



A review of the protection strategies against internal corrosion for the safe transport of supercritical CO₂ via steel pipelines for CCS purposes



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ARTICLE INFO

Article history:

Received 8 November 2013

Received in revised form 12 August 2014

Accepted 14 August 2014

Available online 7 September 2014

Keywords:

CO₂

Corrosion

Pipeline

Supercritical

CCS

Inhibition

ABSTRACT

The transport of carbon dioxide (CO₂) from its source to a storage site is a key component of the carbon capture and storage (CCS) process. CO₂ transportation by steel pipelines presents a durability risk in the form of internal corrosion damage from supercritical or liquid CO₂ transmission. This risk is due to the formation of carbonic acid as a result of any H₂O presence, and in situ speciation of acids such as sulphurous (H₂SO₃), sulfuric (H₂SO₄), hydrochloric (HCl), and nitric acids (HNO₃) due to the presence of impurities. This review paper aims to present three key potential protection strategies to mitigate or reduce the threat of corrosion damage for reliable and potentially cost-effective transport of CO₂. This includes review of (a) relevant corrosion inhibitors, (b) corrosion resistant alloys (CRAs) for CO₂ transport pipeline, and (c) the role and physical properties of a protective iron carbonate layer (FeCO₃).

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1. Introduction

Carbon capture and storage (CCS) is emerging as a potentially effective and promising solution to counter the threat of climate change (Vergragt et al., 2011). The Intergovernmental Panel on Climate Change (IPCC) reports that one of the main causes of global warming is due to burning of fossil fuels (IPCC, 2007a, 2007b, 2007c). Proper implementation of CCS is a vital component in reducing the effects of climate change, and is being actively supported by the Australian Government through a number of initiatives (IPCC, 2007d; Anon, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f). CCS is a three-step process, where waste carbon dioxide (CO₂) is captured from anthropogenic sources (i.e. fossil fuel power plants, etc.), transported via pipelines to a storage site, and deposited into geologic disposal sites to prevent CO₂ from entering the atmosphere (Lilliestam et al., 2012).

Three main methods of CO₂ capture exist and are used according to the process and source of CO₂. This is an important part of CCS, as it relates directly to the transport phase and determines the varying combinations of impurities that could be present in a subsequent gas stream. The first method is known as a post-combustion system, where CO₂ is separated from other flue gases after the combustion of fossil fuel (Merkel et al., 2010). Contrary to

a post-combustion system, the pre-combustion system is the exact opposite of the former method, in which CO₂ is separated before the combustion of fossil fuel. In this case, the fossil fuel is not combusted but reacted at high temperature and pressure. This results in the production of mainly hydrogen (H₂) and CO₂, which is then separated (Kang et al., 2013). Finally, the third method is known as oxyfuel combustion or oxyfiring. In this case, air is replaced with O₂ during combustion, creating flue gases containing mainly CO₂ (80%) and water vapour (Merkel et al., 2010; Kang et al., 2013; Kanniche et al., 2010; Thiruvengkatachari et al., 2009). Recently, the oxyfuel process has been discussed widely as being one of the most promising processes for CCS, with research focused on reducing NO_x and SO_x by using flue gas cleaning systems (Kather and Kownatzki, 2011). As evident from the three processes, streams of different CO₂ compositions will result and have to be determined. After the capture process, CO₂ will then be transported either via ships or underground pipelines for various purposes; including for injection underground, the deep ocean, and enhanced oil recovery (EOR) (Lee and Kam, 2013).

Currently, research studies on CO₂ capture and storage technologies are of great interest (Merkel et al., 2010; Holt et al., 2003; An et al., 2011; Bobicki et al., 2012; Figueroa et al., 2008; Qi et al., 2009), however there is very little open knowledge regarding the CO₂ transport phase. Typically, CO₂ is transported as a supercritical fluid (>7.38 MPa, 31.1 °C) via pipelines, taking advantage of its increased density and to avoid complicated two-phase flow regimes (Kruse and Tekiela, 1996; Vandeginste and Piessens, 2008).

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