UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
DENVER, CO 80202-1129
Phone 800-227-8917
http://www.epa.gov/region08

Radioactive Tracer Surveys for Evaluating Fluid Channeling Behind Casing near Injection Perforations

PURPOSE:

The purpose of this document is to provide EPA staff with guidelines to assist operators in planning and conducting a Radioactive Tracer Survey (RTS). When used properly, a RTS can identify the presence or absence of vertical fluid movement behind the casing near injection perforations. With the exception of very specific circumstances, the RTS is not approved as a stand-alone method for demonstrating Part II (external) Mechanical Integrity (MI). However, a RTS can be used to supplement data from approved Part II demonstrations. If channeling behind casing is detected, a RTS can also be used to evaluate the vertical extent of fluid movement.

As with any logging or testing method, planning a RTS should begin with a clearly stated objective and should identify consequences and follow-up actions based on the results anticipated. It is important to understand the site-specific geologic, construction, and operational factors that may influence the test. Remind the operator that RTS results must be analyzed and interpreted by a knowledgeable log analyst and must be documented with the appropriate narrative descriptions, log records, schematics, and charts, and that advance notification is required 30 days prior to conducting a RTS when it is expected that the Maximum Allowable Injection Pressure (MAIP) will be exceeded. Discussing the RTS procedure with the operator and the logging service company prior to conducting the RTS is strongly recommended.

PLANNING THE TEST

The operator should consider many factors when planning a RTS: wellbore construction, any drilling or completion problems encountered, fracture and acid treatments, proximity of USDWs and confining zones, and the adequacy of the confining zone all play a role in the success of the test. Planning the RTS should include discussion of the following items with the operator and the logging service company:

- LOGGING EQUIPMENT: Determine any limitations of the logging equipment to be used in conducting the RTS.
- THE LOGGING TOOL: The RTS tool should include a collar locator for depth control with at least one ejector and one gamma-ray detector located below the ejector.
- TRACER MATERIAL: The tracer material, typically Iodine 131, should be dated less than one half-life at the time of use.
- TEST PRESSURE: Discuss the test pressure with the operator and the service company prior to conducting the RTS. The results obtained are only valid at (or below) the pressure obtained while conducting the RTS. Therefore, the RTS should be conducted at the MAIP when possible. The MAIP may be reduced in cases where a RTS is conducted at a lower pressure.

- WORKOVERS: Any anticipated workover or treatment operations should be performed prior to conducting the RTS. Workover and treatment operations occurring *after* the RTS may necessitate an additional RTS to reconfirm the presence of adequate cement near injection perforations.
- SEQUENCE OF LOGGING: Because tracer material ejected during early logging runs can interfere with later logging passes, the RTS should be designed to begin in the deepest portion of the well, moving progressively shallower. Alternatively, sufficient water should be injected between logging runs to flush tracer material out of the casing and away from the wellbore where it will not interfere with subsequent tracer runs.
- DETECTOR GAIN: During the pre- and post-tracer logging runs, tool gain should be set to detect changes in lithology and to correlate with other well logs. When logging full-strength tracer slugs, tool gain should be set to deflect nearly full scale at the slug's peak.
- FOR EACH LOG PASS: Operator should record the beginning and ending clock times, the tool location, injection pressure, and injection rate.
- LOG SCALE: Depth scale should be scaled 5 inches per 100 ft to facilitate correlation with other logs. Logs run on time drive should be scaled at 1 inch (or more) per minute.
- LOGGING SPEED: On depth-drive, logging speed should be no greater than 60 ft/min.

SURVEY ELEMENTS

The RTS used to investigate channeling behind casing should include several elements. These are:

- Tool calibration and gain settings
- Pre-tracer background gamma ray log
- Injectivity Profile
- Channel Check (two parts)
- Post-tracer gamma ray log

1) **Tool calibration and setting instrument gain:** Tool gain settings typically vary between different types of logging runs. During the pre- and post-tracer gamma ray log runs, the tool gain should be set so that lithological effects are easily identifiable, background noise is minimized, and correlation with other well logs can be made. This is often about 40 API units or equivalent per inch. To aid in choosing gain settings for the pre- and post-tracer curves, background gamma readings should be made in both a sand and shale to show the magnitude of "noise" measured at the proposed logging sensitivity. The readings should be taken while holding the tool stationary and recording gamma radiation in time drive for a period of 3 to 5 minutes each. This is a statistical check in a shale and sand to set the gain appropriately. The gain on the pre- and post-tracer runs should be set equally to allow the two log runs to be overlaid for comparison. When logging the radioactive slugs on time drive, the tool gain should be set to deflect nearly full scale at the slug peak.

2) **Pre-tracer baseline gamma ray log:** This log provides the baseline gamma ray response through the injection interval and confining zones prior to release of *any* recent radioactive tracer material into the wellbore. This log will be compared to the post-tracer gamma ray log made at the conclusion of the RTS.

- Logging speed should be no greater than 60 ft/min.
- Tool gain should be set to detect changes in lithology and to correlate with other well logs.
- Operator should begin the pre-tracer gamma ray log 200 ft below the lowermost perforation (or at PBTD) and continue to a point at least 200 ft above the top of the uppermost confining zone.

3) **Injectivity Profile:** The injectivity profile will determine the percentage of fluid entering each set of perforations and to confirm no-flow below all perforations. The percentage of fluid entering any set of perforations can be determined by comparing the fluid velocity at points above and below the perforations. Two methods are often used to determine fluid velocity: Method 1) by holding the tool stationary and running the tool on time drive and recording the time needed for the slug to move a fixed distance between the ejector and the detector, or Method 2) by placing the tool on depth drive and logging through a moving slug. In either case, the fluid velocity is determined by comparing the distance the slug has moved with the time required to move that distance. Determining which method to use at each point will depend on the distance between perforated intervals, and the anticipated fluid speed at that point. Consult with the logging service company regarding the appropriate method for each set of perforations. Here are some other factors for the operator to consider:
   - This log pass should be conducted with the well injecting at a test pressure corresponding to the MAIP and with the injection rate stabilized.
   - Fluid velocities should be determined at points 1) below all perforations, 2) between each set of perforations, and 3) at one point above all perforations (moving from deeper to shallower, if possible).
   - Logging below the lowermost perforation should confirm no-flow. Any fluid moving below the lowest set of perforations may indicate injection into an unpermitted interval. **NOTE:** *If the RTS is being used to confirm that no fluid is moving behind pipe vertically below the lowermost perforations, the velocity shot that is made below all perforations should be conducted last (following the post-gamma ray log) in order to prevent the appearance of a 'hot spot' on the post-gamma ray log.*
   - Show the injectivity profile by determining the percentage of injected fluid entering each set of perforations.

4. **Channel Check:** The Channel Check consists of two parts. 1) a time-drive portion where the tool is held stationary inside the casing, watching for vertical flow behind casing, and 2) a depth-drive portion where the interval above and/or below the perforations is logged on depth drive, making note of any fluid that has moved vertically from the perforations.

   a) **Time Drive:** This log is used to detect fluid moving vertically behind casing after entering the perforations. This log should be run with the well injecting at the MAIP, with the tool on time-drive, and with the stationary detector located just above the uppermost set of perforations that are shown to be accepting fluid (uppermost effective perforations). The detector should be located so that it is as close as possible to the top set of effective perforations but at a depth that will allow the radioactive slug to pass entirely below the lower detector before entering the perforations. If the detector is located too close to the perforations, the tool may detect tracer material inside and outside of the casing at the same time, obscuring the results of the test.

Once the tool is positioned, a tracer slug is ejected into the wellbore where it mixes with injected fluid and begins moving downward inside the casing, past the lower detector as it continues toward the perforations. The tool should remain on time-drive as the tracer slug enters the perforations and continue recording for some predetermined time, waiting for evidence of any tracer material moving vertically outside of the casing.

Calculating an appropriate wait-time is crucial for using the RTS to determine if fluid is moving vertically behind casing. The wait-time depends on several factors: 1) the injection rate, 2) the distance between the detector and the perforations, 3) the percentage of fluid moving into the perforations, and 4) the size of any cement channel (which cannot be predetermined). No single wait-time will fit every case, but one hour is the safest default for the majority of injection wells in Region 8. Another method for determining the appropriate wait-time is to use a value of 3*t*, where *t* is the time for fluid inside casing to flow between the detector and the uppermost set of effective perforations. A full discussion of the methodology used to determine an appropriate wait-time should be included as part of the submitted results. In addition, a written justification of the chosen wait-time may be in the operator's interest, particularly if the selection methodology differs from those outlined in these guidelines.

The following considerations apply for a Channel Check utilizing Time Drive:

- The results of the Injectivity profile should be used to determine the uppermost set of perforations accepting fluid and the fraction of fluid entering those perforations.
- The log trace during this first portion of the Channel Check should be made with the tool stationary on time-drive, and with the tool located so that the lower detector is as close as possible to the uppermost set of effective perforations, but at a sufficient distance that will allow the radioactive slug to pass entirely below the lower detector before entering the perforations. It may be preferable to position the tool at a specific depth (the confining zone, for example, if it is close enough to the perforations).
- The operator should use a default wait-time of one hour or calculate *3t*. If site-specific conditions appear to call for longer or shorter test times, discuss this with the operator and with the service company prior to running the RTS.
-

b) Depth Drive: Immediately following the time-drive portion of the channel check, the tool should be switched to depth-drive and the interval between the tool's current depth and the perforations should be logged. If the detector indicates any tracer material moving vertically away from the perforations, the operator should wait briefly and then repeat this pass, tracking the slug as it continues to move vertically. Several passes may be required in order to determine the depth where the slug appears to moves no further. If movement of the slug is detected behind casing in the depth-drive mode, the operator will include a full written description of the extent and the probable causes for the fluid movement, including any justification of why the results indicate the presence of adequate cement despite observed channeling may be in the operator's interest.

6) **Post-tracer gamma ray log:** This log provides a post-tracer gamma ray log to be compared with the pre-tracer baseline gamma ray log recorded prior to running the RTS. Evidence of behind-pipe fluid movement can be evaluated by overlaying and comparing these two log traces, noting any differences or 'hot spots'.

    - Logging speed, gain, and depths run should duplicate settings used for the pre-tracer baseline gamma ray log

SUBMITTING THE RESULTS:

The operator should provide an analytical interpretation of the logging results performed by a qualified analyst. This should include a written description of the procedure including the methodology used to calculate the wait-time, and conclusions drawn from the test. The submittal should include a fluid loss profile across the perforations and a schematic diagram of the RTS tool and well construction on or with the log. The diagram should show:

- Tool layout
- Casing diameters and depths
- Tubing diameter and depth
- Perforated interval(s)
- Open hole intervals
- Packer location(s)
- Total depth and/or plugged back total depth
- The location of the tool when the tracer material was ejected.
- The distance the tracer slug appears to have moved.
- All stationary tests conducted.
- Detector depth and the amount of time elapsed during the test.

ADDITIONAL CONSIDERATIONS:

Ejection of tracer material should occur as close to the perforations as possible. This may help to minimize the occurrence of radioactive material adhering to the inside casing wall or recirculating below a packer, creating 'hot spots' which could be misinterpreted as evidence of fluid movement. In most cases, there is no UIC Permit requirement to use the RTS for a packer check, so eliminate the packer check whenever possible to prevent misinterpretation.