APPLICATION OF A TRI-FUNCTIONAL ANNULAR PRODUCTION LOG IN DEEP WELLS IN WEST TEXAS AND NEW MEXICO

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INTRODUCTION

Production logs that are available to the industry today obtain a more accurate account of production; the main reason for the accuracy is that the well is logged in the dynamic production state.

Interpretation of the production log is dependent upon understanding the mechanics of the well and the function of the combinations of logs used.

The following approach is important in obtaining and interpreting good production logs:

1. Properly prepare the well to be logged prior to survey.
2. Have a basic knowledge of the tools used in each log. Understand the procedure, mechanics, and calculations needed.
3. Understand how to use each log.
4. Learn to combine all logs so they present one overall picture of the production pattern.

In recent years, the production log has mainly been applied in shallow wells (1,000 ft. to 5,000 ft.). Due to the soaring costs of drilling, successful attempts have been made to apply this technique to deeper wells. The case histories to be discussed in this paper are about deeper wells.

WELL PREPARATION FOR A PRODUCTION LOG

Well preparation is an important aspect of the production-logging procedure. This is especially true of wells on rod pump.

Wells on rod pump are more difficult to prepare than flowing wells. If a pumping well has a tubing anchor or packer assembly, this equipment must be removed. It is imperative that the annular space be cleared so the logging tool can be run past the pump. If possible, the pump should be placed 50 to 100 feet above all perforations or open hole sections. This makes the logging procedure much easier, especially the tracer portion of the log.

If for some reason the well will not maintain a fluid level above the pump, it is possible to log the well with the pump in, or to log below the producing interval or intervals. This makes the logging procedure and log interpretation more difficult.

A dual head must be installed with the tubing decentralized. An opening must be situated so that the annular space is opposite the pumping unit. The opening must have an I.D. large enough for a 7/8 inch O.D. tool to pass through. Flowing wells are much easier to prepare. The surface and subsurface equipment should be checked for any inside diameters less than 1 inch. The well should be producing under stable conditions.

TOOL SIZES AND CONFIGURATION

Production logging tools are available in sizes from 7/8 inch O.D. to 2 inch O.D. The tools referred to in this paper are 7/8 inch O.D. and have a pressure rating of 10,000 psi and a temperature rating of 275°F.

The normal configuration is shown in Figure 1. This configuration can be changed, or any combination of the tools can be used.

LOGGING TECHNIQUES, CALCULATIONS, AND PROCEDURES

The example logs that will be discussed use three logging functions; temperature log, tracer profile log, and fluid density log functions. These three logs are run in tandem. The tandem configuration makes

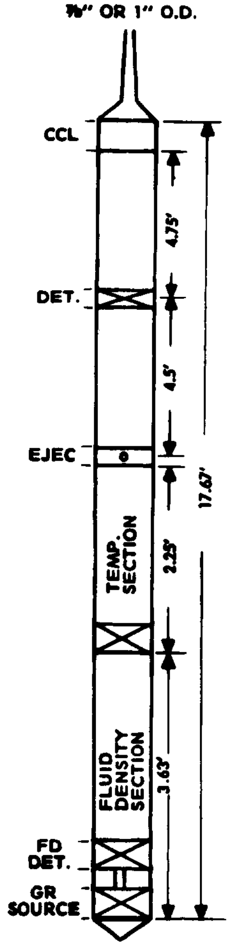

FIG. 1—PRODUCTION TOOL CONFIGURATION

it possible to obtain the three different logs in one run. The chance of wrapping the tool around the tubing is minimized, and time is saved.

TEMPERATURE SECTION

A producing temperature is usually the first log run. It is run going into the hole.

A very sensitive temperature element is needed. A glass-bead type thermistor is used which senses and records minor temperature changes. In most cases, large temperature anomalies will not be found in wells that are producing fluid: fluid temperature and formation temperature are usually close to the same. The temperature logs should be calibrated to show 1^0 F = 1 inch span.

The temperature portion of the log plays an important part in the overall interpretation of the production log. It complements fluid entry points indicated by the tracer log. It, in many cases, identifies communications or channels from outside producing zones.

TRACER PROFILE SECTION

The tracer portion of the log indicates where the fluid or gas enters the wellbore. The tracer log can also tell how much fluid is entering (in barrels per day).

The procedure for obtaining a tracer profile in a production well differs from obtaining a profile in an injection well because of the following reasons.

1. The flow rate of a producing well cannot be accurately controlled. In a well on rod pump, the fluid has a tendency to move up faster on the up stroke of the pump. The fluid can hesitate or slow down on the down stroke. The stationary velocity-shot method, therefore, is not accurate.
2. The drop-shot type profile is also inaccurate. The radioactive materials used in production wells have a tendency to spread at the leading and trailing edges of the radioactive burst.

A tracer method has been devised that combines the principles of several tracer methods. A slug or burst of radioactive material is selectively placed at a predetermined depth in the wellbore (Figure 2). The R/A detector is then moved to a depth some 10 to 20 feet below the point at which the slug is ejected. The tool is then pulled up through the slug, logging on depth. When the highest peak of radiation is reached, a stop watch or time-recording device is started and this point is marked.

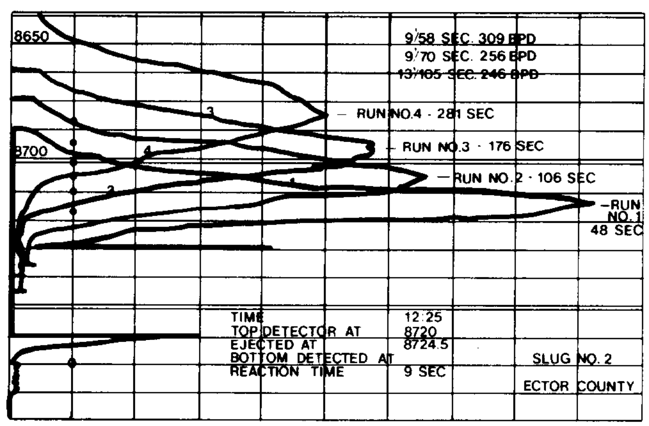

FIG. 2—EXAMPLE OF TRACER SLUG.

This process is repeated several times as the same burst of radioactive material moves up or down the wellbore. This entire procedure is repeated above and across the production intervals until no movement is detected.

For calculation of BPD, three basic factors must be known.

1. How many feet did the fluid move?
2. How many seconds did it take to move a given distance?
3. What is the hole size in which the fluid is moving?

This tracer technique provides answers to two of these questions: the distance moved and the number of seconds it has taken to move this distance. The hole size can be determined with a caliper or by using known I.D. of the casing. The above information can be used in the equation shown in Figure 3.

$$\frac{D \times 83.89 \times (ID^2 - OD^2)}{R} = BPD$$

D = DISTANCE MOVED

ID = INTERNAL DIAMETER OF CASING (OPEN HOLE USE HOLE SIZE)

OD = OUTSIDE DIAMETER OF LOGGING TOOL

R = REACTION TIME (IN SECONDS)

FIG. 3—TRACER EQUATION

Fig 4 is an example calculation.

D = 9'

ID = 4.95 (5 1/2'- 15 lb. CASING)

OD = .875 (7/8" O.D. LOGGING TOOL)

R = 12 sec.

example:

$$\frac{9 \times 83.89 \times (24.5025 - .7656)}{12} = BPD$$

$$\frac{755.01 \times 23.7369}{12} = BPD$$

$$\frac{17{,}921.596}{12} = BPD$$

$$1493 = BPD$$

FIG. 4—EXAMPLE CALCULATION

FLUID DENSITY SECTION

The fluid density tool allows for a distinction to be made between water, oil, and gas in the wellbore. This tool consists basically of a detector tube focused on an encapsulated, 2-curie, thulium source. The detector and source are separated by a vertical opening which allows free movement of fluids, gas, or both.

The tool is calibrated at the surface with freshwater and air (gas). When the tool is calibrated, there is a 5-inch span on the surface recorder between the reading for fresh water and the reading for air (gas) as shown in Figure 5. With the tool calibrated, it is now possible to detect the difference between water, oil, and gas downhole.

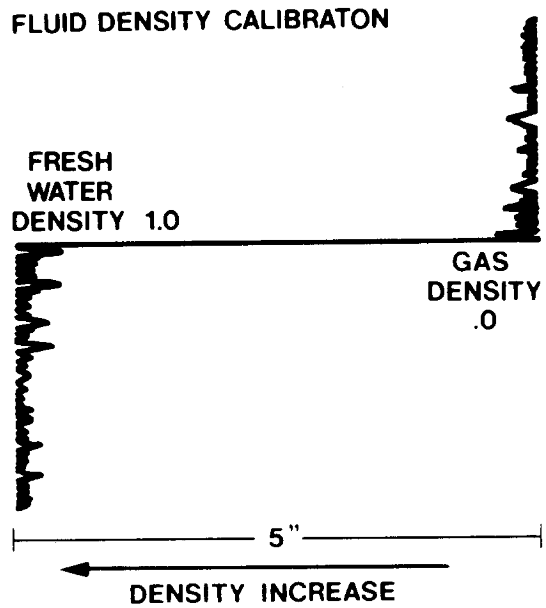

FIG. 5—FLUID DENSITY CALIBRATION.

The thulium source is a soft beta and gamma ray emitter and has been deemed "safe" by the Texas Railroad Commission and by the Texas State Health Department. If the density source is lost in the well, production may be continued, but the well cannot be deepened for one year.

EXAMPLES

Figure 6: Bridge Plug Leaking

The well had a bridge plug set at 8970 feet. The production tests on this rod pump well showed 10 BOPD and 350 BWPD. The three temperature logs showed little change across the perforated interval, but none of the three logs indicated the same bottom hole temperature. This situation is indicative of fluid movement from below logged total depth. The velocity profile indicates 331 BPD coming from below the bridge plug. No appreciable rate increase was noted across the perforated intervals above, according to the velocity profile. With this information the operator set another bridge plug on top of the leaking plug. The well was placed on

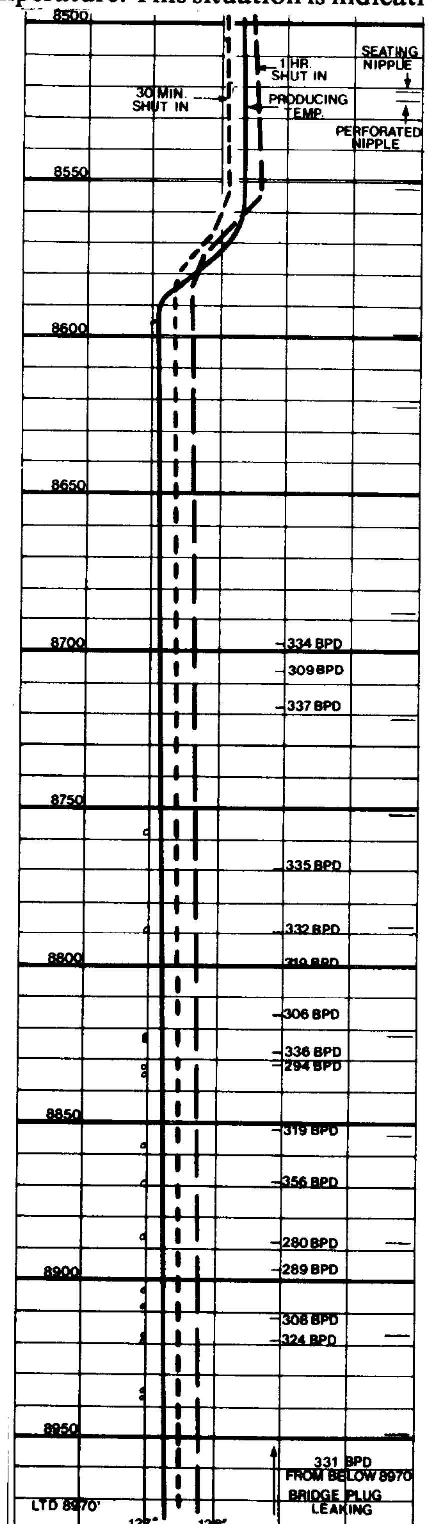

FIG. 6—BRIDGE PLUG LEAKING

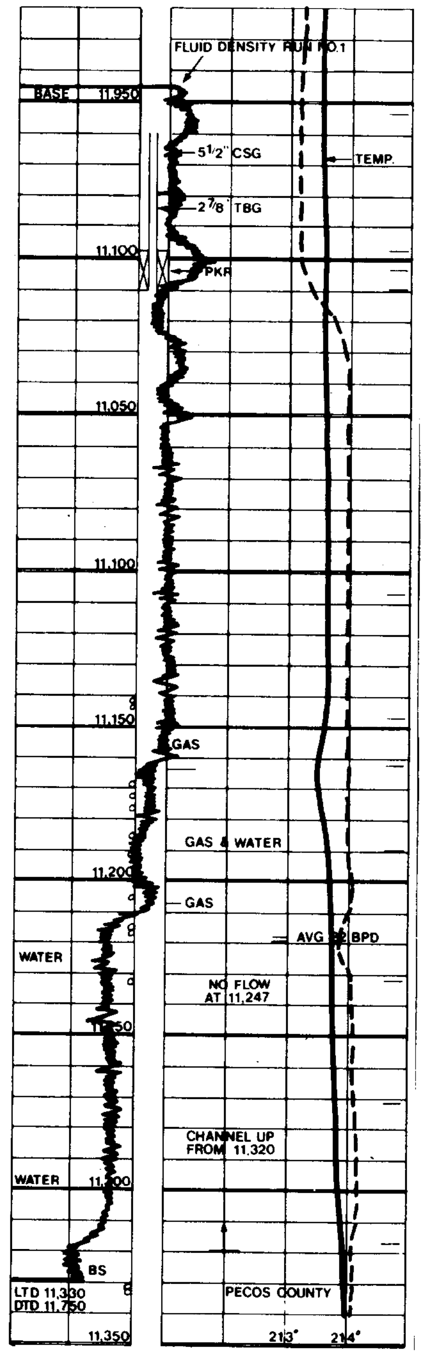

FIG. 7—FLUID ENTRY IN GAS WELL.

production and later production tests showed 50 BOPD and 15 BWPD.

Figure 7: Fluid Entry in Gas Well

The flowing well decreased from 13 MMCF per day of gas to 3.5 MMCF per day with an increase to 90 BWPD. The operator wanted to know where they were getting the water. The density surveys indicate water from 11,215 feet and below, gas and water entry from 11,215 feet to 11,170 feet, and more gas entry from above these depths.

The velocity profile indicates no flow in the wellbore at 11, 247 feet and water entry averaging 82 BPD from the intervals at 11, 232 feet and 11, 215 feet. The two temperature surveys, the solid line being the producing and the dashed line the shut-in, indicate possible channeling up the hole from as far down as 11,320 feet. It can be seen that the calibrated calibrated tool detects the difference between water, oil and gas downhole.

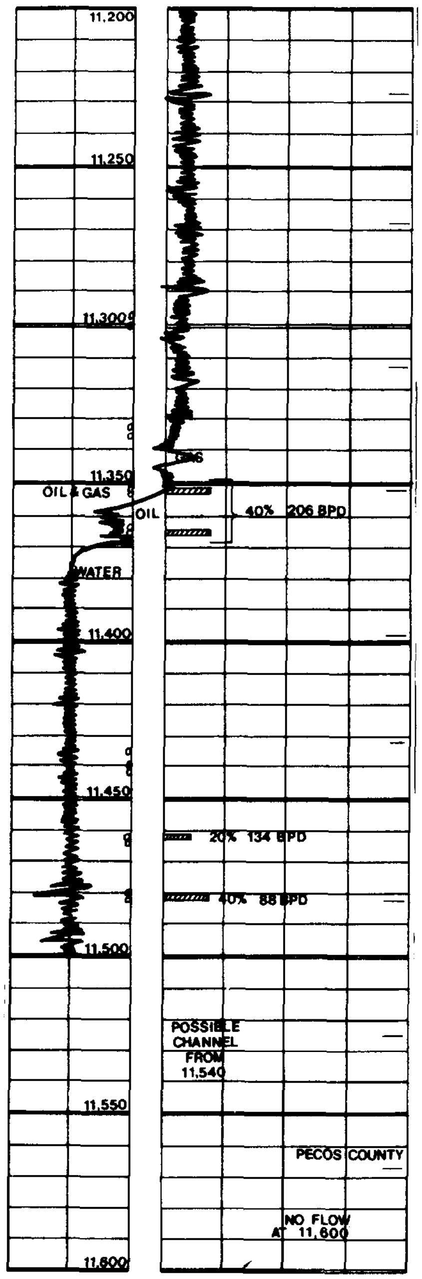

FIG. 8—WATER, GAS AND CONDENSATE ENTRY

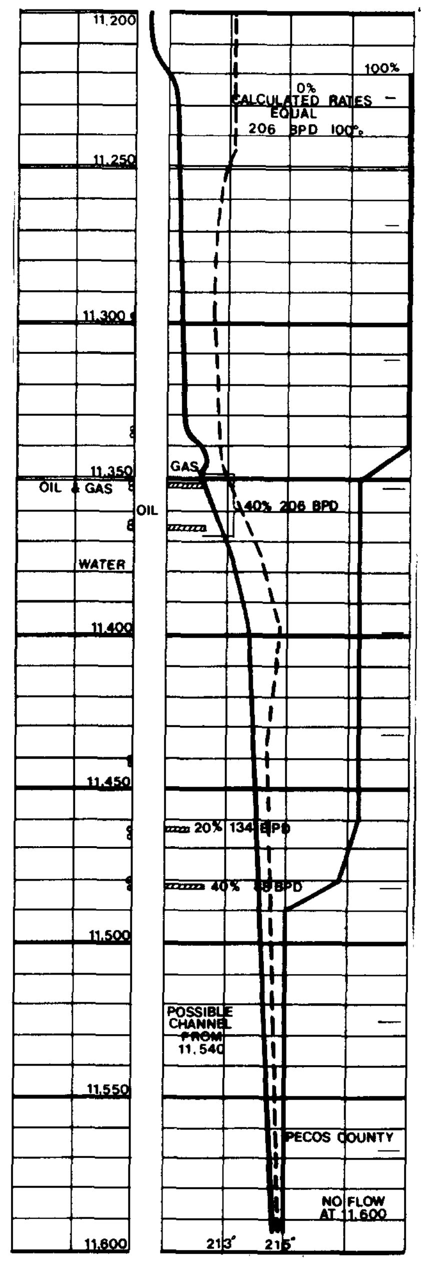

FIG. 9—ENTRY PERCENTAGES AND IDENTIFICATION OF CHANNEL UP.

Figures 8 and 9: Type of Fluid Entering and Flow Percentages

The well had a reported production of 90 BOPD, 105 BWPD and 8.5 MCF per day. The operator suspected water encroachment from below the perforated interval. The density log in Figure 8 identifies the water, condensate, and gas being produced from the different intervals. The velocity profile in Figure 9 indicates no flow in the wellbore below the bottom perforations. The profile also shows 40 percent of the fluid entry from the perforations at 11,480 feet to 11,482 feet, an additional 20 percent entering the perforations at 11,463 feet to 11,466 feet, and 40 percent entering the perforations at 11,352 feet to 11,354 feet and 11,364 feet to 11,369 feet. The temperature logs in Figure 9 indicate a possible channel up from 11,540 feet, which strongly points to the originally suspected lower water encroachment. Again, the calibrated tool can discriminate between water, oil and gas downhole.

CONCLUSIONS

1. The tool ratings of 10,000 psi and 275°F. qualify these tools for logging applications involving wells from 12,000 feet to 14,000 feet deep.
2. The annular production log represents the best opportunity to obtain downhole information on a well that is producing under normal dynamic conditions.
3. Information obtained from the production log is often used in planning desired remedial work.
4. In many cases, the production log is more economical and feasible than testing with packers and bridge plugs.

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