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Autoclave charging for corrosion testing

Using simulation to calculate parameters for autoclave experiments

Contents

Introduction

The selection of the environment for material testing in H_2S and CO_2 content, depends entirely upon the intended application of the material in the oil field. Downhole environments vary considerably in hydrogen sulfide, carbon dioxide, and chloride concentration; downhole temperatures and pressures also vary depending upon the reservoir and location in the well, see Figure 1.

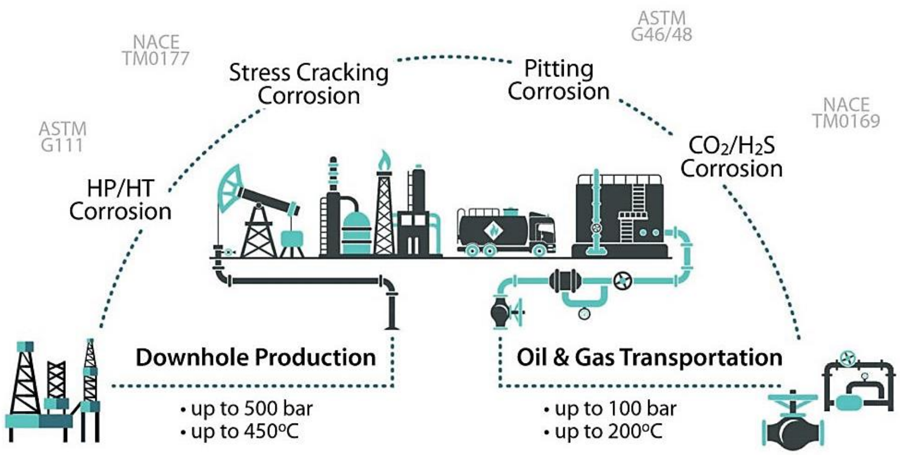


Figure 1. Variation of environments during the oil and gas production

Frequently, as in the case of oil production, there are naturally occurring corrosion inhibitors or water present in the production fluid. A continuous aqueous phase presents the most severe conditions for corrosion of metals downhole; this can occur in sour gas and high "water cut" oil wells. For this reason, almost all corrosion testing for metals in H2S service is performed in aqueous solutions containing H_2S, CO_2, or dissolved chlorides or any combination of these. The environmental parameters that must be controlled in these tests are the partial pressures of the cover gases, temperature, and the chloride content. These solutions are deaerated before the addition of hydrogen sulfide; this prevents or minimize the formation of elemental sulfur by the reaction between dissolved oxygen and hydrogen sulfide [1].

A typical range of downhole environments in oil and gas wells are summarized in Table 1.

Table 1. Typical range of downhole environment in oil and gas wells*

Parameters	Oil Wells	Gas Wells
Temperature of wellhead, ^0C	38-66	38-135
Temperature at bottom of well, ^0C	38-121	121-260
Total pressure, atm	136-531	293-1565
Partial pressure of H2S, atm	0-14	0-544
Partial pressure of CO2, atm	0-14	0-204
Chloride concentration	0 to saturation	2 wt% to saturation

** R. D. Mack, M. Wilhelm, and B. G. Steinberg, "Laboratory Corrosion Testing of Metals and Alloys in Environments Containing Hydrogen Sulfide," in Laboratory Corrosion Tests and Standards, American Society for Testing and Materials, 1985, pp. 249–250.*

There are different standards that depending upon the location of the production, you can set up an experiment with autoclaves and evaluate the corrosion effect.

Most material corrosion testing is determined by the service environment to determine the resistance of alloys in sour oil and gas production. This is accomplished by autoclave testing. The most common autoclave used by customers is the final condition autoclave, where the total pressure and acid-gas pressures (i.e partial pressures) are specified at the heated conditions.

Simulation for setting up autoclave experiments

Using electrolyte simulation prior to performing an autoclave experiment can effectively ensure that the autoclave experiment input will more precisely match the target final conditions.

A limiting condition of autoclave experiments is that once the autoclave is sealed and at experimental pressure and temperature, it is difficult and sometimes impossible to sample and measure the final phase compositions within the vessel. Consequently, one cannot know for sure if the experiment will meet the design specifications until it is performed.

Simulation with electrolyte thermodynamic modeling changes that. Formulating the autoclave experiment in OLI software reduces the uncertainty in setting up autoclave conditions. OLI calculations incorporate the chemical reactivity of species like CO_2 and H_2S, and can predict their composition among the aqueous, gas, hydrocarbon, and solid phases [2].

Autoclave properties that can be calculated

This rigorous simulation of the autoclave can determine a number of properties of the experiment. Calculation results include:

- The reactive gas partial pressures at the elevated temperatures and pressures;
- The aqueous phase properties, such as pH, alkalinity, conductivity, osmotic pressures;
- The solubility of reactive gases into a hydrocarbon phase and the consequential effect of this phase on the final gas partial pressures;
- The formation of solid phases, such as FeS, $FeCO_3$, $CaCO_3$ or other phases that may affect the final properties or a corrosion study;
- The dissolved aqueous species concentrations and properties. From this, the reactivity of these species to metal corrosion can be estimated; and,
- The amount of material (e.g., grams of CO_2 and H_2S) to add to the autoclave so that the experiment meets the total pressures and partial pressures specified in the experimental procedure

Spotlight case study

To illustrate how this type of simulation can be used to augment corrosion testing, become more precise in necessary autoclave loading conditions, and even simulate the rate of corrosion on the metals in the experiment, we will develop an illustrative case study:

Consider that an oil and gas operator wants to test the corrosivity of a production gas/brine on their production tubing. In response, we can setup an OLI Flowsheet: ESP case that simulates the autoclave experiment. Further, once we have the final condition of the liquid phase, we would also be able to evaluate the corrosion rate of different alloys using OLI Studio Corrosion Analyzer.

Method

- Use flowsheet ESP to create an autoclave that resembles reservoir conditions, i.e. partial pressure of the reactive gas.
- Evaluate the composition of the final liquid phase using Flowsheet: ESP.
- Use OLI Studio to evaluate the corrosion rates of different alloys using final liquid phase composition.

Specifications

The production conditions are 100 bar and 300 ^{0}C. The production gas contains CO_2 and H_2S at 1% and 0.003%, respectively (which is equivalent to P_{CO2}=1 bar and P_{H2S}=0.3 bar).

The produced water analysis has a pH of 5.9, alkalinity of 200 mg/L as HCO_3^-, and a salinity of 75,000 ppm TDS.

The operator needs to charge the autoclave with sufficient CO_2 and H_2S so that the final conditions, their vapor concentrations match the measured values.

Steps

The steps needed to calculate how to charge the autoclave to reach the final conditions, i.e. specified partial pressures of the reactive gas, are shown in Figure 2.

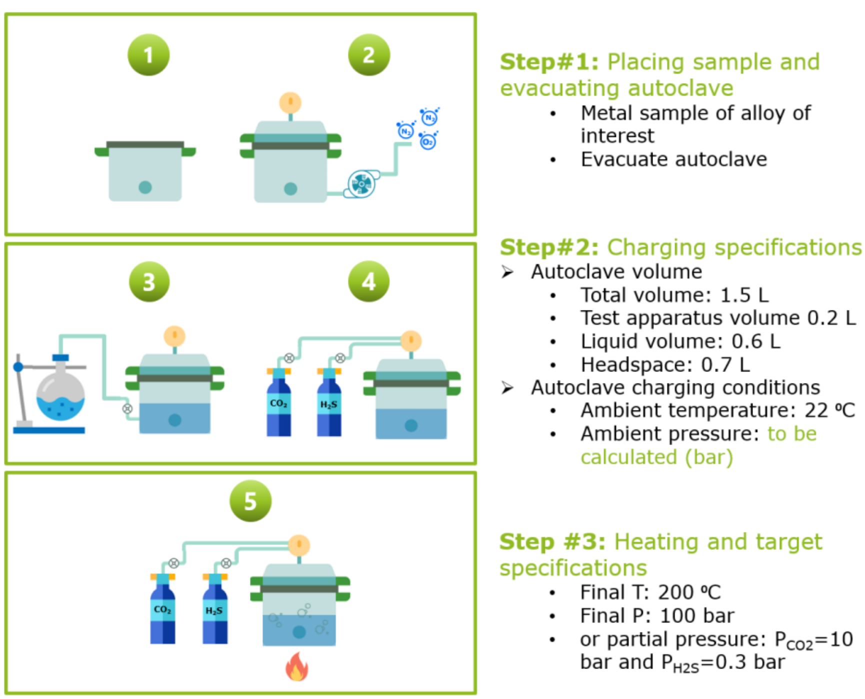
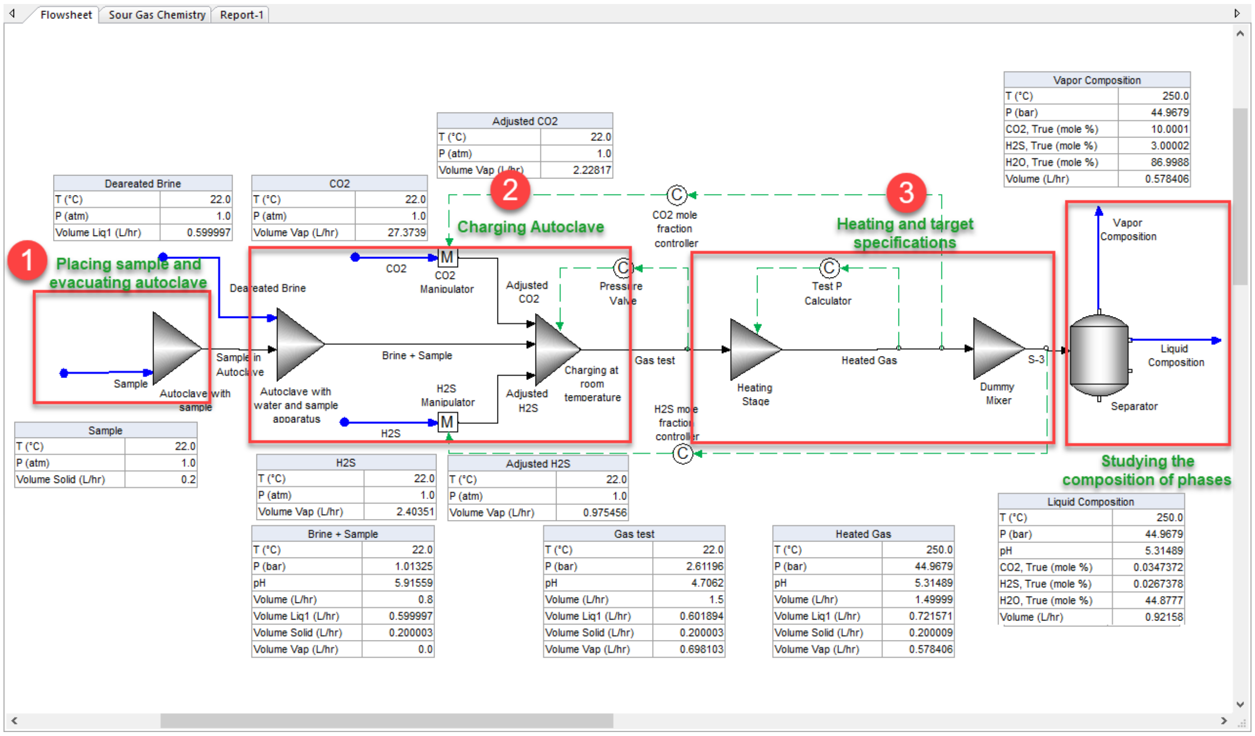


Figure 2. Steps for charging autoclave for corrosion testing

Simulation results

The flowsheet simulation and the results are summarized in Figure 3. You can see that the targeted partial pressures were achieved in the simulation. To reach these values the of CO_2 and H_2S inflows need to be 2.23 L/h and 0.98 L/h respectively. Additionally you can get the liquid composition and pH for further evaluation of corrosion rates for different alloys.



Bibliography

[1] R. D. Mack, M. Wilhelm, and B. G. Steinberg, "Laboratory Corrosion Testing of Metals and Alloys in Environments Containing Hydrogen Sulfide," in *Laboratory Corrosion Tests and Standards*, American Society for Testing and Materials, 1985, pp. 249–250.

[2] "Autoclave simulation," *OLI Systems Inc. wiki page*. [Online]. Available: http://wiki.olisystems.com/wiki/Autoclave_Simulation.

For more Information

- **This case study was presented by Diana Miller, PhD in an OLI Spotlight Seminar, "Autoclave charging for corrosion testing" on 20 September at 10am EDT**

  https://www.olisystems.com/webinar

- **OLI Spotlight Seminars are a series of webinars developed by OLI process simulation experts on simulation techniques. Seminars are available on-demand following the live presentation**

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