Regulatory Framework for Acid Gas Disposal in Western Canada

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What is Acid Gas?

Acid gas is a mixture of H$_2$S and CO$_2$ with a minor fraction of hydrocarbon gases separated from sour gas to meet pipeline and market specifications for natural gas.

Acid gas disposal is a commercial-scale analogue to CO$_2$ geological storage!
Why Inject the Acid Gas?

- Natural gas containing $H_2S$ and $CO_2$ (sour gas), is being produced in increasing quantities in the Alberta basin.

- Acid gas ($H_2S$ & $CO_2$) is stripped off the sour gas.

- By regulation, gas producers are allowed to emit (flare) <1 t/d sulphur into the atmosphere.

- Sulphur is recovered at surface (Claus process) at high cost, which is uneconomic on the market; or

- The acid gas is injected close to the gas plant into deep depleted hydrocarbon reservoirs and saline aquifers, at a lesser cost than sulphur recovery.
Aerial View of the Zama Gas Plant
Sulphur recovered from Sour Hydrocarbons at Zama, Northwestern Alberta
Current Acid Gas and CO₂ Injection Operations in Canada

- Acid Gas Disposal
- Pilot CO₂-EOR
- Commercial CO₂-EOR
Typical Compression Cycle and Injection for Acid Gas

![Diagram showing typical compression cycle and injection for acid gas, with temperature on the x-axis and pressure on the y-axis. The diagram includes lines for Hydrate at Saturated Conditions, Injection Well, and Pipeline, with the Acid Gas Phase Envelope highlighted.](image-url)
Location of Acid Gas Injection Operations in Western Canada
Type of the Injected Stream at Acid-Gas Injection Sites in Western Canada
Average Composition of Acid Gas Injected In Western Canada
Average and Maximum Approved Injection Rates for Acid Gas Injected in Western Canada
Cumulative Amounts of Acid Gas Injected Annually in Western Canada

Annual Injection Rate all Sites (kt/year)

- H₂S
- CO₂
- Other

Years: 1990 to 2006
Cumulative Amount of Acid Gas Injected in Western Canada
Host Unit at Acid-Gas Injection Sites in Western Canada

- Oil reservoirs
- Gas reservoirs
- Oil and gas reservoirs
- Deep saline formations
Rock Type at Acid-Gas Injection Sites in Western Canada

- Carbonate
- Siliciclastic
### Operating Ranges of Acid-Gas Injection Schemes in Western Canada

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licensed $H_2S$ (mol fraction)</td>
<td>0.05</td>
<td>0.97</td>
</tr>
<tr>
<td>Actual injected $H_2S$ (mol fraction)</td>
<td>0.02</td>
<td>0.83</td>
</tr>
<tr>
<td>Actual injected $CO_2$ (mol fraction)</td>
<td>0.14</td>
<td>0.95</td>
</tr>
<tr>
<td>In-situ acid gas density (kg/m$^3$)</td>
<td>204.8</td>
<td>728.3</td>
</tr>
<tr>
<td>In-situ acid gas viscosity (mPa·s)</td>
<td>0.02</td>
<td>0.09</td>
</tr>
<tr>
<td>Maximum well head pressure (kPa)</td>
<td>3,750</td>
<td>19,000</td>
</tr>
<tr>
<td>Maximum injection rate ($10^3$ m$^3$/day)</td>
<td>4.2</td>
<td>900</td>
</tr>
<tr>
<td>Actual average injection rate ($10^3$ m$^3$/day)</td>
<td>1.0</td>
<td>500</td>
</tr>
<tr>
<td>Maximum injection volume ($10^6$ m$^3$)</td>
<td>6</td>
<td>1,876</td>
</tr>
</tbody>
</table>
Characteristics of the Aquifers and Oil or Gas Reservoirs Used for Acid-Gas Injection in Western Canada

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average injection depth (m)</td>
<td>824</td>
<td>3432</td>
</tr>
<tr>
<td>Formation thickness (m)</td>
<td>4</td>
<td>276</td>
</tr>
<tr>
<td>Net pay (m)</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>Permeability (mD)</td>
<td>5</td>
<td>4,250</td>
</tr>
<tr>
<td>Formation pressure (kPa)</td>
<td>5,915</td>
<td>35,860</td>
</tr>
<tr>
<td>Formation temperature (°C)</td>
<td>34</td>
<td>110</td>
</tr>
<tr>
<td>Water salinity (mg/l)</td>
<td>19,740</td>
<td>341,430</td>
</tr>
<tr>
<td>Brine density (kg/m³)</td>
<td>998</td>
<td>1273</td>
</tr>
<tr>
<td>Brine viscosity (mPa·s)</td>
<td>0.36</td>
<td>1.32</td>
</tr>
<tr>
<td>Oil gravity (°API)</td>
<td>16</td>
<td>68</td>
</tr>
<tr>
<td>Gas specific gravity</td>
<td>0.573</td>
<td>1.121</td>
</tr>
</tbody>
</table>
Alberta’s Regulatory Agencies

• Alberta Department of Environment is in charge of groundwater protection (establishes the depth of protected groundwater: TDS<4000 ppm; licenses water wells)

• Alberta Energy and Utilities Board (EUB) has jurisdiction over oil and gas production, and deep well injection and disposal (licenses all deep wells), including well construction and abandonment


Main Regulatory Objective in Deep Well Injection

Ensure that there is no migration and/or leakage out of the injection target that would:
- Contaminate energy and mineral resources
- Contaminate potable groundwater resources
- Endanger life and property

Regulatory attention focuses on:
- Wellbore integrity
- Formation suitability to ensure confinement
- Suitability of the injected stream in regard to the nature of the fluid and well and formation integrity
- Reporting
- Early detection and mitigation of potential problems
EUB Information Requirements Regarding Acid Gas Disposal Zone

- Aquifer/reservoir conditions (P, T) and characteristics (fluids, φ, k)
- Capacity of disposal zone
- Thickness, integrity and extent of caprock
- Location & extent of bottom and lateral bounding formations
- History of neighboring wells
- Effect on resources in disposal zone
Injection Well Classification in Alberta

In decreasing order of monitoring and surveillance requirements

- **Class Ia**: oilfield or industrial waste fluids
- **Class Ib**: produced water and common oilfield waste streams
- **Class II**: brine and brine-equivalent fluids
- **Class III**: hydrocarbons, inert and sour/acid gases
- **Class IV**: potable water or steam
Class III Injection Wells in Alberta

Injection of hydrocarbons, or inert or other gases, for the purpose of storage or enhanced hydrocarbon recovery

- Solvent or other HC products for enhanced recovery
- Sweet natural gas for storage
- CO₂, N₂, O₂, air, other gases for storage or enhanced recovery
- Sour or acid gases for disposal, storage or cycling operations
Requirements for Class III Injection Wells in Alberta

- Hydraulic isolation of the host zone and of hydrocarbon-producing zones
- Injection through tubing
- Annulus filling with corrosion-inhibiting fluid
- Installation of safety devices above ground and in the wellbore
- Cementing across protected groundwater
- Logging for cement top, hydraulic isolation and casing inspection
- Initial annulus pressure test
- Annual packer isolation test
- Wellhead pressure limitation at <90% of rock fracturing threshold
- Area of review based on reservoir modelling
- Hydraulic isolation of offset wells that penetrate the same zone within the area of review
Monitoring and Reporting Requirements for Acid Gas Disposal Schemes

• Well head pressure and temperature

• Gas composition

• Wellhead flow rate

• Maintenance and special well workovers

• Annual or bi-annual reporting
Public Concerns

• Preference by public for acid gas injection rather than flaring or other forms of sulphur recovery

• Potential for flaring and/or atmospheric emissions in the event that the injection facility is shut down for whatever reason

• Potential for contamination of groundwater resources

• Whether other operators now and in the future will know about the existence, location and extent of an acid gas disposal scheme (hence, by extension, of a CCGS scheme)
Conclusion

Deep injection of acid gases is a mature technology that can be used for the large-scale implementation of greenhouse gas capture and sequestration in geological media.