Safety in CCS

Neil Wildgust, Mike Haines and Ludmilla Basava-Reddi

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Overview

Safety & Health

- Hazards associated with CO$_2$ streams in CCS
  - Toxicity
  - Low temperature
  - Dry ice erosion
  - High pressure and corrosion
  - High density
  - Detection
  - Other substances and contaminants
MSDS classifications

**CO₂**
- Label 2.2: Non flammable, non toxic gas.

**SO₂**
- Toxic
- Corrosive

**H₂S**
- Label 2.3: Toxic gas.
- Label 2.1: Flammable gas.
- N: Dangerous for the environment
- T+: Very toxic
- F+: Extremely flammable
Health effects of Carbon Dioxide

Typical 8hr exposure limit 0.5%
Typical STEL 3% (varies between countries)
Typical Human exhaled air

Oboe and Bassoon players breath analysis with time:

- <1 No effects
- 1-1.5 Slight effect on chemical metabolism after exposures of several hours
- 3 Weakly narcotic, deeper breathing, reduced hearing, headache, increased blood pressure and pulse rate.
- 4-5 Deeper, more rapid breathing. Signs of intoxication after 30 minutes
- 5-10 Breathing more laborious, headache and loss of judgement
- >10 Unconsciousness in under one minute, further exposure to high levels eventually results in death.
Toxicity of key contaminants

**H2S**
- TLV 10 ppm  STEL 15 ppm

**SO2**
- TLV 2ppm STEL 5 ppm

*Hence if H2S > 0.1-0.2% or SO2 > 400ppm these contaminants are potentially more toxic than the CO2*
Impairment

\[ \text{CO}_2 \text{ can be tolerated in quite high concentrations without permanent risk to health} \]

\[ \text{BUT if those exposed have key tasks to execute their response may be impaired} \]

\[ \text{THUS need to consider effects during emergency situations} \]

Atmosphere in submarines is typically 4000ppm CO2!!
Just below the TLV. Crews should not be impaired.
However levels up to 10,000ppm are reported
Low temperature hazard

Critical pressure 73 atm
Critical temperature 31.1°C

Risk of cryogenic burns, brittle failures, and damage or injury due to abrasion

-78.5 1 atm atmospheric sublimation point
High pressure and corrosion

**Usual risks of vessel or pipe rupture**
- Low temperature embrittlement is a risk factor

**Consequences**
- Flying objects
- Injuries if hit by jet

**Have to keep CO₂ dry to avoid corrosion**
- Effects of other acid gases – H₂S, SO₂?

**Effects of trace amounts of oxygen**
- Further research needed on O₂ induced corrosion
A running fracture – result of a test

Fractured gasoline line—undetected damage

Results of metal embrittlement

15th January 2009 Vancouver—line rupture
High vapour density

**Vapour accumulates in low points**
- Need to review layouts to identify areas at risk
- Cold vapour has even higher density and will seek out low areas
- Need to consider pipeline routes

**Location of safe haven**
- Dilemma offshore – high or low on platform?

**Spill collection**
- Solid floors prevent CO\(_2\) dispersion
Detection issues

Location of detectors different for heavy gases

Flammable gas detectors do not detect CO$_2$

- May not work in CO$_2$ atmosphere
- Low temperatures can deactivate detectors
Other substances

**Absorption chemicals**
- Amines, can be mildly toxic and mists might be flammable

**Oxygen**
- Cleanliness, concentration limits - oxygen burning of deposits or steel
- Increased flammability of combustible substances

**Hydrogen**
- Wider explosion limits but faster dispersion
Other substances – cont.

*Ammonia* *(if chilled ammonia process used)*
- Moderately toxic (TLV 25ppm STEL 35ppm)

*Nitrogen – used to dilute hydrogen*
- Increase asphyxiation risk e.g. in turbine hood
2008 IEAGHG Study

Study undertaken by UK Health and Safety Laboratory

Systematic identification of hazards associated with all surface facilities forming part of a CCS system

Contributions from power, industrial gas, pipeline and oil and gas industries
Objectives

1. Establish baseline of non-CCS facilities and activities
2. ID CCS additions to this baseline
3. ID exposure to new hazards which these bring
4. ID possible resulting major incidents
5. Assess consequences of major incidents
Objectives - continued

6. Analyse where change from established practice could be a significant additional factor in causing incidents

7. Propose measures for eliminating risk of incidents

8. ID gaps in ability to quantify risks and evaluate consequences

9. Propose emergency response measures
IEAGHG conducted a study of safety in CCS. Resulted in identification of potential hazards.

Results are summarized in “Bow Tie” diagrams. These show “top event” initiators, barriers to their development as well as the further consequences, barriers and recovery measures and further escalations.

Computerised interactive generic diagrams have been published with the report.
Study conclusions

- *Industry has wide experience in handling CO₂*
- *No fundamental safety issues found*
- *Retrofitting CCS into existing plants causes space constraints and increased complexity.*
- *Sharing of information/ experience will contribute significantly in early years*
Knowledge Gaps

- CO$_2$ source term modelling
- Fracture models for pipelines
- CO$_2$ dissolving heavy metals & toxics underground?
- Design and operation standards
- Emergency response plans need development
- Stenching agent for CO$_2$?
Recommendations

• **Hazards and bow-tie used to design future CCS projects**
• **Continue to develop design standards to CCS and resolve knowledge gaps**
• **Particular attention to layout and interface issues when retrofitting**
• **Training and competency considered at the outset of project**
• **International incident database with free access**
• **Emergency response plan to be developed**
The biggest risk.............

CHANGE

Altering and adapting established designs and practices could be a significant contributor to accidents in the emerging CCS industry
Closing remarks

**CCS can be very safe providing:-**

• Safety is given adequate attention from an early stage

• Good safety management practices are adopted throughout CCS project lifecycles

**SAFETY IS ALWAYS GOOD BUSINESS**
Thank you for your attention