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Experimental investigation of inhibitors injection to control salt precipitation using wetted wall column

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ABSTRACT

Dry gas injection into wells will vaporize unwanted water, causing salt precipitation. The vaporization starts from the well base and proceeds outward. The salt precipitation may produce a severe loss of gas injection, which eventually results in a complete blockage of injection. The wells which are located in south oil field of Iran face such problem. The analysis of produced sediments shows that the majority of those compounds are sodium chloride (NaCl). This paper discusses the advantages of applying salt inhibition to reduce mass transfer between gas and water. This concerns an experimental study of the effect of inhibitor addition on the NaCl precipitation. A pilot-scaled dynamic loop was developed to test the performance of NaCl formation and inhibition. Experiments were performed by injecting natural gas into the pilot test apparatus in which formation water flows down the wetted wall column. The amount of evaporated water is measured and represents the amount of precipitated salt. In this work, sodium dodecyl sulfate (SDS) and polyethylene glycol (PEG) used as inhibitors have been investigated for application in halite scaling that was produced by evaporation mechanism. The experiments show that both substances (SDS and PEG) have been effective in reducing the quantity of salt precipitated. Furthermore, it shows that SDS is more efficient than PEG, and the optimum SDS concentration in solution is 400 ppm to inhibit halite formation.

1. Introduction

Gas injection is a widely used recovery method for oil production. It is one form of oil reservoir pressure maintenance operation that provides a higher recovery coefficient for oil reservoirs. Precipitation is one of the important issues in the injection wells. Dry gas injection into wells will vaporize unwanted water and cause salt precipitation. This condition eventually results in a complete blockage of well injection. The wells located in south oil field of Iran are faced with such problem. In this area the reservoir brine is near the saturation with respect to sodium chloride salt. Sodium chloride salt is commonly removed by periodic washing with low salinity water, although this method costs a lot. Hence, one of the challenges in operating these wells is to prevent and control the scale precipitation.

Field observations of salt deposition in gas wells, reported in the study by Kleinitz et al. (2001), show that salt may accumulate in the wellbore, perforation zone and in the reservoir. It is common to observe the deposition of salt in the wellbore and tubing which are then cleaned with periodic water-wash operations.

Kleinitz et al. (2003) discussed precipitation of dissolved salts from the entrained water, chemical parameters for early detection of salt precipitation in the reservoir, the dissolution behavior of halite scale and evaluation of the stimulations performed in a selected gas field in Northern German.

Zuluaga and Monsalve (2003) show that sodium chloride salt concentration increases above solubility limits and causes solid salt to precipitate. In their experiments, the authors identified two vaporization periods: first a constant drying rate period followed by a falling rate period. The drying experiments were analyzed by the use of traveling wave solutions to predict both saturation profile and the drying rates (Zuluaga and Lake, 2004). Some scales, precipitation occurs soon after saturation, with Nieuwland and Collins (2004) reporting halite deposition with only 5% oversaturation. Unlike the evaporation sequence for seawater under atmospheric pressure carbonates, gypsum, halite and potassium salts (Tucker, 2001), under the higher pressures of reservoir systems, it is possible that halite precipitates prior to calcium carbonate and gypsum deposits. It is possible that halite can deposit directly from the trace amounts of sodium chloride found in hot, high-pressure, sour gas (Place and Smith, 1984), although field evidence is not

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Nomenclature

A	mean film surface area (m^2)
H	gas humidity (kg vapor/kg vapor free gas)
k_g	mass transfer coefficient (m/s)
M	mass ratio of salt in saturated solution (kg NaCl/100 kg H_2O)
M_g	molecular weight of gas (kg/kg mol)
M_{H_2O}	molecular weight of water (kg/kg mol)
$\dot{N}$	molar flow rate (mol/s)
p	total pressure (Pa)
$p_{g,m}$	mean partial pressure of gas (Pa)
p_{H_2O}	partial pressures of H_2O (Pa)
$p_{H_2O,I}$	partial pressures of H_2O at the interface (Pa)
$\Delta p_{H_2O,\ \ln}$	mean logarithmic pressure difference
R	universal gas constant (J/(mol K))
T	temperature (°C)
$T_{g,m}$	mean gas temperature (K)
y_{H_2O}	mole fraction of H_2O in the gas phase

available. Until relatively recently, the only method of inhibiting salt precipitation was dilution with water.

Frigo et al. (2000) and Brown (2002) show that conventional threshold inhibitors that are protected against carbonate and sulfate scale nucleation and crystal growth have no effect on halite. A proprietary polymer inhibitor was reported by Szymczak et al. (2007) that can be deployed with a scale, squeeze or through a capillary line, whilst Kirk and Dobbs (2002) demonstrate the effectiveness of an (unspecified) inorganic salt and an organic oligomer inhibitor (like a polymer, but not an endless chain). Bellarby (2009) shows that common additive for drilling through salt and an anticaking agent for cooking salt, potassium hexacyanoferrate, can be used as an inhibitor.

Chen et al. (2009) examined halite formation and inhibition under both traditional static and dynamic conditions. The possible mechanisms of halite inhibition are discussed.

Similar problems are documented for injection wells in gas storage operation where CO_2 is injected in saline aquifers (Giorgis et al., 2007; Zeidouni et al., 2008; Bacci et al., 2011).

Hereby, the evaluation and application of sodium dodecyl sulfate (SDS) and polyethylene glycol (PEG) as inhibitors for controlling halite scale are reported. Halite scale is produced by evaporation mechanism. These two inhibitors were selected because of good results previously experienced with these in gas–liquid flow. Lu et al. (2000) reviewed the use of neutron reflectometry to study the structure and composition of surfactant layers adsorbed at the air–water interface. Some authors have different explanations about surfactants mechanism. Surfactants would create both a modification of the local hydrodynamic at the interface and a new resistance to mass transfer due to a change in local diffusion in the boundary layer film (Painmanakul et al., 2005; Sardeing et al., 2006). By reducing surface tension, the accumulation of surfactants at the interface would decrease interfacial renewal and so the diffusion of gas into the liquid (Rosso et al., 2006).

Experiments were performed by injecting dry natural gas into the pilot test apparatus that formation water flow down the column and the inhibitors are added into the gas.

2. Experimental

2.1. Setup

The schematic diagram of the experimental setup is shown in Fig. 1. The setup consists of three major sections: (1) the main part of the unit consists of the wetted wall column; (2) the liquid flow section consisting of the formation water storage, pump, heater and rotameter; and (3) gas collection section consists of gas storage, rotameter, storage of inhibitor, heater and two psychomotor.

The wetted wall column is a pipe made of Plexiglas concentric where the liquid is distributed as a thin liquid film on the pipe wall while the gas flow co-currently in the center of the pipe. An internal pipe is used to separate the liquid film and the gas core. The inner diameter of the wetted wall column is 0.2025 m. The gas/liquid contact length is 1 m. The gap between the inner pipe and the wall of the wetted wall column is about 2 mm to achieve a uniform distribution.

The formation water is pumped from a Plexiglas tank (0.3 m × 0.3 m on a side and 0.6 m deep) to the top of the column. To adjust the liquid temperature, a heater is installed. The liquid inlet temperature could be regulated between ambient temperature and 343 K. The liquid flow rate was regulated by valves and a bypass line, and

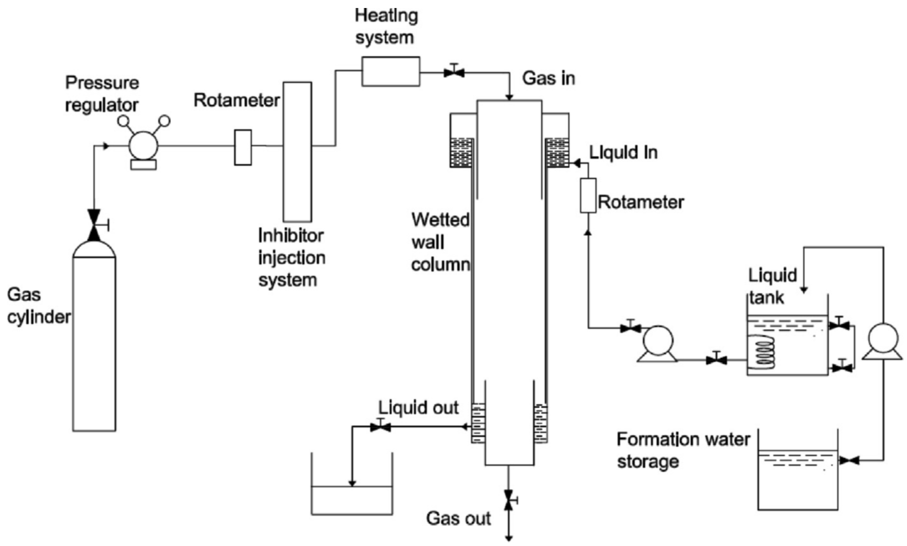

Fig. 1. Sketch of experimental setup.