Journal of Natural Gas Science and Engineering 27 (2015) 769–775

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

journal homepage: www.elsevier.com/locate/jngse

Characterization and preliminary root cause identification of black powder content in a gas transmission network – A case study

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ARTICLE INFO

Article history:
Received 6 June 2015
Received in revised form
8 September 2015
Accepted 9 September 2015
Available online 11 September 2015

Keywords:
Black powder
Natural gas
Pipeline contamination

ABSTRACT

Black powder is a global issue faced by almost all gas producing countries. Understanding characteristics and nature of black powder is required for successful pipeline operations and to assess root-cause of its formation. This paper is mainly divided into two parts. First part gives a synopsis of the global black powder experience and summarizes associated issues and challenges. Second part of the current study is dedicated to chemical characterization of black powder samples received from a sales gas pipeline and root-cause assessment of its formation in a gas processing plant in the Middle East. Elemental analysis of black powder samples show presence of mainly iron and sulfur with traces of various other elements. Further analysis shows presence of both iron sulfides and iron oxides in the network. Root-cause assessment measurements are made from three gas treating and dehydration units in a gas processing plant. Analysis of about 5 month's data indicated that the H_2S levels in one of the trains were 3–4 times higher than the other two trains. Assessment analysis points to the possibility of black powder being generated in some processing units and in the sales gas pipeline.

1. Introduction

The presence of fine black powder particles in gas pipelines is one of the major challenges that global gas processing and distribution companies are faced with. Black powder is a generic name loosely used to designate fine & brittle particles with ferromagnetic and pyrophoric properties that are present in natural gas transmission networks. Experience from world-wide operators indicates that black powder severely impacts pipelines reliability, operation and integrity leading to malfunctioning of equipment such as compressors, sensors, control valves and flanges. Most importantly, it contaminates the gas end customer fuel supply and increases the risk of associated H&SE events, (Sherik, 2007; Sherik et al., 2008; Azadi et al., 2012; Baldwin, 1998; Trabulsi, 2007; Tsochatzidis, 2008; Zhang et al., 2012; Dugstad and Sirnes, 2011).

The main objective of the current study is to report on black powder characterization results and a preliminary root cause assessment of black powder formation in a gas network in UAE. Black powder samples were collected online from different sites in gas manifolds and pipeline systems. Elemental chemical analysis of black powder is presented. Analysis of H_2S concentrations in three different processing plant trains is presented with a view to identify preliminary possible root cause of solid particles formation in the network.

2. Global experience of black powder in gas sales distribution systems

Almost all major gas pipelines operator companies across the world have faced black powder nuisance in one way or the other. Some of the major affected countries are USA, Saudi Arabia, Libya, China, UAE, Qatar, Japan and Greece, (Baldwin, 1998; Trabulsi, 2007; Tsochatzidis, 2008; Zhang et al., 2012; Saremi and Kazemi, 2011, Tsochatzidis, 2007 and Yamada et al., 2011).

Black powder may be generated as a product of internal corrosion due to presence of liquid aerosols and corrosive species (e.g. CO_2, H_2S, organic acids or O_2). Some of the most common constituents of black powder are iron sulfides, oxides and carbonates, (Sherik, 2007). In gas transport pipelines, there are usually two potential sources of water: (1) treated natural gas whose water dew point exceeds the temperature of the pipeline (water vapor may condense on the pipe wall in case of high dew point and low temperature) and (2) water absorbed with Tri-ethylene glycol

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http://dx.doi.org/10.1016/j.jngse.2015.09.022
1875-5100/

(TEG) carryovers or co-condensed with vapors of amines or TEG as the temperature and pressure of the gas decreases after entering the pipeline, (Sherik et al., 2011). Dissolved iron in liquid carry over precipitates as black powder when the H_2S content increases or the temperature is increased.

Presence of black powder may cause several types of problems, including product contamination, erosion, failure of valves and instruments, clogging, fouling and flow reduction in the pipelines. Presence of black powder may also affect in-line inspection tools accuracy that subsequently causes criticality to the field verification of data, (Perez, 2011). Additionally, it represents a health and environmental issue. Hence presence of black powder decreases system efficiency, drastically affects quality of gas and increases corrosion rates.

The removal of black powder from gas pipelines is reasonably well established. Currently, the best practice for controlling black powder in sales gas lines includes gas dehydration and mechanical removal (i.e. filtering and pigging) of the solids formed. Several gas companies separate the black powder from gas by using particle cyclone separators and filter technologies with modular, high flow and particle holding capacity systems. Chemical methods using surfactant, gel, and chelate agents etc. are also used for cleaning of pipelines. These methods can be applied in combination or separately. However, they do not offer one time solution to the problem. These methods are not only costly but require subsequent handling and disposal procedures as well.

The best approach to deal with the black powder is to reduce its potential generation by better controlling the gas plant performance in order to minimize excursions into the gas transmission pipe lines, particularly, in specified dew point, in liquid carry over and in other contaminants such as H_2S and CO_2. However, potential carryover of liquid, TEG and H_2O vapors and particles are generally a big challenge for operators especially when there is always a variation in the inlet gas composition and flow rate to the gas treating plants as well as operating pressures in the gas distribution systems. These variations have to be taken into consideration in the design and operation philosophy of plant upgrades and in new plants.

Sherik et al. (Sherik et al., 2008) suggested several black powder prevention methods. For the new pipelines internal coatings, moisture control and good commissioning practices can offer better control on preventing black powder formation. For old uncoated pipelines, strict adherence to sales gas standards can ensure elimination of condensed water and hence the formation of black powder.

A major issue recognized by most of the gas processing and transport companies is sampling of the black powder. Unless there are preinstalled sample ports available on the high pressure pipelines, it is not easy to collect a real contamination sample that has not been exposed to water or oxygen. Being pyrophoric in nature, usually black powder is flushed with water while it is collected at some filter manifolds or other collection points in the pipelines. Trifilieff and Wines (Trifilieff et al., 2009) used isokinetic sampling techniques combined with membranes. This combination allows for collection of particles into a sample membrane that will retain the same characteristic sizes as present under operating conditions. Similarly, to determine presence of liquids they used a liquid/gas coalescer to collect a sample under isokinetic conditions. Zhiyi et al. (Xiong and et al., 2008) developed and tested a Null-type sampling nozzle to isokinetically measure the particle concentration and size distribution. Tests have been reported to reveal relatively smaller errors. A detailed summary of previous studies conducted on black powder composition, morphology, prevention and mitigation techniques is provided by Khan and Alshehhi (Khan and Alhehhi, 2015).

The above mentioned information from across the globe highlights the importance of black powder characterization and analysis needed to develop a better understanding of the ways black powder is formed and therefrom establish remedial plans to tackle the contamination problem more effectively.

3. Characterization and assessment of black powder in a UAE gas network

It is known that UAE's gas is rich in sulfur content, making the gas handling a bigger challenge for the local gas industry. Some of the local gas processing plants and sales gas pipelines have been facing black powder contamination problem since the beginning of the last decade. Presence and generation of black powder has been identified as a major business challenge. After commissioning of two 1.07 m diameter lines in year 2000 black powder emerged as a problem, likely due to construction issues leading to damage of intelligent pigs and instruments.

The drastic effects of black powder on gas network performance and compromise on gas quality necessitate the analysis of black powder generation, its characterization and development of detection and mitigation techniques. The sections below describe natural gas potential and challenges faced by United Arab Emirates gas industry, followed by characterization of black powder samples and root cause analysis of its formation. The outcome of these analyses can be used to evaluate equipment performance, to select appropriate separation techniques and to improve control systems in the process and field operations.

3.1. Natural gas in UAE

United Arab Emirates (UAE) has the world's seventh largest natural gas reserves measuring more than 215 trillion cubic meter (IEA, 2011). Bulk of the gas produced in UAE is used domestically. Its major consumers are the electric power generation sector, water desalination and re-injection of the gas in enhanced oil recovery (EOR) operations in the country. As per 2011 statistics (IEA, 2011), UAE is the eighth largest gas re-injecting country in the world. In fact, UAE has re-injected more than 25% of its gross production of natural gas into its oil fields, while more than 98% of the country's electric power generation and water desalination through mainly combined cycle co-generation plants uses natural gas. On the other hand also, UAE is a member of gas exporting countries forum and has been exporting liquefied natural gas (LNG) to Japan since 1977 through a long term export contract. More than 90% of LNG produced by Abu Dhabi goes to Japan.

Fig. 1 gives an insight into natural gas statistics of United Arab

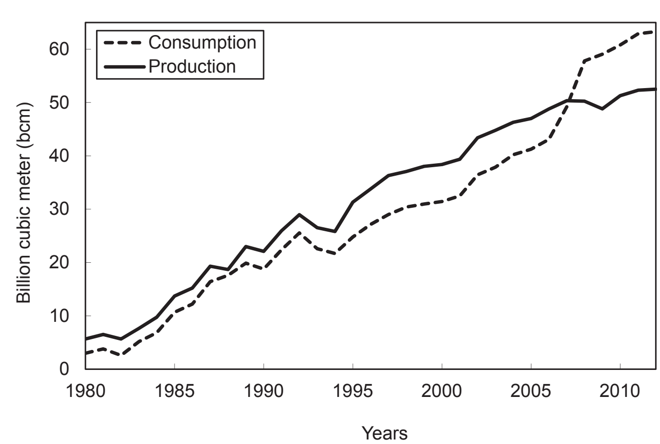

Fig. 1. Natural gas statistics for United Arab Emirates, (IEA, 2011).