and it acted in the same manner as the non-tagged sand. That is, it fell out because of its high specific gravity in relation to the treating fluids involved. Ion exchange resins, on an average, have a specific gravity of from 1.1 to 1.23, or slightly higher than fresh water. Therefore, the resin flows with the fluid and does not fall out as does sand. As a result, virtually no radioactive material falls to the bottom of the well.

Figure No. 3 is an actual log which shows fallout of proppant to the bottom of the well. As you can

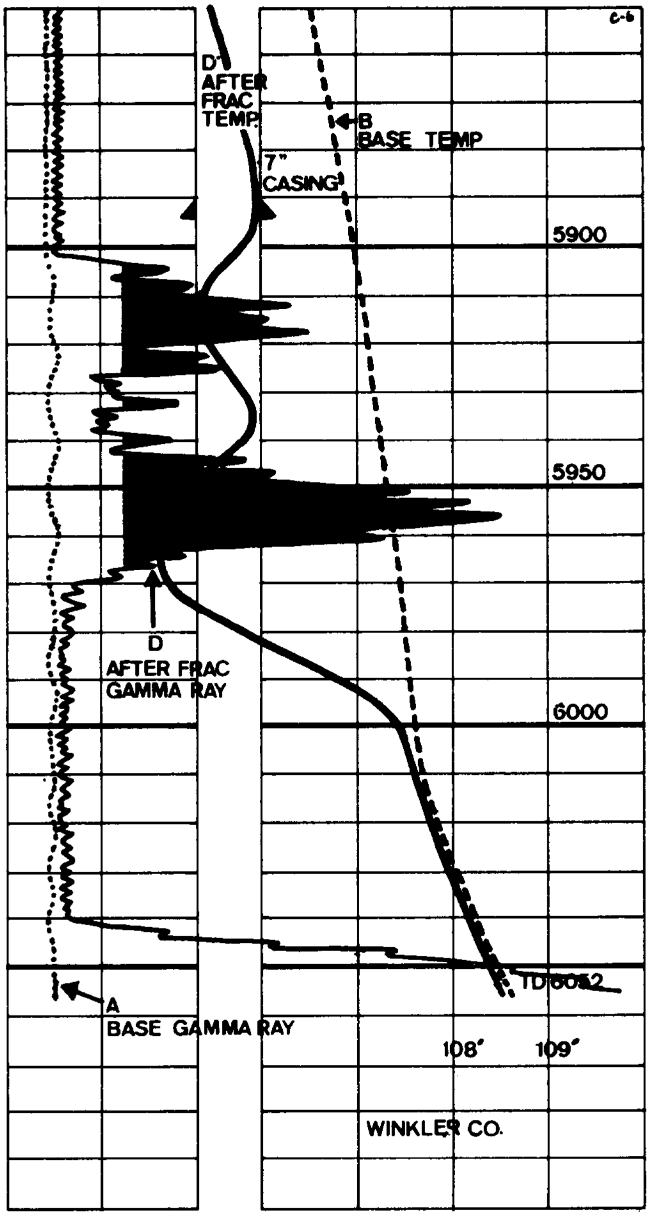


FIGURE 3—LOG SHOWING FALLOUT OF PROPPANT TO WELL BOTTOM (EXAMPLE 1)

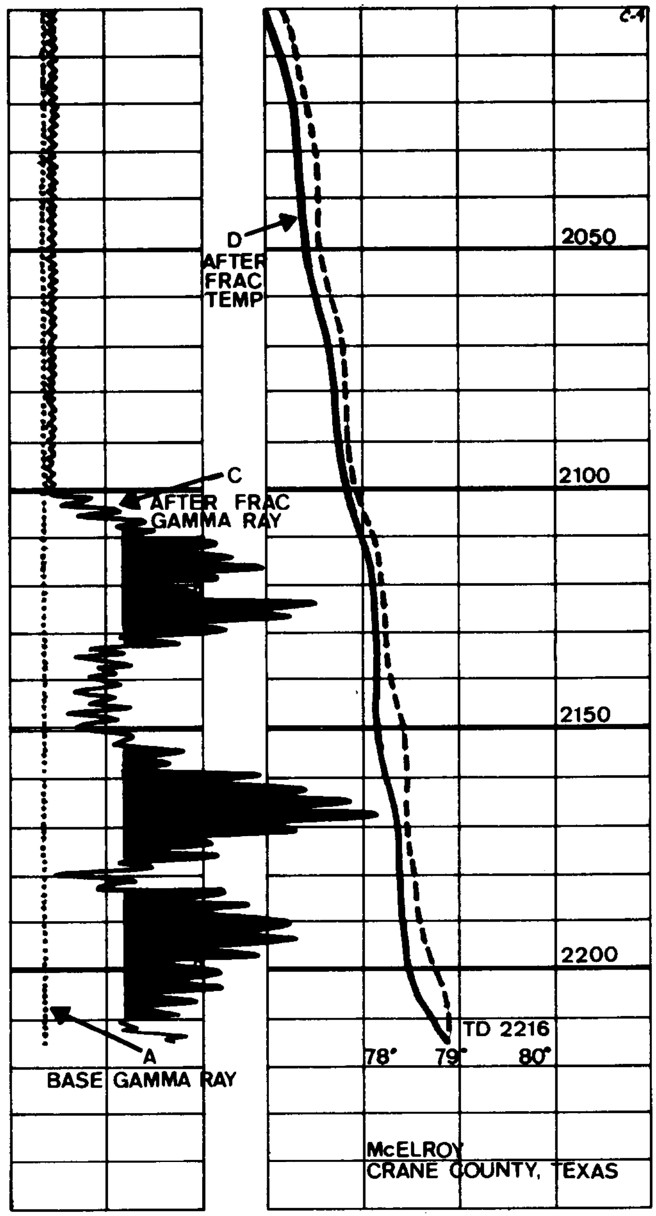


FIGURE 4—LOG SHOWING FALLOUT OF PROPPANT TO WELL BOTTOM (EXAMPLE 2)

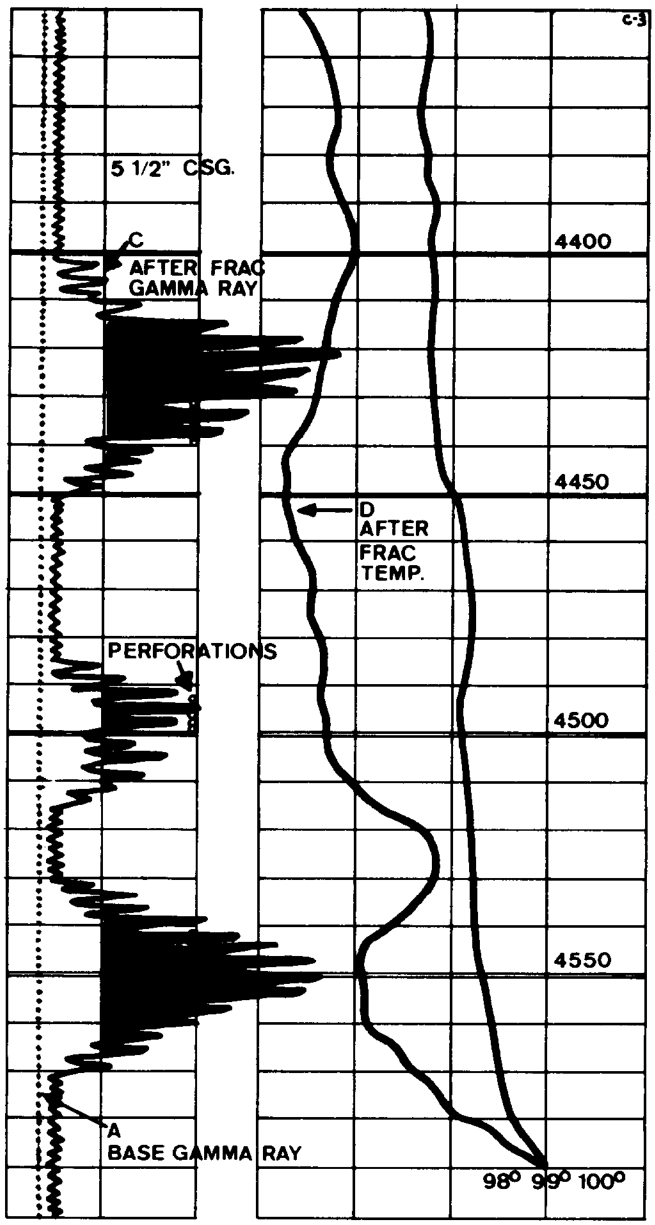


FIGURE 5—LOG SHOWING IMPROVED QUALITY DUE TO MECHANICAL TAGGING SYSTEM

see, without the temperature log, the bottom of the well could have been interpreted as having a treated zone in an open-hole section. Figure No. 4 is another actual log reflecting the same problem.

Figure No. 5 is a typical log showing how the mechanical tagging system has improved log quality relative to using radioactive materials. In this particular log, the line nearest the right is the shut-in temperature run, taken before the well was treated. Moving to the left, the next line is the "After Frac Temperature," which was run after the first stage of frac. For an inexperienced engineer or wireline operator, this temperature log would be difficult to interpret. However, when the "After Frac Gamma-Ray" line is added, the log becomes very clear, and the temperature log complements the gamma-ray log. This log also reflects the lack of contamination problems at the bottom of the well. The log returns back to the base gamma-ray level between the perforated sections. This is extremely important in the upper two sets of perforations because the temperature indicates communication between these zones. The gamma-ray reflects a certain amount of channeling above and below each set of perforations, but no communication between zones. This log quality is excellent and can be depended upon when special emphasis is put on the tagging procedure.

## CONCLUSION

It has been shown that acid and fracture evaluation, through the use of temperature and radioactive surveys run before, during, and after a stimulation operation, can be greatly improved by utilizing ion exchange resins and pressurized mechanical tagging systems. Of course, this is not a "cure-all," nor is it intended to be presented as such. It is, however, a valuable asset to tagging operations.

## REFERENCES

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