

CO_2 PIPELINE SYSTEMS: ASSESSMENT OF THE RISKS AND HEALTH & SAFETY REGULATIONS

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The widespread deployment of carbon capture and storage (CCS) to address climate change will require the construction and operation of a large network of pipeline systems to transport the CO_2 from the capture facility to storage sites. Because of the expected scale of these systems and the properties of the CO_2 being transported, CCS pipeline systems may require different approaches for risk assessment and regulation compared to other, more common gasses, such as natural gas. There is also a general lack of knowledge amongst stakeholders around the safety issues of CCS, which must be addressed to achieve acceptance. This paper outlines the results of a study undertaken by Environmental Resources Management (ERM) for the CO_2 Capture Project (CCP) to better understand these considerations. This includes:

- A comparative overview on the risks posed by natural gas, sour gas and CO_2 pipelines
- A review of the safety regulatory requirements for pipelines in general, with a special focus on CO_2 pipelines where these exist (for Canada, US, UK and Europe).
- Characterizing the current state of acceptance of CO_2 pipelines from NGOs and other stakeholders that could have an influence on the implementation of regulations and oversight for CO_2 pipeline systems

An assessment of the risks associated with pipelines transporting CO_2, along with stakeholder acceptance of their operation, will be a key element in securing a 'license to operate' for CCS facilities.

INTRODUCTION

The primary objective of the CO_2 Capture Project (CCP) is to develop new, breakthrough technologies to reduce the cost of CO_2 separation, capture, and geologic storage from fuel combustion sources such as turbines, heaters, and boilers. CCP has a parallel work stream exploring 'softer' issues around policies and incentives for CCS activities. Phase 3 of CCP is planned to be an industrial-scale demonstration of some CCS technologies, which would represent a major step towards wider commercial deployment (Ref 1). A common requirement for all these technologies is a safe pipeline system for the transportation of CO_2 from capturing facilities to storage sites.

This paper presents an overview of key risks associated with the operation of natural and sour gas and CO_2 pipelines, an evaluation of how the current regulations associated with pipeline operations address these risks, and highlights relevant stakeholder views and perceptions of the risks of CCS and/or CO_2 pipeline operation.

PIPELINE COMPARATIVE RISK OVERVIEW

'Risk' has two key components:

- A likelihood or frequency component
- A consequence or severity component.

The overall level of risk to humans and the environment associated with pipeline operation is a combination of the above two factors. This combination of the likelihood of failure and the severity of the impact is illustrated in Figure 1, which also highlights some of the failure causes and the different categories of impact (or consequences).

The safety related issues that could potentially differentiate CO_2 from natural gas, sour gas or CO_2 transportation for Enhanced Oil Recovery (EOR) operations can be summarised as follows:

- Additional risks associated with higher population densities where CO_2 is transported via pipeline as part of

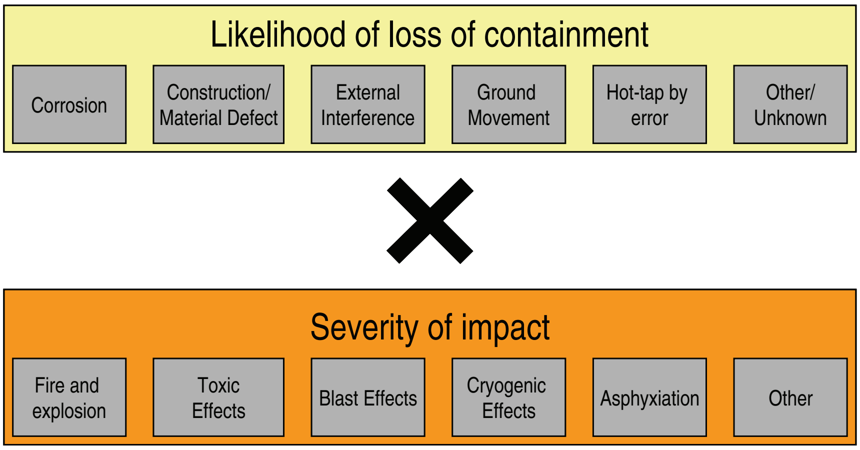

Figure 1. Overview of risk for a pipeline system

CCS activities compared to CO_2 for EOR pipeline and other pipelines.

- Purity requirements and impurities in the transported stream.
- Higher operating pressures and the volume associated with transporting CO_2 in the dense/supercritical phase for CCS than other gas pipelines.

Research, modelling and interviews undertaken by ERM suggest that the overall level of risk posed by CO_2 pipelines may be difficult to assess with a high degree of confidence at the current time. This is due to knowledge gaps currently surrounding the behaviour of supercritical CO_2 releases and limitations in existing models for simulating a 3-phase release associated with supercritical CO_2.

When the level of uncertainty concerning the risk increases, regulators' decisions related to the management of risk tend to be more cautious in order to provide higher levels of protection. However, the European Commission's preliminary analysis of available empirical and modelled evidence indicates that the risks from CO_2 pipeline transport are "*no higher than for pipeline transport of natural gas*" (Ref 2).

Furthermore, when risks posed by CO_2 pipelines are viewed in the context of risks imposed by existing hydrocarbon pipelines it appears that CO_2 pipelines should not pose higher risks than those already tolerated by wider society provided that standards, controls and design factors for supercritical CO_2 transportation are taken into consideration (Ref 3). Standard controls and design factors have been in place for some time for supercritical CO_2 transportation in North America (for enhanced oil recovery). The experience so far with CO_2 transport in the US suggests that the existing pipeline technology would be suitable for transportation of CO_2 from the perspective of providing adequate protection to the public (Ref 4).

It is likely that the already established design, construction and operating requirements that apply to existing gas pipelines operating in densely populated areas would be applicable for CO_2 pipelines sited in sub-urban and urban areas and would be able to deal with the population density issues.

The US Office of Pipeline Safety statistics indicate that the frequency of incidents for CO_2 pipelines is similar to that of natural gas pipelines. This finding is also supported by IPCC Special Report on Carbon Capture and Storage (Ref 3).

In relation to impurities, despite the fact that work has been undertaken in this area, there is currently no uniform definition of the required quality of CCS streams in order to transport CO_2 safely; standards may therefore need to be developed to expedite permitting.

As transportation of CO_2 cannot be seen in isolation from the rest of the CCS chain, all relevant parties (i.e. capture, transport and storage site operators) would need to be involved in an effort to understand the practical implications that pipeline safety requirements (especially in relation to impurities) could have at each CCS stage.

Prospective CO_2 pipeline developers should anticipate that filling the current knowledge gaps in relation to CO_2 modelling, risk assessment and the effect of impurities in the overall level of risk could help support potential risk based planning, safety and permitting issues and thereby inform the regulatory development process.

PIPELINE REGULATORY REVIEW

CO_2 can be treated by regulators as a fluid or gas, hazardous or non-hazardous. CO_2 has been categorised in the US and Canada as Class 2.2 non-flammable hazardous material and Class 2.2 Non Flammable, Non Toxic Gas respectively; however, in the UK there is currently no categorisation for CO_2. Based on an extensive regulatory review and interviews with regulators in the UK it is likely that CO_2 will be regulated under the existing Pipeline Safety Regulations.

CO_2 pipelines are built to defined standards and are subject to regulatory approval in the US and Canada where experience in CO_2 transportation exists. In the UK there is currently a knowledge gap in transporting supercritical CO_2. A regulatory framework is currently being developed but in the meantime UK regulators consider that there may be technical benefit in applying the US Federal Code for CO_2 transportation in the supercritical phase in the UK.

Higher population densities are likely to be encountered in CO_2 pipeline deployment for CCS and hence the overall risk would be higher compared to equivalent CO_2 pipelines for EOR. The existing regulatory approach for dealing with risk, along with the uncertainty that surrounds modelling of supercritical CO_2 releases, indicate that CO_2 pipelines might be routed to avoid centres of population and individual dwellings where possible. In cases where this is not possible additional design, construction and operating requirements established for existing pipelines operating in densely populated areas could be applicable for CO_2 pipelines sited in sub-urban and urban areas; however the process of planning, licensing and building new pipelines may be difficult and time-consuming.

No regulatory amendments are anticipated in the countries and regions examined in this study in relation to population density issues.

Purity requirements are not currently addressed by UK legislation; at a European level the Commission has no intention of mandating specific purity requirements at this stage and it would be dealt with on a case by case basis at a member state level through a risk assessment approach.

In Canada, there are no specific purity requirements for CO_2 pipelines as the regulator assesses the pipelines risk on a case by case basis. However, pipeline regulations refer to the Z662 Standard which only covers high-purity onshore CO_2 for EOR; therefore some generic minimum purity requirements are indirectly in place. In a wide-scale CCS deployment scenario this case by case approach could present difficulties and some minimum explicit purity specifications that address safety issues could be required in the future.

In the US D.O.T regulations specify 90% purity levels in their definition of CO_2 and the majority of CO_2 currently transported ranges in purity between 90% and 96%. Neither the States of Colorado nor Texas regulates the purity for transport; purity requirements is a concern expressed by industry as CCS moves forward especially for purities $<90\%$ CO_2.

Table 1 provides a snapshot of the regulatory gaps in relation to the above CO_2 transportation issues discussed in this section for each jurisdiction. The colour coding used in Table 1 is as follows: green – no issue; orange – minor issue; and red – major issue.

RISK PERCEPTION

Pipeline routes are frequently the subject of public inquiries and the public perception of risk could be an important factor for CCS acceptance in a wide-spread deployment scenario. When risks are perceived by the public as being too high then societal concerns can arise. Such concerns could potentially result in socio-political responses, loss of confidence by society in the provisions and arrangements in place for protecting people and a loss of trust in the regulator and duty-holders. Eventually such developments could have an impact on CCS deployment and related implementation costs.

Key messages from the surveys and interviews undertaken by ERM suggest that:

- CO_2 pipelines are perceived as safe by the majority of the stakeholders
- There is a lack of awareness of CCS among the participants of the surveys, which is likely to be even greater amongst the general public.
- The perception of CO_2 pipeline risk demonstrates variation between different countries and regions with some being less risk averse (Germany, UK, Italy and Norway, State of Texas) than others (Sweden, Denmark, State of Illinois) based on the surveys that ERM reviewed or interviews with stakeholders.
- Some of the positive aspects associated with hydrocarbon pipelines (such as economic growth or enhanced energy security) which are sometimes used to influence the acceptance of projects by affected communities are typically absent for CO_2 pipeline projects.

Nonetheless, given the higher relative population densities between countries and regions it is likely that some public opposition to CO_2 pipelines could develop in the UK and in certain states or regions in other countries (e.g. Illinois).

Problems can be exacerbated when affected communities are not well informed about the CCS pipeline project, as suggested by the experience of past hydrocarbon pipeline projects.

The current lack of awareness concerning CCS suggests that individual stakeholders as well as the general public would like more information in relation to risks of CO_2 leakage and the associated risks to human health and the environment. This can present an opportunity to establish communication channels that will enable a wider distribution of the relevant information on CCS technologies, and serve to influence the risk perception of CCS and its related infrastructure in order to ease the CCS deployment process.

CO_2 pipeline developers are aware of the wider societal benefits, whilst acknowledging that the risks are borne by the local communities affected by pipeline projects. Pipeline developers and government should engage early on to educate local communities on the wider societal benefits to support project acceptance. It can be reasonably expected that communities would be more positive to CCS projects when they feel that by supporting a CCS project they form an integral part of the solution to climate change.

Table 1. Summary of safety regulatory gaps for onshore CO_2 pipeline transport by issue and jurisdiction

CO_2 transport issue	UK	US (Federal)	US (Texas)	US (Colorado)	Canada (Federal)	Canada (Alberta)	Canada (Saskatchewan)
Population density	Covered by existing gas transportation regulations. ALARP risk-based approach	Covered by existing gas transportation regulations. HCA risk- based approach	State level legislation follows federal and in Texas includes rural areas	State follows federal regulations	Covered by existing Federal and Provincial gas transportation regulations under pipeline design specifications (i.e. operating pressure) that are dependent upon population density	Covered by existing Provincial gas transportation regulations. Pipeline design specifications (i.e. operating pressure) are dependent upon population density	Covered by existing Provincial gas transportation regulations. Pipeline design specifications (i.e. operating pressure) are dependent upon population density
Impurities in the transported stream and applicable purity requirements	The European Commission has no intention of mandating specific purity requirements at the current time. It would be dealt with on a case by case basis at a member state level through a risk assessment approach; CO_2 pipeline risks are not yet fully understood and more research would be required	Not covered by existing gas transportation regulations, but covered in tariff cases and contracts	Not covered by existing gas transportation regulations, but covered in tariff cases and contracts	Not covered by existing gas transportation regulations, but covered in tariff cases and contracts	CO_2 is treated as a commodity and existing pipeline federal regulations do not apply	Existing gas transportation regulations require that "high purity". CO_2 pipeline applications must indicate corrosion mitigation and monitoring issues due to water content and other impurities	There are no specific requirements in the provincial regulations. There is reliance on CSA Standard Z662
Supercritical/ dense phase issues	No UK safety regulations or standards for pipelines transporting CO_2 in the supercritical phase. The UK HSE considers there may be technical benefit to applying the US Federal Code to proposals for conveying supercritical CO_2	Comprehensive safety regulations for transporting, design, and operation of these pipelines	Covered by existing gas transportation regulations	Enforces federal requirements, but no additional specific requirements	CO_2 is treated as a commodity and existing pipeline federal regulations do not apply	Existing gas transportation regulations require that CO_2 pipeline applications must indicate specific operating pressure ranges and pressure drops to avoid unnecessary phase change. Minimum pressure must be 7.4 Mpa which ensures CO_2 is in dense state	There are no specific requirements in the provincial regulations. There is reliance on CSA Standard Z662
Categorisation of CO_2	HSE intends to consult on an amendment to the Pipelines Safety Regulations which would deem pipelines carrying bulk quantities of CO_2 at high pressure as "Major Accident Hazard Pipelines"	DOT regulations list CO_2 as a Class 2.2 hazardous material (non-flammable)	Follows federal regulations	Follow federal regulations	Covered by existing Federal and Provincial gas transportation regulations and classified as Dangerous Goods (Class 2.2 Non Flammable, Non Toxic Gas)	Covered by existing Provincial regulations and classified as Non Flammable, Non Toxic Liquid	The province adopts the federal TDG regulations (with some exceptions). Same as federal categorization

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