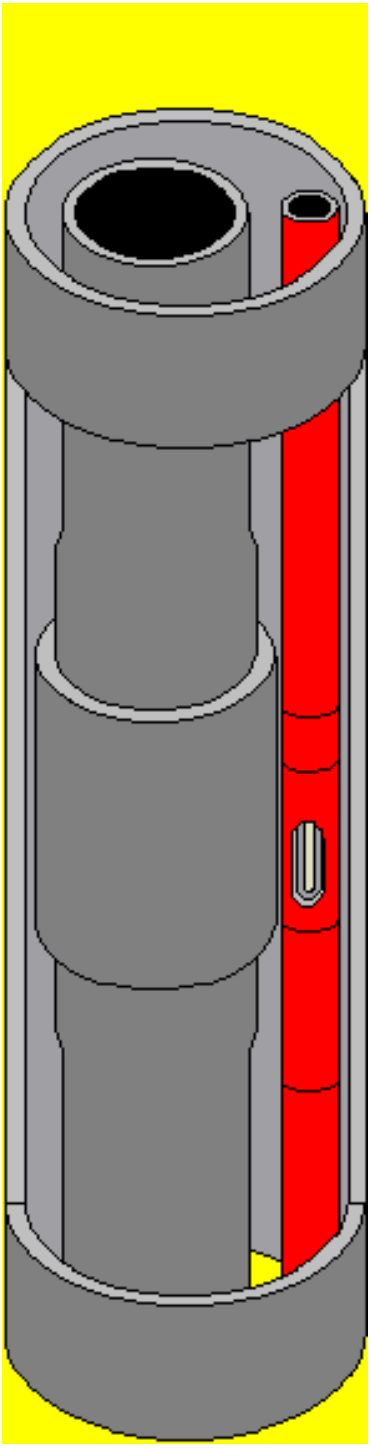
TRAC III
Flowing and Annular Production Logging

Procedures and Applications



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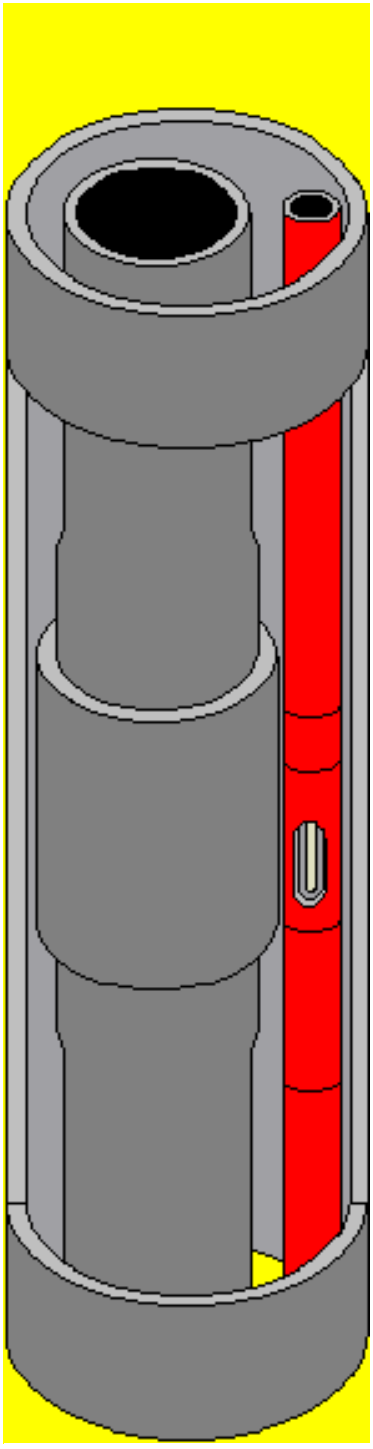
The Annular Production Log

In the late 1960's, Cardinal Surveys Company recognized a need to obtain production information from wells with rod pumps, while under stabilized producing conditions. The problem was how to convey tools to the production zone, since the rod string blocked the production tubing. The obvious answer was to enter the well in the tubing annulus, but this proposed method created the requirement for very small logging tools due to clearance constraints.

The early 1970's introduced the first of Cardinal Survey's 7/8" diameter production logging tools into the Permian Basin. Since three logs were normally required (temperature, tracer and capacitance - fluid composition), the service was called the Trac-III log. Over the years the Trac-III log has been refined to become the best annulus logging service in the Permian Basin, and the world. The small tools are a truly unique and powerful weapon in Cardinal Survey's arsenal of services, incorporating an amazing blend of technology that no other logging company has been able to achieve.

The Trac-III production log provides the maximum amount of information possible while a well is under dynamic, producing (e.g., actual or "real-time") conditions. The Trac-III includes a temperature log, a capacitance log, or a radioactive tracer log, or any combination of the three. All logs can be run simultaneously during one trip in the well. With Cardinal Survey's 7/8 inch O. D. tools, wells with 5 1/2 inch casing and 2 7/8 inch tubing or even 4 1/2 inch casing and 2 3/8 inch tubing can be successfully logged.



Cutaway View Of Casing

Trac-III Production Log Benefits

The Trac-III allows for more positive monitoring of reservoir performance than is possible through analysis of surface data only. Without this detailed, zone-by-zone, information, changes in the down-hole conditions may go unnoticed (assuming the well was ever producing as originally expected) resulting in lost production for reasons other than normal reservoir depletion. The production log can prevent this, resulting in production increases for the well. One of the primary applications for the Trac-III log is to re-evaluate marginal production wells. Watered-out or gassed-out wells can frequently be

profitably reworked based on information obtained from production logs. Information gained may also lead to recompletion of unproductive offset wells.

By helping with production management of reservoirs during primary and secondary depletion, the production log also provides essential guidance for remedial-workover designs. Reliable data allows accurate and precise design of remedial workover procedures. This leads to more efficient and cost-effective well recompletions, and, in some cases, results in workover designs that would otherwise be impossible. Knowledge gained from the production log may also lead to different completion techniques for future wells. The immediate verification of perforation accuracy and positive identification of the actual production intervals is invaluable.

On a new well, the evaluation from the production log allows confirmation of open hole log analysis and assumptions used in the initial completion. Even the most accurate, state-of-the-art primary log analysis does not guarantee a successful completion. Cementing (cement bond), perforating efficiency, and initial stimulation treatment all play important roles in well completion and performance. The production log can accurately identify actual producing intervals, and pinpoint mechanical problems.

While sometimes viewed as a "science" log, the production log has proven to be economical. Many case studies have verified the use of production log data to plan and successfully implement workovers and even aid in the design of new drills.

Some benefits of running TRAC-III's are:

- Document baseline production profile for future reference.
- Optimize pump placement.
- Discover unwanted water sources for remedial procedures.
- Correlate production results with injection profiles for sweep efficiency of floods.
- Determine perforation activity and efficiency.
- Confirm engineering and geological assumptions and analysis.
- Verify stimulation job effectiveness and techniques.
- Plan accurate placement of mechanical isolation tools (bridge plugs and packers.)
- Locate thief zones and undesirable cross-flows.
- Real-time snap shot of production well.

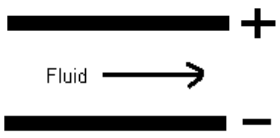
Trac-III Tool Configuration and Description

The following is a brief description of the physical characteristics and limits of the separate tools that comprise the Trac-III logging string.

Collar Locator - 7/8" O. D. by 28" in length. Magnets inside the tool casing produce a constant magnetic field. The magnetic field is altered as the tool passes by various thickness of metal.

Capacitance - 7/8" O. D. by 40" length. The capacitance tool is a capacitor. An insulated probe functions as one plate, and the tool casing as the opposite plate. Various materials passing between the plates have different dielectric properties that change the total capacitance of the circuit. In

most instances, a 3% or more oil cut is necessary before a noticeable change in the capacitance is registered. This 3% threshold varies with the salinity of the water and the gravity of the oil.



Capacitance Tool - Parallel Charged Plates

The primary advantage of the capacitance tool over the older density tool is that its readings are not dependent on a radioactive source and sensor. Thus, fluid identification cannot be affected by radioactive material in the well bore or in the ejector. In addition, there is no long half-life source of radioactive material to be fished should the tools be dropped.

Temperature Tool - 7/8" O. D. by 37" in length. The temperature tool is part of a microprocessor-controlled, digital temperature system with accuracy approaching 0.1 degrees Fahrenheit. The Temperature Tools are designed for high accuracy and reliable operation under adverse downhole conditions. They are available in three sizes and several configurations, these tools offer unsurpassed accuracy of temperature measurement and simplicity of operation. They are compatible with various tool string combinations.

The Temperature Tools utilize platinum Resistor Temperature Detector (RTD) elements for consistent and readily compensated temperature sensing. A stable crystal oscillator serves as an accurate, drift-free frequency reference in the tool electronics. Each tool is individually calibrated in a total immersion oil bath and supplied with a calibration certificate giving its actual temperature/frequency characteristics.

Each Temperature Tool is designed for protection against shock and vibration and for continuous operation at rated temperature. Quality control procedures include a three-day burn-in at maximum rated temperature, after which the tool is checked, calibrated, and made ready for delivery.

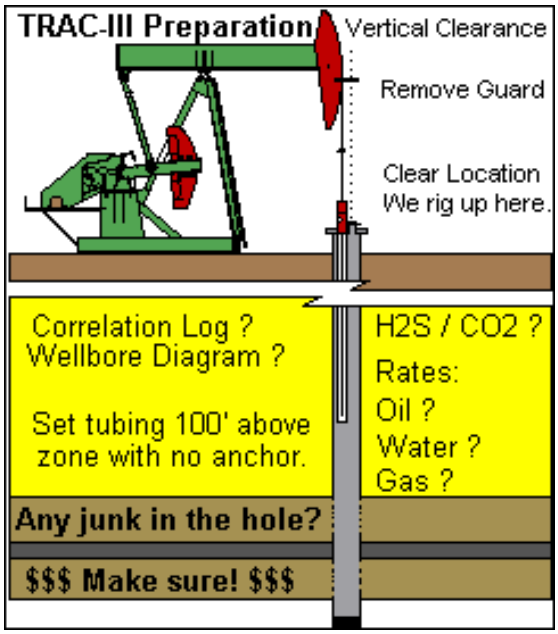
Caliper - 7/8" O. D. by 68" in length. It has three 9. 5" arms capable of measuring the I. D. of a hole up to approximately 14" in diameter.

Ejector - 7/8" O. D. by 74" in length. The ejector is digitally controlled. Its motorized plunger forces small bursts of radioactive material out of a pressure chamber through an o-ring sealed exhaust port on the side of the tool casing. The tool has the ability to consistently eject selected slugs from 0.1 cc to a full 20 cc ejector dump.

Detector - 7/8" O. D. by 60" in length. The detector is a scintillation type. It utilizes a sodium iodine crystal that emits a small ray of light each time a gamma ray passes through the crystal. The light pulse is detected and amplified by a photo multiplier. Each light pulse is counted by this continuous process.

Digital Surface Data Acquisition System

Signal telemetry is accomplished on the wire line by the pulse encoding method. Once the signal is received at the surface, the logging computer decodes the data using DSP technology. All data are logged to the hard drive in real time while simultaneously available for viewing. Each pass may be scaled in either axis. Multiple passes may be merged as required to produce the final presentation. Merged passes may be linked to other data and to other information such as the log heading or descriptive graphics for printing.



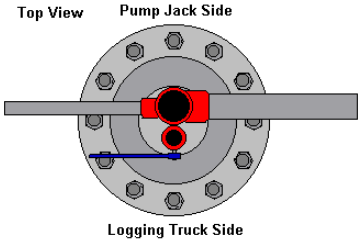
Preparation – Information Required Prior to Logging

With the well ready for logging, information is needed to prepare and execute the Trac-III. The minimum information needed is:

- Collar Log & Gamma Ray log for depth correlation
- Current Production rates: Water, Oil & Gas
- Current well bore sketch and detailed depths of perforations, pump, liner tops, etc.
- Recent History of production.
- Known effects of remedial work over or water flood.
- Well performances vs. Lease performance.

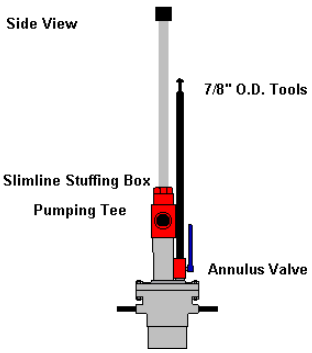
Any additional information can be a great help in maximizing the results of a Trac-III. For this reason, Cardinal prefers to have an oil company representative on location during a Trac-III. His intimate knowledge of the well and field can be crucial in aiding in the analysis as the survey is run.

Preparation – Configuration of the well and well head for Annulus Log



Proper preparation of a well for a Trac-III is the single most important step in obtaining a good Trac-III. The mechanical configuration of the well and well head are critical to the success of the annular product log.

Below are the steps needed to prepare your pumping well for an annulus log:



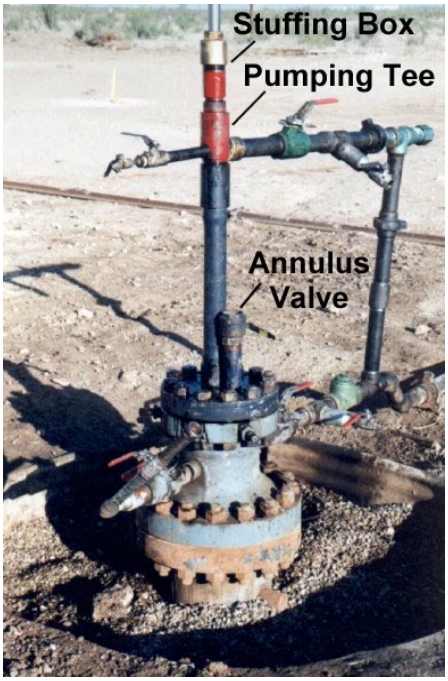
1. Tubing anchor, if present, normally must be removed. If the pump is well below the zone of interest, the tubing anchor may be left in. See number two.

2. Pump should be set 50 to 100 feet above the top perforation (free hanging).

   If the fluid level does not permit the pump placement above the perfs, place the tubing pump below the perfs. Caution: Great care must be taken in the exact placement when setting the pump below the perforations.

Special circumstances of restricted movement, sufficient room to check for leaks at plugback total depth, and multi-phase flow must be addressed with a representative of Cardinal Surveys prior to the spending of money on well preparation. In some instances, these circumstances will not allow a conclusive Trac-III.

3. Dual well-head must be installed with the annular opening AWAY from the pumping unit. There can be no vertical obstructions above the annulus opening and we must be able to back our equipment up to the side of the well head with the annulus opening. Consult the Cardinal Surveys Company web site for dual head suppliers.



4. Conventional stuffing box must be replaced with a slim line stuffing box and a small pumping tee. The Hercules type of stuffing box will not allow the use of any type of packoff device and will usually prevent tool entry into annulus.

5. Install slim Pumping Tee if needed. The strict vertical clearance rule comes into play. It might be necessary to be able to screw a 1.875" O. D. sub into the valve on the annulus opening that will clear the top of the stuffing box. This is required when it is necessary to run a lubricator.

6. The bridle guard on the horse's head must be removed.

7. Allow production to stabilize from 3 to 5 days, depending on well characteristics. Fluid levels and production rates are usually monitored to determine the status of a well. However, the mechanical changes made to run the Trac-III must be taken into account. Stabilization of production is not an important issue in some instances were a Trac-III is to be run for remedial purposes. Examples include situations where high water cut is not influenced by changes in well configuration.

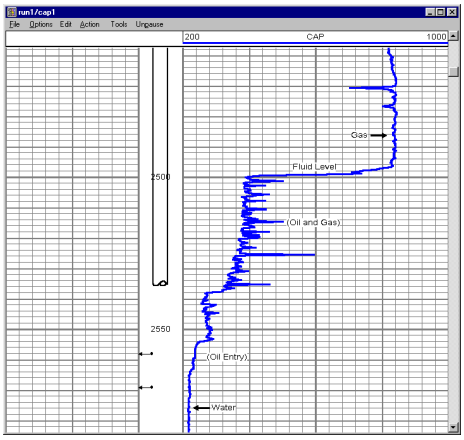
Running Log Through Packoff

Trac III Production Log - Logging procedures

The pumping unit will be stopped while the logging unit is rigged up on the well. The pump will be restarted after the tool string has been lowered into the annulus. The first survey to be run is the producing temperature and collar locator log. This log is run beginning approximately 100' above the pump and run to PBTD . Note that logging procedures for flowing and annular production logs are essentially identical once on formation with the tools.

The producing (pumping) temperature log is the first information available for determining the status of this well's production and it can greatly influence the strategy for investigating the well.

A correlation gamma ray survey and collar log is then run from T.D. up through zones of interest. The correlation log is compared to customer file logs to make adjustments to depth.

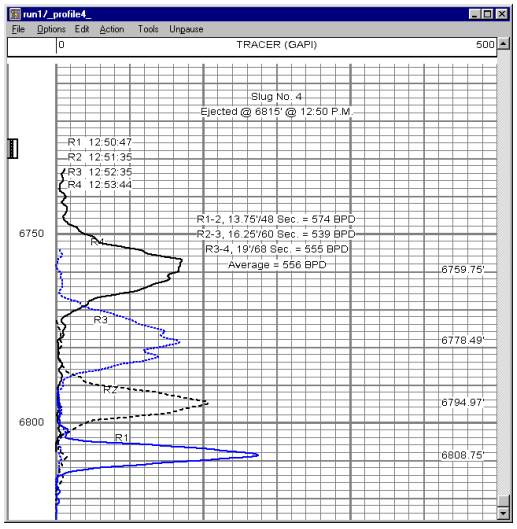


A capacitance log is then run from T.D. to above the pump. The capacitance tool, as explained earlier, can differentiate between water, oil, and gas in the well bore. However, it must be remembered that as the survey is run up the well bore the surface reading is, if you will, a percentage, or cumulative reading of the fluid composition at that particular point. Note that when calibrated, pure water is one extreme, pure air or gas the other, and pure oil is about a 75% reading.

The next step is to run the radioactive tracer survey. The tracer will allow the determination of the direction and rate of fluid movement. There are the three basic components of the tracer: 100% shot, zone breakdown shots, and no-flow shots.

The 100% shot is ejected above the top perforation. As the single radioactive slug travels up the well bore, at least three passes through the slug are recorded . By measuring the distance of movement and the time of travel, it is possible to calculate the velocity and therefore, the volumetric flow rate in the casing. This method of velocity measurement is necessary because of pump surges in the fluid column. Stationary velocity readings are not accurate.

Zone-by-zone breakdown is accomplished by the same velocity method as the 100% slug. Readings are taken in areas between sets of perforations. Each set of rates obtained are compared back to the 100% shot and a percentage of entry is calculated for each set of perforations .



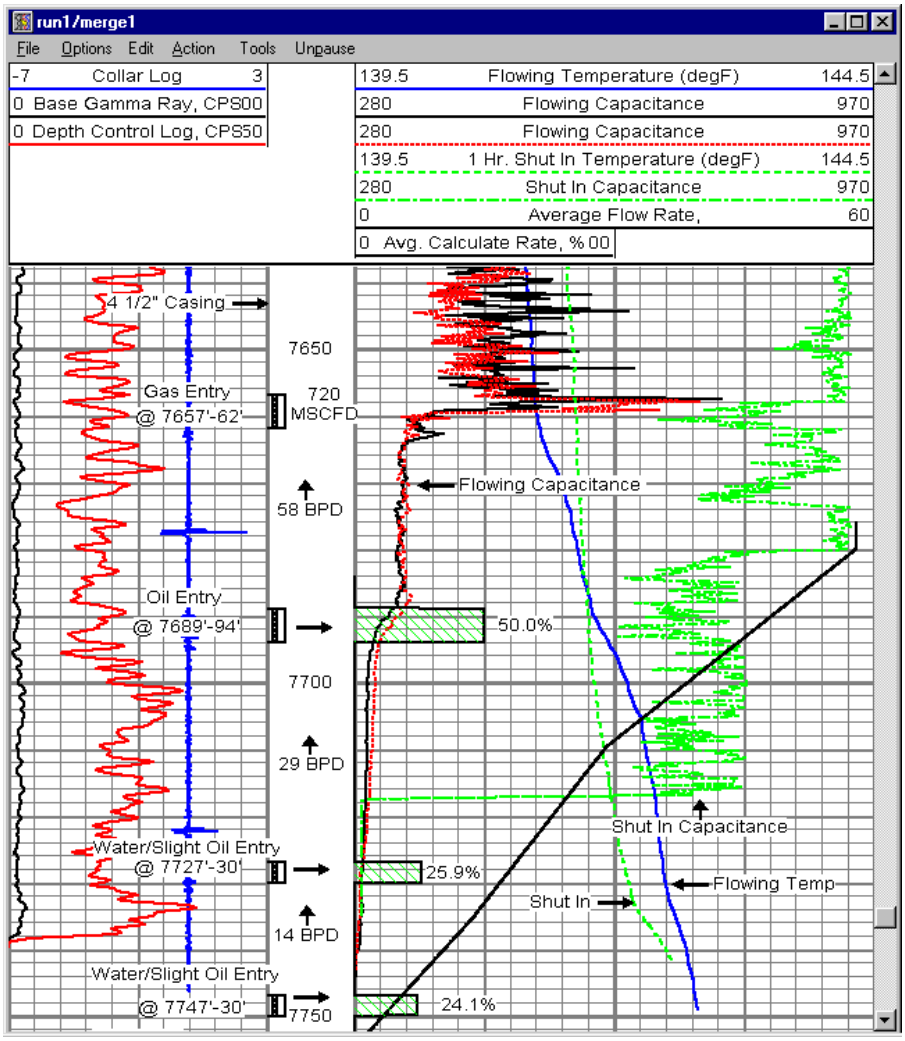
A no-flow shot is ejected between the bottom perforation and LTD. It is monitored in the same manner as the other velocity measurements. The primary objective is to determine if there is any fluid movement from below LTD in the casing. This is essential information. If the temperature surveys indicate fluid movement from below LTD, the no-flow shot is the only means to prove whether the movement is inside or outside the casing.

The log may or may not be complete at this point. After determining the type and quantity of fluid being produced from each zone, decay temperatures and cross flow surveys may be needed for further definition. It is almost always a good idea to run at least one decay temperature survey

unless all objectives for running the survey have already been conclusively reached through the prior survey methods.

Trac III Production Logs - Interpretation

Production log interpretation involves review of all the data collected. After all logging passes are merged and production rates are calculated, a picture of the well's performance should begin to emerge. While not always quantitative, the capacitance log identifies fluid composition near entries. The temperature logs show entries, especially gas entries.



Temperature logs are frequently difficult to grasp. The key to temperature surveys is the relative change of temperature from point-to-point and also changes in the temperature at the same point for different producing rates (for example, while pumping and then after the well is shut-in). Absolute temperature values, and warmer or colder areas, while interesting, are not as relevant as a change.

The example shown indicates relatively minor fluid entries from the lower three sets of perforations with the major gas entry from the top perforations. The second set of perforations indicates oil, but even the bottom two sets show some hydrocarbon. From the example, one can see the necessity for all three tools (temperature, capacitance and tracer) in order to quantify the well's performance completely.

Trac III Production Log - Conclusion

The Trac-III is one of the best services offered by Cardinal Surveys. Those who use and understand it realize economic returns faster than from information obtained from most services offered by any service company. The Trac-III is the only means of obtaining a production log on a well with a rod pump under stablized, dynamic, producing conditions.

915-580-8061 (Odessa, Texas) / 505-397-1069 (Hobbs, New Mexico)