6th Well Bore Integrity Network Meeting

Alberta ERCB
CO2 Injection Well Classification
The Hague, The Netherlands
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The Alberta Energy Resources Conservation Board (ERCB) is a quasi-judicial Board enabled by legislation who, among other things, regulates the design, construction, cementing, testing, monitoring, and abandonment of wells associated with oil and gas production in the province of Alberta, Canada. This includes CO2 injection wells.

web link: http://www.ercb.ca
Wellbore Integrity Concerns Re: CO2 Injection

Atmospheric loss: health and safety concerns; loss of carbon credits (profits)

Groundwater contamination: liberation of minerals & heavy metals that may be toxic

Cross flow saline water from disposal aquifer into other subsurface aquifers or upper groundwater zones
Wells 01_2005 vs. 03_2010

Wells at January 2005
Legend
- Wells
- Major Cities
- Frost Range and Foothills Edge

Wells at March 2010
Legend
Well Status
- Wells
- Major Cities
- Frost Range and Foothills Edge

# Wells = 321, 497

# Wells = 410, 027
Ongoing Well Evaluations

• What should we be evaluating that might trigger an operating or abandoned well work-over within a CO2 injection pressure plume?
  – Casing Integrity
  – Cement and Cement Bond Integrity
  – Tubing and Packers
  – Formation Fluid Changes
Base Line Information

- Sampling for Soil Gas and Surface Casing in All Seasons
- Ground Water Testing
- Porous Zone Above Caprock Characterization (Fluid, Pressure, etc.)
- Cement Bond Log /Casing Inspections
- Other Logging For Water, Gas or CO₂
Ongoing Monitoring

Injectors
- Radioactive tracer logs have shown migration outside of casing between cement and formation.
- Annual test help to show changes, not just empirical measurement.

Cased Wells
- Combination of cement evaluation and casing inspection (must directly indicate external corrosion)
- Change in casing condition is easier to detect than subtle changes in compressive strength

Combination Casing Inspection & Cement Evaluation

Figure 14. Example of well log analysis showing cement bond quality and casing corrosion with example of corrosion due to cement channeling in good cement.

What You May Not Know Maybe Critical

Factors that may impact wellbore integrity or cause concern due to unknown conditions:

- Cement of unknown quality and type;
- Unknown mud properties (such as oil based muds with no spacers run to protect cement from contamination);
- Cement top not located to confirm location;
- Occurrence of abandoned open-hole wells or not properly abandoned cased wells in the vicinity that may be conduits for communication to surface groundwater or natural fractures and faults.

ERCB Well Integrity Directives

- Dir 51 – Wellbore Injection Requirements
  - Dir 08 – Surface Casing Min. Depth
  - Dir 09 – Casing Cementing
  - Dir 10 – Min. Casing Design
  - Dir 36 - Drilling Blowout Prevention
  - Dir 20 – Well Abandonment

Details can be found at:
http://www.ercb.ca/portal/server.pt?
Select <Industry zone>; <Rules, Regulations…>; <Directives>
Focus on Directive 51: Wellbore Injection Requirements

- First implemented in 1994: Prior to that was done on a case-by-case basis.
- Provided basis for approval of more than 50 acid gas disposal schemes in Alberta between 1994 and 2010.
- Directive 51 (D51) is currently being updated

Different Well Classes Cover Injection of:

- **I** – Common Oilfield Waste
- **II** – Produced Water & Brine
- **III** – Acid Gas (CO2 & H2S)
  - Hydrocarbons/Other Gas
- **IV** – Non-Saline Water.
  - Steam for Thermal Operations re: In-Situ Bitumen in Oil Sands Areas
  - Definition in Water Act (4,000 mg/l TDS, anions, bicarbonate, Na, Cl, K).
D51: Common to All Wells

➢ Zonal Isolation: Need Hydraulic Isolation of Zone.

Can be confirmed with a combination of the following requirements (under revision) depending on the type and the age of the well

• Initial pressure test of casing & packer to a 15-minute stabilized pressure of the greater of:
  – 7000 kPa for 15 minutes or,
  – maximum approved wellhead injection pressure;
• Tubing & casing grade & weight appropriate for fluid/gas injection (in-situ steaming at much higher T,P conditions);
• Packer Initial logging requirements;
• Cement integrity log (depends whether acid gas or conventional);
• Hydraulic isolation log;
• Casing integrity log.
Specific Considerations For CO2 Injection

➢ Application Requirements:
  – Show cement and casing will provide long term containment;
    – Use low permeability cement over injection formation;
    – Use appropriate casing;
    – Must have two master valves on wellhead.

➢ Casing & Cementing:
  – Surface casing must be set to base of groundwater protection;
  – Must show good cement on surface casing & next casing string;
  – No remedial cementing allowed.

➢ Casing Integrity Log:
  – After surface casing is set, an initial cement integrity log must be run on the next casing string.
Specific Considerations For CO2 Injection

Cement Integrity & Hydraulic Isolation Logs:
Run cement integrity log plus one of these for hydraulic isolation
- Radioactive tracer;
- Cased hole neutron (capable of detecting gas movement);
  - Temperature log;
  - Oxygen activation log.

Some Considerations Monitoring & Reporting
- Continuous annular Pressure & WHIP;
- Annual packer isolation to 7 m Pa (at surface) or 1.3 x wellhead injection pressure for 15 minutes;
- Hydraulic isolation log every 5 years;
- Casing integrity log every 10 yrs;
- Subsurface safety valves tested semi-annually;
- All information retained for the life of the well.
## Summary Proposal Not to Industry/Board Yet

<table>
<thead>
<tr>
<th>Wellbore Design</th>
<th>Logging Requirements</th>
<th>Minimum Reporting / Monitoring Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Casing to BGWP</td>
<td>SC - cement returns to surface; Next casing string - cement returns to surface.</td>
<td>Cement integrity log and one of the following hydraulic isolation logs: - temperature; - radioactive; - cased hole neutron log; - any approved log capable of detecting gas movement.</td>
</tr>
<tr>
<td>Cementing Requirement</td>
<td></td>
<td>Casing integrity log No casing patches or liners allowed</td>
</tr>
</tbody>
</table>
# ERCB vs EPA Proposed Class for New CO\textsubscript{2} Injection Wells

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Surface Casing</strong></td>
<td>Set through base of lowest USDW</td>
<td>Set through base of lowest USDW</td>
</tr>
<tr>
<td><strong>Surface &amp; 2\textsuperscript{nd} casing</strong></td>
<td>Cement to surface</td>
<td>Cement to surface</td>
</tr>
<tr>
<td><strong>Packer</strong></td>
<td>Opposite cement and within 15 m of perfed interval</td>
<td>Opposite cemented interval</td>
</tr>
<tr>
<td><strong>Cement</strong></td>
<td>Cement appropriate for type of injection fluid</td>
<td></td>
</tr>
<tr>
<td><strong>Pipe Metallurgy</strong></td>
<td>Appropriate for the type of fluid injected</td>
<td>High strength steel alloy or fiberglass</td>
</tr>
<tr>
<td><strong>Monitoring</strong></td>
<td>•Continuous monitoring of WHIP and annular pressure</td>
<td>•Continuous monitoring of injection pressure, flow rate, volumes, mechanical integrity&lt;br&gt;•Downhole auto shut-off&lt;br&gt;•Corrosion monitoring&lt;br&gt;•Position of CO2 plume and pressure front&lt;br&gt;•Groundwater quality and geochemical changes ¹</td>
</tr>
</tbody>
</table>

¹ Addressed in ERCB scheme approval conditions
ERCB Well Integrity Directives

• Dir 51 – Wellbore Injection Requirements
  ➢ Dir 08 – Surface Casing Min. Depth
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• Dir 36 - Drilling Blowout Prevention
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D08 Surface Casing Depth

Two Main Purposes for Surface Casing:

- Well control;
- Protection of Groundwater (BGWP) non-saline water (i.e. water containing < 4000 mg/l total dissolved solids).

D09 Casing Cementing

- Applies to conductor pipe; surface production, intermediate and liner casings;
- Addresses cement top, application method, volumes, fillers/additives, temperature, record keeping.

Cement Type & Placement:

- Higher cement porosity & permeability may contribute to cement degradation due to CO2;
- Cementing problems such as channeling, micro annuli, poor centralization or poor filter cake/ mud removal will lead to loss of integrity.
D10 Minimum Casing Design
– Applies to surface, production, and intermediate casing as well as liners;
– Addresses design factors associated with:
  Minimum burst-pressures & collapse-pressures;
  Minimum tensile strength (tension).

D10 Minimum Casing Design (Updated 12_2009)
– To address sulphide stress cracking concerns, upgraded design factors & material specs now incorporate NACE MR0175/International Association for Standardization (ISO) 15156. Also:
  – Compliance and enforcement;
    – Detailed design and metallurgy criteria for sweet, sour, and critically sour wells;
    – Casing requirements for re-entry wells;
    – Casing wear considerations;
  – Design criteria for burst strength, body yield strength & tension;
  – Design burst loads using assumed /calculated gas gradient.
Cover all non-saline (> 4,000 mg/l TDS) ground-water & isolate or cover all porous zones.

- Addresses minimum requirements for abandonments, casing removal, zonal abandonments and plug backs.

Well abandonment requirements need to become more stringent to ensure that CO2, EOR and CO2 storage is viable in the future;

- All wells, not just ones think in the project;

- Combination of hole conditioning prior to open hole abandonment & incorporate the best of the regulation.
Low Abandonment Plug Can Lead to Cross-Flow

Result of Subsurface Cross-Flow

Abandoned Well: Sequestration Zone Exposed
CO2 or Increased Pressure
Cross-Flow

Spud 1956-05-30
Abandoned 1996-07-04

Ground Water Protection Depth
300.8 mKB

No Cement Plug in Ireton

Porous Zone- 1047.90 mKB
Cap Rock- 1087.20 mKB
Sequestration Zone- 1112.20 mKB

2 sack cement plug
Surface Casing: 323.85 mm open hole. Ran 244.5 mm casing and landed at 187.5 mKB. No cement information available.

Cement Top Unknown
Production Casing: 200 mm open hole. Ran 79 jts, 139.7 mm, 20.83 kg/m, J-55, landed at 783 mKB. No cement information available.
Bridge plug at 752 mKB capped with 8 m cement.

Perforations 758.6-759.9 mKB

Cement plug 1009-1041 mKB
35 sacks, tagged

200 mm Open Hole

Cement plug 1120.14-1129.28 mKB
45 sacks

TD 1129.28 mKB

Need to Look at Zone of Influence. How Far Out Do We Have To Go?

Open Hole Abandonment Challenges & Evaluation

Exacerbated if increased Pressure due to CO2 Injection (Ex: Redwater)

Depiction of cement plug with filtercake and washout

Improve Cased Hole Abandonment Techniques

Casing
Cement
Rock
Cement Cap
Bridge plug with nitrile sealing element between cast iron slips.
Infiltrating CO₂

Current Abandoned Wells

Need to Protect Future Modes of Operation (In Consultation)

Watson, T., Bachu, S., Identification of Wells with High CO₂-Leakage in Mature Oil Fields Developed for CO₂ Enhanced Oil Recovery. SPE 112924 Tulsa, OK, 19-23 April 2008
Remediation & New Well Designs

➢ Abandoned Wells
  – This is going to require a lot of money where wells are identified as problematic, in particular for open hole abandonments;
  – Section milling and squeezing at the zone/caprock interfaces;
  – New products such as ceramic cements and metal alloys may have good application

➢ New Wells Design/Considerations
  – Deviation of wells through the caprock;
  – Details of cementing, including: centralization, hole conditioning, mud condition, filter cake removal;
  – Cement design for low permeability/porosity;
  – Dead Legs.

Open hole evaluation of plugging techniques

Casing inspection for external needs

What’s Needed?

Cement evaluation logging
Other Future Concerns

Horizontal Drilling in Organic Shales: Multifracs. Would This Be Caprock Integrity Loss to Other Producing Conventional Fields and also to potential CO2 Sequestration Sites?

Questions & Discussion ???