
9.0 APPENDIX A - RECOMMENDED PRACTICE FOR GAMMA EMITTING TRACERS AND SPECTRAL GR LOGGING

This recommended practice was developed by Ian McConnell (ian.mcconnell@energy37.ca) an independent world expert on gamma emitting (GE) tracers and gamma ray (GR) Spectral logging utilized for the purposes of tracing materials injected into wellbores. It is based on deploying the technology of the only known full service provider of non-contaminating gamma emitting tracer products and a Spectral gamma ray logging tool to detect the placement of the gamma emitting tracers in the wellbore.

This recommended practice is also supported by the following Society of Petroleum Engineers (SPE) papers:

- SPE 17962. A Relative Distance Indicator from Gamma Ray Spectroscopy Measurements with Radioactive Tracers.
- SPE-77442. A Practical Guide to Tracer Diagnostics.
- SPE-31105. Measuring Hydraulic Fracture Width Behind Casing using Radioactive Proppant.

Introduction:

The use of gamma emitting tracers is proven technology in identifying the placement of fluids and materials in a wellbore. Areas of accepted use to date include the following applications:

1. Fracture stimulation and identifying the placement of proppants in a wellbore.
2. AER Directive 51 *Injection and Disposal wells*, to confirm hydraulic isolation when converting a producing well to an injector well.
3. Primary Cementing to confirm placement of a specific slurry or a cement slurry lost to fluid thief zones during drilling and/or cementing operations.
4. Remedial Cementing to confirmation of thief zone(s) and final placement of cement slurry.

In order for this technology to be successful, it requires the following properties:

- A gamma emitting radioactive energy source.
- A GE source with a reasonable “half-life” duration of approximately 60 – 85 days.
- Be non-contaminating leaving no residual radiation. The recommended practice utilizes ceramic beads with the GE material contained inside the bead. Only the outside of the bead will contact any surface area and the carrier fluids and other materials do not become radioactive. The radiation travels with the impregnated ceramic bead.
- Utilize a purpose-built Spectral gamma ray logging tool that can distinguish isotopes and their location in the annulus, including the relative distance (near vs far) from the outer casing. A traditional gamma log is inadequate due to the low radiation levels in the wellbore annulus from the GE tracer and the non-spectral nature of a gross gamma tool.

GE Tracing Materials:

The only known global source of gamma emitting and non-contaminating patented tracer material is ProTechnics Div. of Core Lab. The marketing name of the tracer product is “ZeroWash” as the product does not wash off fracturing proppant.

The three tracer products are contained in ceramic beads in which three different heavy metal flakes are impregnated into a ceramic slurry forming ceramic beads. The impregnated beads are irradiated in nuclear reactors to commence the emitting of gamma radiation. The only location of radiation is where the ceramic beads are located / placed. The carrying fluids and other materials do not become radioactive.

There are other tracing materials with radioactive coatings that can be placed on sand grains. When crushed, or when the coating is abraded off the sand, a radioactive signature remains wherever the sand grain has been. Many coatings will also soften in the presence of chloride ions resulting in a radioactive signature left on pumps, treating lines, downhole tubulars and wellbore fluids.

Safety Training & Exposure:

The Canadian Nuclear Safety Committee (CNSC) issues an operating license to any company that uses/handles gamma emitting isotopes based on approved and audited shop and field operations safety programs. ProTechnics trained technicians are authorized to handle / use these isotopes and Spectral logging tools.

The level of external radiation from these GE tracers is extremely low. Ingestion of the isotopes is the greatest hazard for radiation exposure to the public and tracer technicians. To reach the “body burden limit”, a maximum annual radiation dose allowance, a person would need to ingest 22 kilograms of iridium isotope on one occasion. The ZEROWASH beads are too large to pass through the olfactory channel and as such cannot enter the body through the nose. The only method of internal consumption is through the mouth.

Planning the Well Intervention:

1. Define the purpose of the wellbore treatment including the objectives and information that is to be acquired from the operation.
2. Identify the anticipated product / fluid injection rate and pressure including the expected pressure stability / volatility.
3. Determine the expected volume and density of the injected fluids / materials.
4. Plan the time interval between AP fluid injection and logging the well.
5. Ensure there is access to the wellhead for a slick line or braided line operation. Select the wireline company with a contact name and number and review the planned operation with them.
6. Construct a current down hole diagram including; tubulars, deviation, perforated interval(s), packers, any wellbore restrictions etc.

Equipment and Material Required For Well Treatment:

1. High pressure down hole injection pump, usually a cement or acid mobile pump unit.
2. Access to the suction side of the injection pump for adding tracer beads into the injected fluids or products.
3. Hammer union connections where the “injection stinger” can be attached to the suction side of the high-pressure pump.
4. A volume of product or fluid to be traced.

5. A slick line unit when Spectral GR logging operations are required.

ProTechnics to Provide on Location for Tracing Operation:

1. CNSC federal license, copy to operate anywhere on land or seas of Canada.
2. Functioning Ludlum radiation survey meter.
3. Gamma emitting non-contaminating ZERO WASH isotopes.
4. Trained and certified tracing technician and ancillary lead-lined transportation overpack containing isotope storage cannisters, peristaltic injection pump and hoses, PPE, and ancillary safety equipment and signage.

ProTechnics to Provide on Location for Logging Operation:

5. CNSC federal license, copy to operate anywhere on land or seas of Canada.
6. Functioning Ludlum radiation survey meter.
7. Spectral Gamma Ray memory logging tool and backup tool.
8. Trained and certified logging technician with ancillary portable field office truck, software, PPE, and ancillary safety equipment and signage.
9. Radio communication with back up (when required) between wireline operator and logging operator.

Equipment To Be Provided by Well Operator:

1. Service rig or coil rig if required.
2. Any tubing and down hole tools / equipment required for injection.
3. High pressure down hole injection pump (cementing or acid unit) with an associated treating line to wellhead.
4. Product and fluid mixing materials and equipment to perform blending operations.
5. A slickline or braided line truck when logging operations are required. A braided line truck may be used if already on location. Slickline unit is normally used to control costs.
6. A backhoe should it be necessary to construct an earthen barrier for disposal of fluid or material containing GE tracers. This may be required if all of the product containing GE tracers was not squeezed behind casing resulting in product containing GE tracers still in the wellbore tubulars. Approval by the CNSC is not required for any burial operation and is included in the ProTechnics operating license. Burial of isotope residue on location is the preferred CNSC method of disposal due to the non-contaminating nature of the ZERO WASH tracer material.

Typical Job Procedure for Tracer Injection:

1. Perform safety meeting with all personnel on location using check list.
2. Perform pre-job radiation survey of downhole high pressure pump using Ludlum survey instrument.
3. Pre-injection survey of wellhead and area around the wellhead using Ludlum survey instrument.
4. Confirm and /or establish downhole injection rate using high pressure down hole pump to confirm and verify that the injection rate is acceptable for the operation.
5. Determine product and fluid injection volume.

6. Determine how many isotopes to use based on job size, injection rate, fluid type, information to be gathered. Up to three different isotope types can be selected for different fluid blends.
7. Set-up barrier signage from truck, mixing area, tracer injection & pumping area to restrict access.
8. Set-up injection pump and injection hose/stinger assembly to suction manifold of down hole pump. Be aware of pipes, cables set up by service company, observe caution tape if present. Run injection hose out of travel path. Follow 'as low as reasonably achievable' (ALARA) risk procedures.
9. Mix tracer in special gelled carrier fluid in tracer pump reservoir, in restricted area.
10. Upon commencement of pumping fluid and product, inject tracer(s) at pre-determined concentration into flow line, continuing to monitor injection rate of AP fluid to maintain tracer injection concentration.
11. Flush injection pump and injection hose after injection of traced fluid downhole.
12. Once downhole injection is complete, rig down high-pressure pump injection stinger, injection hose, injection pump.
13. Perform post-job radiation survey of mix area, down hole pumps, surface lines, downhole high-pressure pump, wellhead and surrounding area. If radiation is found in suction area of down hole pump, physically remove radiation material with adhesive tape or other material. Place any beads recovered in waste bag in lead lined transportation overpack.
14. If any volume of traced AP fluid ends up on surface for whatever reason, the CNSC recommended method of disposal is that the fluid or material containing beads of isotope be placed in an earth barrier (pit) below ground with a minimum of one meter of dirt on top of the burial location. **IMPORTANT TO UNDERSTAND:** The fluid or product itself is not radioactive, it is the ZERO WASH beads in the fluid which is emitting radiation. If the beads can be removed from the fluid / product, the radioactivity stays with the beads and the fluid is left "clean".

Typical Job Procedure for Logging Operation:

1. Perform safety meeting with all personnel on location using check list. Wear PPE.
2. Perform radiation survey of wellhead and surrounding area.
3. Place safety barrier signs in working area to restrict access.
4. Program memory logging tool.
5. Rig up memory logging tool and encoder to slickline/wireline or braided line unit. Run cables such that they do not become a trip hazard. Choose a clear path to wireline unit. Make sure brake is set on wireline drum before connecting the memory logging tool.
6. Communicate encoder attachment with wireline unit operator.
7. Rig into wellhead.
8. Confirm radio communication with wireline unit.
9. Run in hole to top-end depth of logging interval.
10. The logging interval is dependent on a number of variables of individual well conditions and historical primary cementing placement interval operations.
11. A minimum logging interval is 150 meters above and 50 meters below the targeted product placement interval or the tool hold-up depth if less than 50 meters.

12. Logged interval can be affected, but not limited to, any of the following well history and/or conditions, which may change the recommended logged interval. As the number of variables increases, the logged interval should be reviewed and possibly increased due to the potential vertical “travel” increase vs the designed/expected placement location risk.
- a. Well age / history. The older a well is, the higher the risk of poor hydraulic isolation due to original cement slurry quality and the condition of existing cement.
 - b. Primary initial cement placement and top of cement. Upper intervals were sometimes not isolated at time of primary cementing resulting in potential crossflow.
 - c. Cement slurry design including dispersant and fluid loss additives (if used). Without fluid loss additives and dispersants to increase the efficacy of the fluid loss, the potential for slurry “free water” increases and therefore channel development.
 - d. Preflush volume / plus surfactant water-wetting agent (if used) efficacy with drilling mud removal before pumping primary cement. If the preflush / surfactant mix has not removed the drilling fluids and the film of drilling mud from both the casing and the formation surface contact area (filter cake); with a resulting a water wet formation contact, hydraulic isolation may not have been achieved.
 - e. Casing centralization and wellbore deviation. Slant wells will have the highest potential for channel leakage as the free water will travel to the high side of the wellbore and the slant angle creates the pathway for leakage. Most slant wells are shallow and the production casing primary cement slurry was neat cement (no additives). This potentially results in a high free water cement slurry environment. This is conducive to creating a channel on the top side of a deviated wellbore.
 - f. Wellbore stability / hole conditions at time of primary cement job. Thief zones and wash outs create areas of instability and therefore increased risk of lack of hydraulic isolation.
 - g. Total interval to be covered with product. The larger the interval to be covered, the greater the risk of incomplete coverage or thief zone(s).
 - h. Volume of fluid and product to be pumped. The larger the volume, the greater the chance of breaking down an existing stable zone and / or fluid channeling.
 - i. Product and fluid injection circulating rate and pressure. Low and stable injection pressure suggests ease of flow placement in the annulus, and therefore potentially less potential for channeling.
 - j. Unknown wellbore conditions.
13. Perform duplicate logging runs at 6 m/minute logging speed.
14. Pull out of hole. Lay down tool string and detach tool string from slickline/wireline.
15. Download data from memory tool; confirm data quality is good.
16. **NOTE:** If initial data download indicates the traced AP fluid material interval has not been completely covered, an additional logging run, above or below the annular interval is recommended, in order to determine the total AP fluid injected placement interval.

17. If initial data suggested AP fluid interval has been completely logged successful, send raw data to the processing center.

Review Processed log data allowing ~2 days for initial processed spectral gamma ray log.