Solving Oil and Gas Production Problems with Radioactive Tracers

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ABSTRACT

Many problems encountered in oil and gas production can be solved if the fluid in the well is known. It is the purpose of this paper to discuss the application of radioactive isotopes to the solution of these problems.

This paper will discuss how a radioactive tracer survey is possible and the following applications of it: injection profile, channel location, evaluation of perforating and fracture treatment, and cement location. The actual radioactive tracer units used will be discussed briefly.

A recently developed method to determine the fluid flow rate in an injection or producing well will be described. This method can be run through tubing and requires no special pumping equipment or well preparation.

INTRODUCTION

Radioactive isotopes, used as tracer elements, are being used to solve many problems encountered in the production of oil and gas. Tracer surveys can determine the injectivity profile, locate channels, cement and lost circulation zones, evaluate perforating and fracture treatments. With a radioactive isotope, any material added to a well can be traced.

The radioactive tracer is mixed with the injection material and injected into the well. A gamma ray detector locates the radioactive material and traces it to indicate the travel of the injected fluid. The tracer will not easily separate from the injection material, so the movement of the radioactive tracer corresponds to the movement of the injection material.

TRACER UNITS

The physical preparation of the tracer is determined by the injection fluids and the information desired. Typical tracers are particles, fluid (oil or water), sand and gas.

The particle tracer is a synthetic resin chemically impregnated with the radioactive isotope. The particles range in size from 16 to 400 mesh with a specific gravity of 1.0 The size of the formation pores determines the particle size used since plating on the formation face is desired to obtain an injection profile. The standard tracer unit will contain a range of particle sizes, (i.e., 50 to 100 mesh). This range of sizes provides some large particles to plate the formation face and some small particles that will wash into the formation or into any channels that might exist. Particle tracers are available dry or wetted for mixing with oil or water. Very fine particles can be added to cement to be located.

To mix with frac sand, a radioactive isotope is baked onto Ottawa sand. This tagged sand is mixed with frac sand and located with a gamma ray detector after the frac process is completed.

A radioactive isotope dissolved in a fluid is usually used to locate channels, packer leaks and any other application in which no plating of the radioactive is desired.

To trace a gas, the isotope is dissolved in a low boiling point liquid. The tracer is delivered in a sealed glass ampoule. The ampoule is placed in a pressure injector, broken and blown into the well with compressed air. A common gas tracer is iodine-131 prepared as methyliodide which has boiling point of +42.5° C.

Many isotopes are available for use by the oil industry. The chemical characteristics and the rate of decay or half life usually determine the isotope to be used. The table below lists some of the isotopes and their half life.

ISOTOPE	SYMBOL	HALF LIFE
Iodine-131	I^{131}	8.1 days
Iridium-192	Ir^{192}	74.0 days
Antimony-124	Sb^{124}	60.0 days
Silver-110	Ag^{110}	225.0 days
Radium-226	Ra^{226}	1590 years

The half life is the time required for the amount of radioactivity of an element to be reduced by one-half. The decay is exponential, so in seven half lives the activity will be less than one per cent of the original amount. After this length of time, the small amount of activity present would not affect a normal gamma ray survey on the well. Usually the survey could be run in less time as the tracer is rapidly dispersed in the well.

Iodine-131 is usually the first choice for a tracer element. It is economical and has an 8.1 day half life. The decay is slow enough to allow a few days' delay in use but rapid enough to not contaminate a well for a long period of time. Iridium-192 with a 74 day half life can be stocked at a field location for surveys which do not require a short life tracer.

Logging Procedure

Most tracer surveys are logged with a small diameter gamma ray instrument, using a 3/16 inch diameter line with a special flow-by packoff lubricator. A correlation log is run to tie in with the previous logs and then a base log is recorded on a very low sensitivity. The gamma radiation from the tracer is much greater than the natural radioactivity of the formation.

The radioactive material is placed in the well with a downhole ejector or at the well head and pumped down. A departure from the base log is indicative of the presence of the tracer. Repeated recording runs are made through the zone of interest to trace the material as it is being pumped away. This procedure is continued until the desired information is recorded.

A. E. C. Regulations and Safety

The Atomic Energy Commission controls the sale, preparation and use of all radioactive isotopes. The AEC sells only to licensed buyers who must have personnel trained to handle radioactive materials. The buyer is responsible for the isotopes until a final disposition is made, such as pumping into a well or until the material is turned over to another licensed buyer. If the radioactive material returns to the surface, the person who placed it is still responsible for the monitoring and disposal.

The AEC requires a licensed user to place the radioactive material in the well. He must wear a film badge and necessary protective clothing, gloves and mask if necessary. He will use a geiger counter to monitor the radiation and detect any spills. If any contamination is detected, he must supervise the decontamination procedures.

As only a few millicuries of an isotope are usually used for a tracer survey, the radiation hazard is very low. The danger comes from ingestion — taking into the body by mouth, nose or open wound. The various isotopes will concentrate in certain parts of the body and cause cell damage. Some of the isotopes used are not easily eliminated from the body.

For additional safety, many of the tracer units can be ordered in sealed containers that are placed directly in the downhole ejector. No open container of radioactive material then need be handled.

RADIOACTIVE TRACER APPLICATIONS

The following examples illustrate some practical applications of tracer surveys.

Injection Profile

A frequent application of a tracer is to obtain an injection profile. Fig. 2 shows a survey on a water injection well water flooding a reef limestone reservoir. The injection zone is 4-3/4 inch open hole from 6835 feet to 6995 feet. 5-1/2 inch casing was set to 6825 feet and 2 inch tubing was run to 6710 feet.

Particles containing 4 millicuries of iodine—131 were placed in the flow line at the check valve and pumped down the tubing. The injection rate was 1 barrel per minute at 700 pounds psi.

A correlation and base log was recorded before the radioactive particles reached the injection zone. Run 1 was recorded as the tagged water reached the bottom of the zone and started to enter the formation. Run 2 indicates the injection profile and the relative amount each section is taking. Run 3 shows the effect of flushing with uncontaminated water. The particles were washed into the formation. The three runs shown were selected

FIG. 1

TYPE "D" TRACER EJECTOR

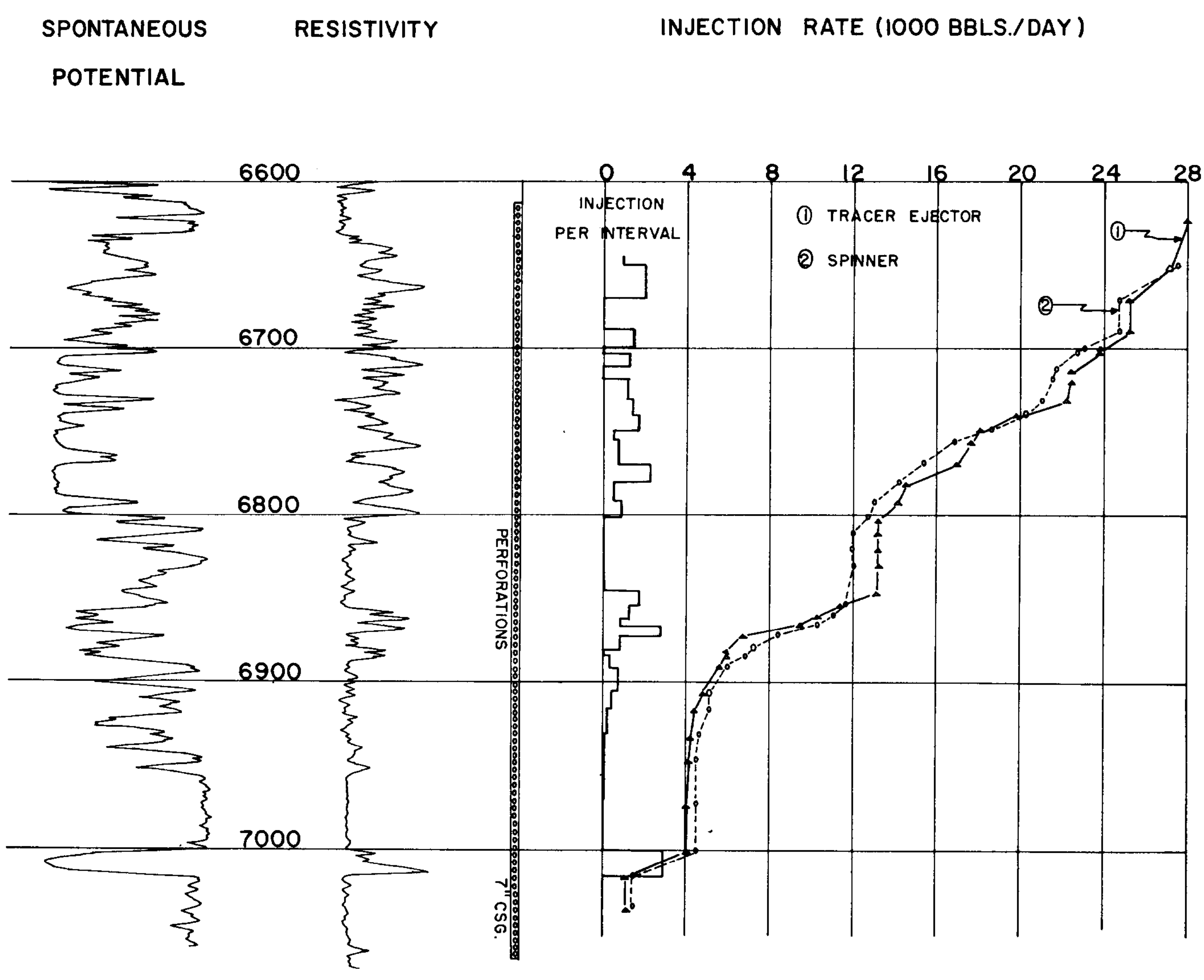
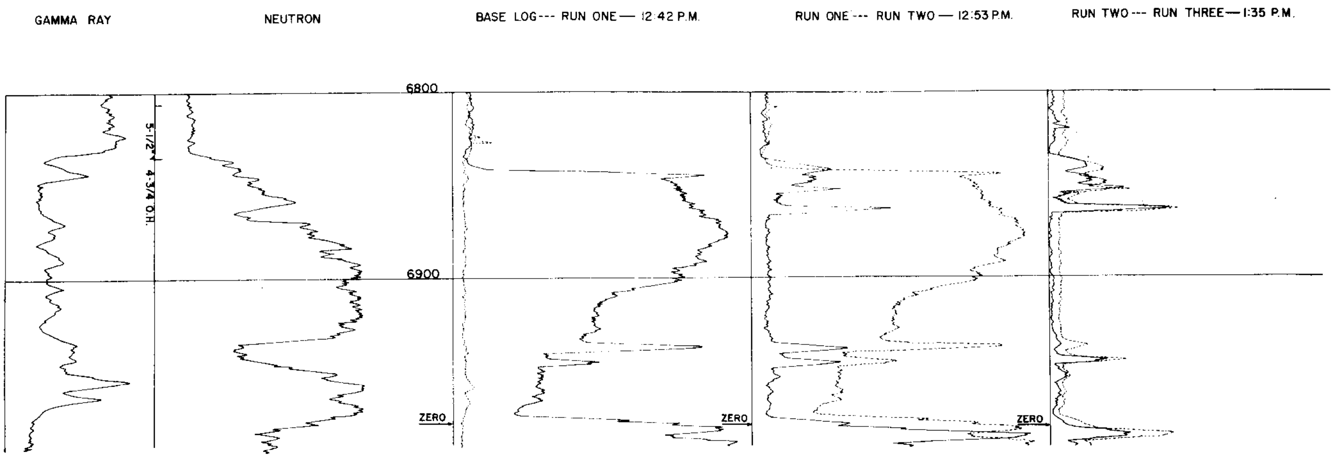


FIG. 2

INJECTION PROFILE

WATER INJECTION WELL



from a total of 13 runs recorded over this section as the particles were pumped away. Most of the water appears to be entering in three zones: 6825 feet to 6865 feet, 6840 feet to 6855 feet, and 6870 feet to T. D.

Channel

Channels often exist between adjacent zones due to treating processes. Some wells have been saved by determining the source of water being produced with oil or gas.

The well depicted in Fig. 3 was first perforated from 9170 feet to 9159 feet and 9140 feet to 9120 feet. Water and a little oil was produced on the test. The perforations were squeezed off and dry tested. The casing was reperforated from 9100 feet to 9074 feet and 9050 feet to 9006 feet and acidized.

The well made mud, oil and 90 per cent water. No water was thought to be in the upper zone so a tracer survey was run to determine the source of the fluids. 2.5 millicuries of iridium—192 impregnated particles were pumped down the tubing with water and into the formation.

Run 1shows the tracer entering the perforations. Run 2 shows the tracer continuing to enter the perforations; but it is building up in the lower section which was squeezed off. Further pumping caused a buildup in the zone that was thought to be squeezed off.

To repair the well all perforations were squeezed again and the casin was reperforated in two upper zones. The well flowed 26 barrels of oil per hour and no water.

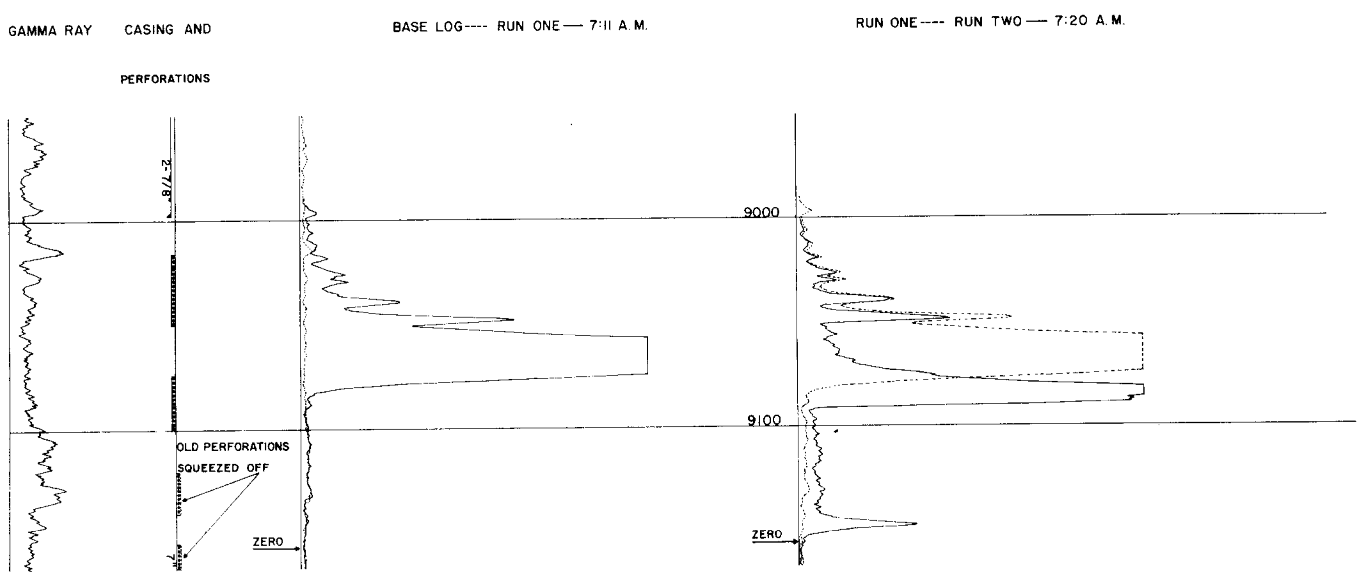
Fig. 4 illustrates the detection of an unusual channel in one of several gas injection wells in a field. Gas was being injected into a zone below 8600 feet. Due to a change in injection pressures and rate, a channel in the cement was suspected. The well was killed with salt water in

FIG. 3

CHANNEL LOCATION

IN

PRODUCING WELL



preparation for a tracer survey.

The channel was expected to be small and some 1000 feet up the hole. 100 millicuries of iodine—131 prepared as a solution of sodium iodied was used to insure detection. A normal tracer requires only 2 to 10 millicuries of activity.

A tracer ejector containing the iodine was attached to a logging instrument and run down the 2-1/2 inch tubing. A correlation log and base log was recorded before the iodine was ejected at 8530 feet. The radioactive slug was pumped down into the perforations below the packer. A small landing nipple and valve prevented logging below the packer.

The logging instrument was positioned at 8550 feet to detect any radioactive water that might pass. Injection rate was 1.5 barrels per minute at 1400 pounds psi.

An increase in radioactivity was detected in 13 minutes. The radioactivity was followed up the hole. Run 1 indicates the tagged water has gone above 7600 feet. Run 2 shows the radioactivity continuing to build up as the injection is continued. Run 3 shows the distribution of the tagged water in an upper zone.

The channel was repaired by squeezing the perforations and reperforating. A second tracer was performed, following the same procedure as the first. As shown, no radioactivity was detected to indicate a channel above the packer.

The example is unusual, but similar results were obtained on several wells in the same field and definitely indicated channels in some.

FRACTURE TREATMENT EVALUATION

Fig. 5 shows an injection profile to determine the effect of a frac treatment. 10,000 pounds of sand with balls was pumped in at the rate of 17 barrels per minute at 4000

FIG. 4 CHANNEL IN GAS INJECTION WELL

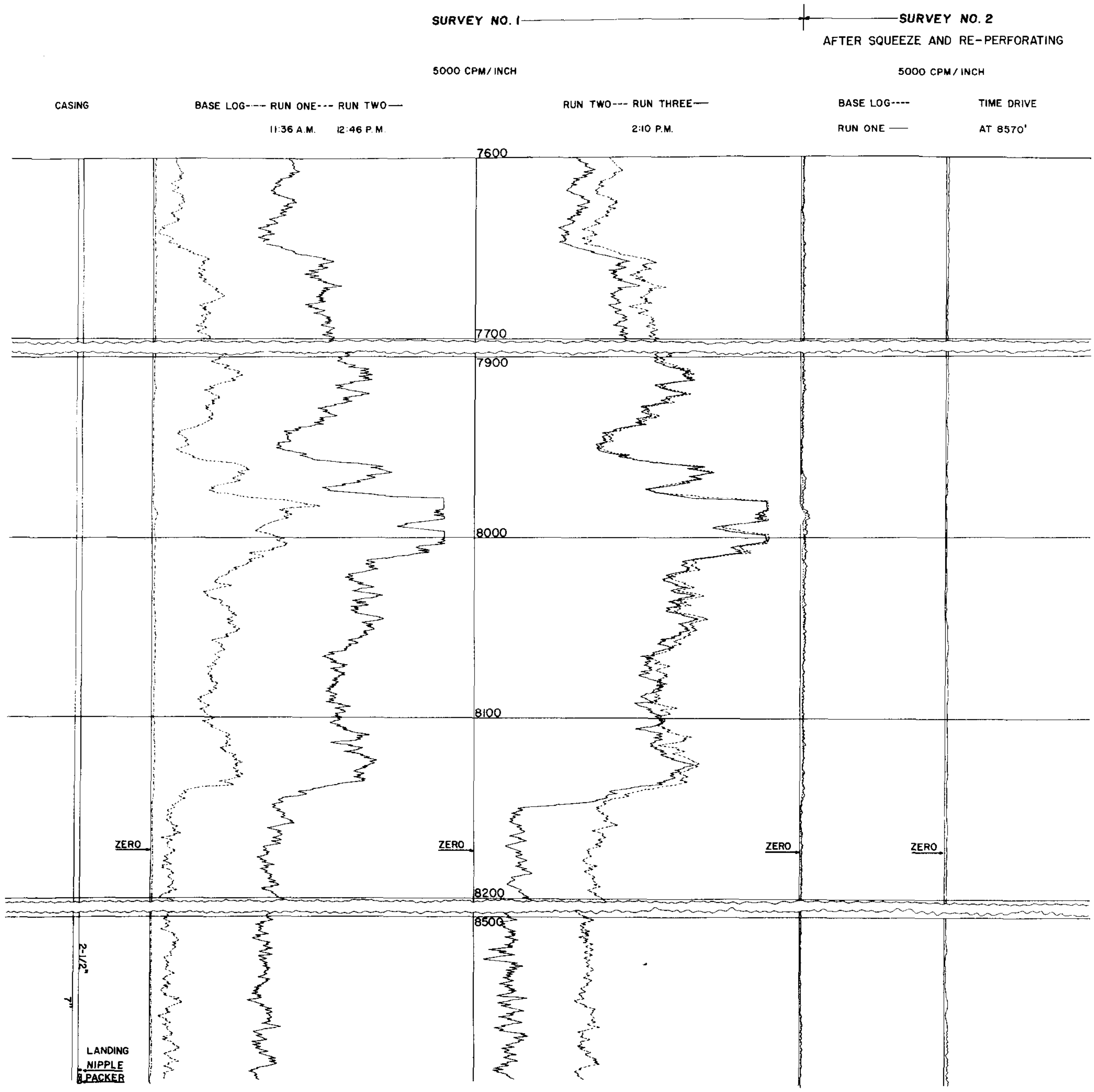
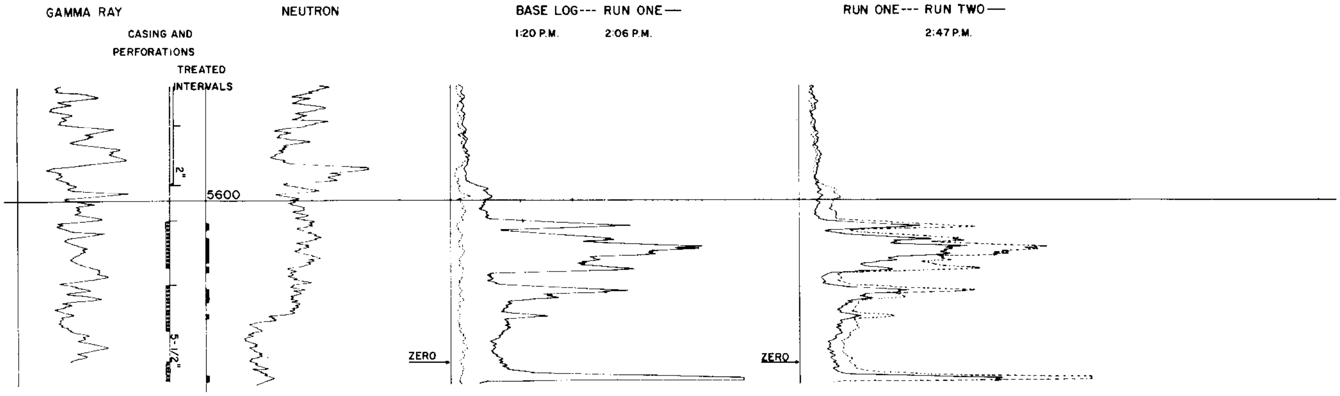


FIG. 5 PARTICLE TRACER IN OIL AFTER FRAC



pounds psi. The well was cleaned out and the tracer was run.

Particles containing 2.5 millicuries of iridium—192 was placed in the flow line and pumped down with oil. The injection rate was 3/4 barrel per minute at 600 pounds psi.

Run 1 shows the zone opened by perforations from 5611 feet to 5635 feet was nearly uniformly treated. In the perforation from 5644 feet to 5668 feet an 8 foot interval in the upper part and a 4 foot interval in the lower part are taking fluid. Only the bottom of the perforated interval from 5684 feet to 5694 feet is taking fluid.

Since an injection profile is basically a permeability study, the tracer indicates the effective permeability after the frac treatment. A change in permeability could be detected by comparing a before and after frac profile.

Radioactive Ottawa sand can be added to the frac sand and detected with a gamma ray instrument after the well is cleaned out. This procedure works well if the radioactive sand is in the formation close enough to the borehead to be detected.

100 SHOT TRACER EJECTOR

The need for an accurate and easily obtained flow rate log has long been acknowledged. The spinner type surveys in several forms have been offered in addition to the balanced flow surveys.

The spinner surveys have the disadvantage of being inaccurate at low flow rates and requiring a large diameter instrument for reliable results. The balanced flow type survey requires special well preparation, pumping and metering equipment.

To overcome some of these disadvantages, a 100 shot tracer ejector was designed to attach to the top or bottom of a 1-3/4 inch O.D. logging instrument. To measure the flow rate, the instrument with the ejector is positioned at the desired depth as the injection is continued.

Upon actuation of a single switch in the surface equipment, a slug of two cubic centimeters of the radioactive tracer is ejected from the tool. Simultaneously with the ejection, the recorder pen is deflected to the right to mark the chart. See Fig. 6. As soon as the well fluid carries the tracer slug to the gamma ray detector, the chart indicates the presence of the radioactive slug.

By the use of an accurate constant speed time drive for the recorder, the time interval required for the radioactive slug to leave the ejector and arrive at the detector can readily be read from the chart. Since the ejector has a capacity of 100 two c.c. ejections, a complete profile can be made of the interval on one run by taking readings at consecutive stations in the well and plotting measured travel times versus depth.

Fig. 7 shows a comparison of the 100 shot ejector survey and a spinner survey on the same well. As indicated, the two agree very well. The real advantage of the ejector is not illustrated by this example. As the flow rate decreases, the spinner survey becomes less accurate, but the ejector survey is still accurate. The only well condition required for the ejector survey is for the tubing to be above the open zone or zones of interest.

The 100 shot ejector flow rate log has the advantage of being able to be run through tubing, accurate at low injection or flow rates, simple to perform and requires a minimum of time on the well.

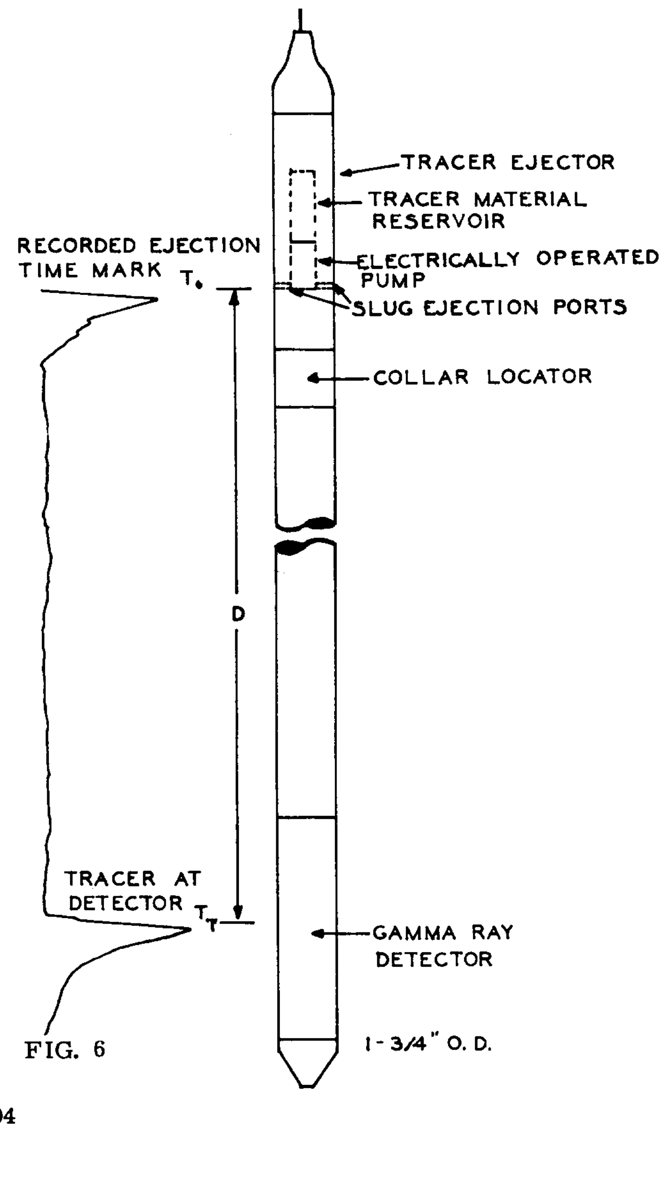


FIG. 6