FUNDAMENTALS OF GAS LIFT ENGINEERING

Well Design and Troubleshooting

Ali Hernández

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Dedicated with love and gratitude to Carmen *and* Mauricio *for their continuous support and understanding*

And

In memory of my friend and mentor Walter George Zimmerman, *a very practical engineer who always based his technical decisions on sound engineering judgment.*

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Contents

Chapter 1

Gas properties

The working fluid of a gas lift installation is, in most cases, the natural gas associated with the oil that is produced from the same field or from a nearby gas source. The calculation of the injection gas properties is a necessary first step to predict pressures, temperatures, flow rates, etc. at in-situ conditions in the different components of a gas lift installation. Without the knowledge of these properties, it is simply not possible to determine the important parameters that are frequently used in gas lift designs and troubleshooting analyses, such as the pressure and temperature gradients along the injection annulus that are used to locate the depths of the gas lift valves.

The correlations that can be used to calculate the properties of hydrocarbon gases are described in their general forms in the chapter. Many of the correlations given in the list of references in the chapter were developed a long time ago and have been successfully applied during the last decades; however, it is important to always use values of these properties that have been measured in field laboratories in order to: (1) corroborate the accuracy of these correlations for different operational conditions, and (2) calibrate the correlations that are used by commercially available gas lift design and troubleshooting software to calculate these properties.

The natural gas used as the injection gas in most gas lift installations is a mixture of different hydrocarbon substances of low molecular weight in gaseous state, such as methane, and some nonhydrocarbon impurities like nitrogen, hydrogen sulfide (H_2S), and carbon dioxide (CO_2). If the mixture has significant quantities of H_2S and/or CO_2, the gas is an "acid gas" because it forms an acidic solution in presence of water. An acid gas mixture is not recommended for use in a gas lift field because of the problems it creates for the safety of the personnel and the corrosion of tubular goods and equipment.

If the H_2S concentration is greater than 4 parts per million (ppm), the gas is also called a "sour gas," otherwise the gas is called a sweet gas. It is important

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to maintain the H_2S concentration at values less than 4 ppm because higher concentrations could cause the following problems or inconveniences:

- Because these high concentrations are highly toxic, special safety measurements must be taken to avoid health related problems or even deadly accidents when dealing with sour gases.
- Sour gases can cause sulfur precipitation that can accumulate in the production tubing, flowline, injection gas lines, etc.
- Sour gases are also highly corrosive, especially in presence of salt water.

H_2S reacts with water and iron to form iron sulfide and hydrogen. CO_2, on the other hand, reacts with water to form carbonic acid, which then reacts with iron to form iron carbonate and hydrogen. A gas mixture could be corrosive if its CO_2 partial pressure (defined in Section 1.1) is greater than 3 psi. Actions that need to be taken to overcome the negative effects of CO_2, H_2S, and water are presented in different sections in this book. The necessary corrections in the calculation of the properties of natural gases and water vapor are addressed in the chapter if impurities such as CO_2 and H_2S are present in small quantities, but the equations to calculate the properties of these impurities alone are not presented.

1.1 EQUATION OF STATE

It is very important in many gas lift calculation procedures to be able to express the volume that a given gas, or a mixture of several gases, occupies in terms of its pressure and temperature. The general gas law given in the form of Eq. 1.1 is one of the many so-called "equations of state" that are used to correlate volume, pressure, and temperature of a gas:

$$PV = nR_uT \tag{1.1}$$

Where V is the volume the gas occupies, P is the gas absolute pressure, R_u is the universal gas constant, T is the absolute temperature of the gas, and n is the number of moles inside volume V.

A mole is a given number of molecules of a particular gas with a mass numerically equal to the molecular weight of the gas in the system of units being used. The number of molecules depends on the mole definition being used. For example: (1) in 1 pound-mole (lb-mol) there are 2.73×10^{26} molecules of the gas, (2) in 1 gram-mole (g-mol) there