The Debrining and Operation of a Gas Cavern with Variable Cushion Gas due to Adjustable Gas Brine Contact

*By W. LITTMANN, F. BRODERSEN, M. KRIETER, and O. ZWIGGELAAR**

Abstract

Cavern A7 is operated with varying volumes. As the already implemented cavern supervisory algorithms of CavBase were not designed to handle this new approach and appropriate changes in the existing functions were too complex, it was decided to include the program CavBox in the existing NomiX/CavBase environment.

CavBox was developed to calculate the gas storage process parameters in a cavern with varying volume. It reads the gas rates and calculates the cavern pressure and temperature. The cavern volume is calculated according to the produced brine or injected water, and the fluid level in the cavern is determined using the sonar measurements giving a relation between depth and cumulative cavern volume.

Introduction

When gas is injected into a cavern it is compressed and due to this compression the temperature of the gas increases. When the gas is produced from the cavern it is expanded and the temperature decreases. Further heat flows according to temperature differences to the surrounding salt and to the brine which is left in the cavern.

The gas properties are considered in CavBox using the Hall-Yarborough correlation for the calculation of z-factors. The heating or cooling of the gas is calculated assuming adiabatic pressure change. The heat flow is accounted by a global function, which calculates heat flow linearly during a time step depending on the temperature difference between gas and rock/salt and brine.

CavBox uses different files for input data and creates output files to be used for graphical display and post processing for storage in databases.

The program calculates well head pressure, well head temperature, casing shoe pressure and average cavern temperature and pressure.

Storage Processes

The main physical processes during gas storage in a salt cavern are shown in Figure 1. During operation of such a cavern it is important to know the pressure changes in the cavern, at the casing shoe as well as the temperature in the cavern. The parameters that are being measured during storage operations are rates and well head pressures and temperatures. All other values needed for operations and gas nomination have to be calculated.

Differing from the regular case of cavern storage it was a pre-requisite due to market requirements for the described case that the cavern volume could be variable to optimize cushion gas volumes. The cavern volume can be changed by producing brine or injecting water.

The storage pressure is calculated by material balance and the equation of state for gas (Eq. 1).

$$pV = znRT \qquad (1)$$

where p is the cavern pressure, V the cavern volume, n the amount of gas in moles, R the gas constant and T the cavern temperature. The z-factor is calculated according to the gas composition.

The temperature change in the cavern is calculated as an adiabatic compression/expansion according to Eq. 2.

$$T_2 = T_1 \left[\frac{p_2 z_2}{p_1 z_1} \right]^{(\kappa - 1)/\kappa} \qquad (2)$$

where T is the temperature, p the pressure, z the real gas factor and ê=cp/cv the adiabatic exponent. The indices 1 and 2 refer to the corresponding state. Heat flow is from the gas to the surrounding salt. It is calculated according to the temperature difference between the salt and brine and the cavern gas

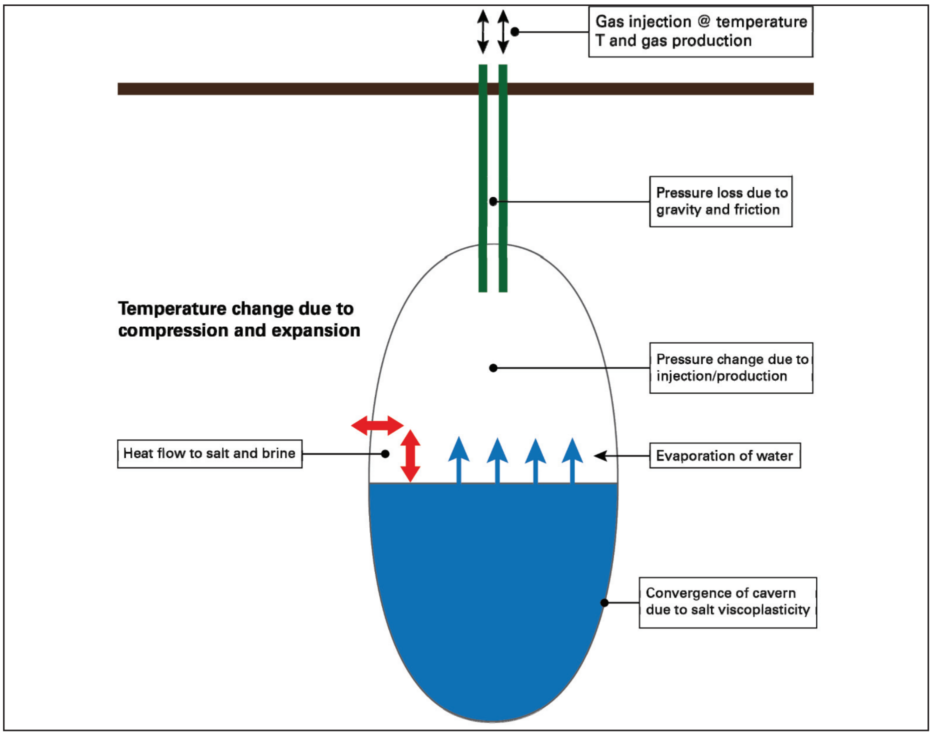

Fig. 1 Main processes during gas storage in a salt cavern with dual well completion

* Wolfgang Littmann,Consulting Reservoir Engineering (CRE), Wunstorf, Germany (E-mail: W.Littmann@cre-geo.de); Frédéric Brodersen, Bilfinger Greylogix GmbH, Flensburg, Germany; Michael Krieter, SOCON Sonar Control Kavernenvermessung GmbH, Giesen, Germany; Olaf R. V. Zwiggelaar, N. V. Nederlandse Gasunie, ??Groningen?? The Netherlands. Lecture, presented at the Solution Mining Research Institute Fall 2014 Technical Conference, 29–30 September 2014, Groningen, The Netherlands.

0179-3187/15/4

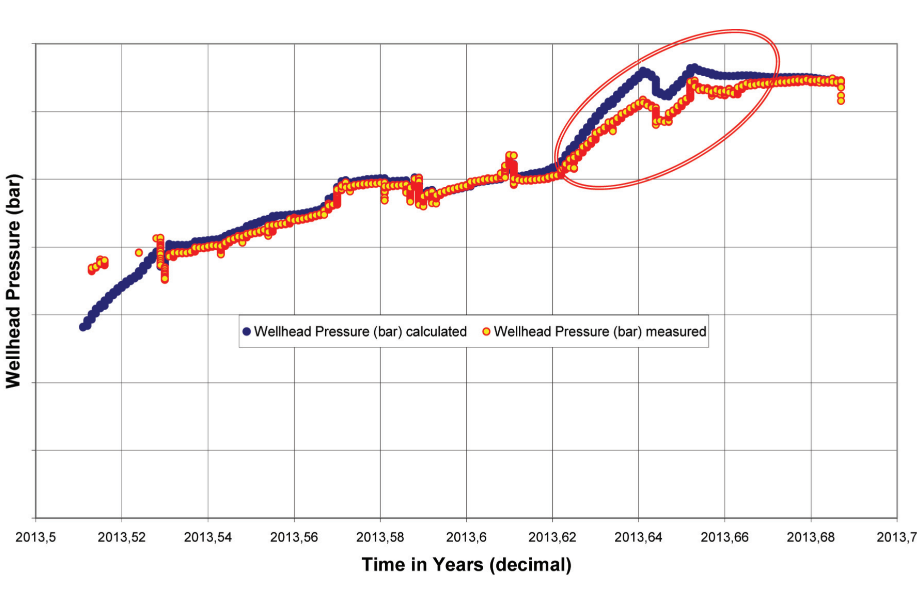

Fig. 2 Gas well head pressure development during debrining, measured (dots) and calculated (line)

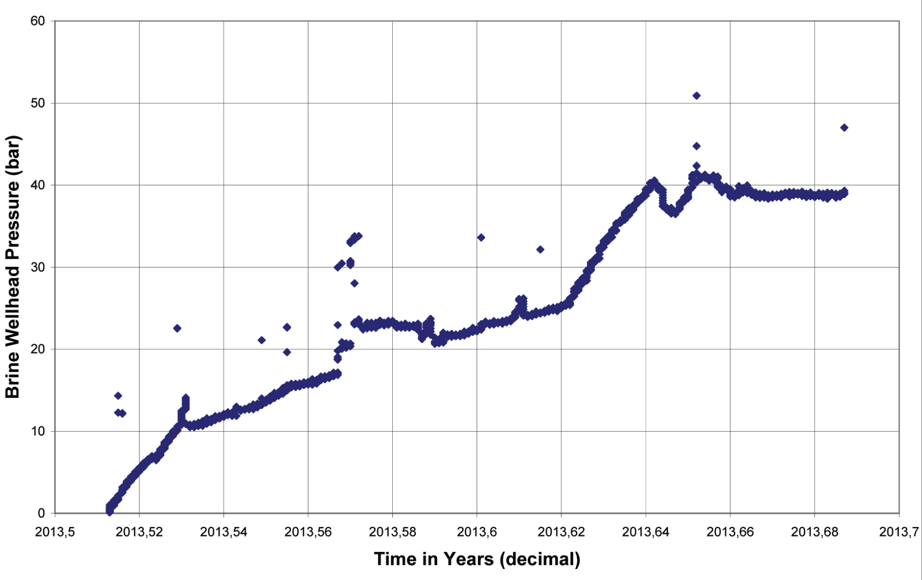

Fig. 3 Calculated brine well head pressure development

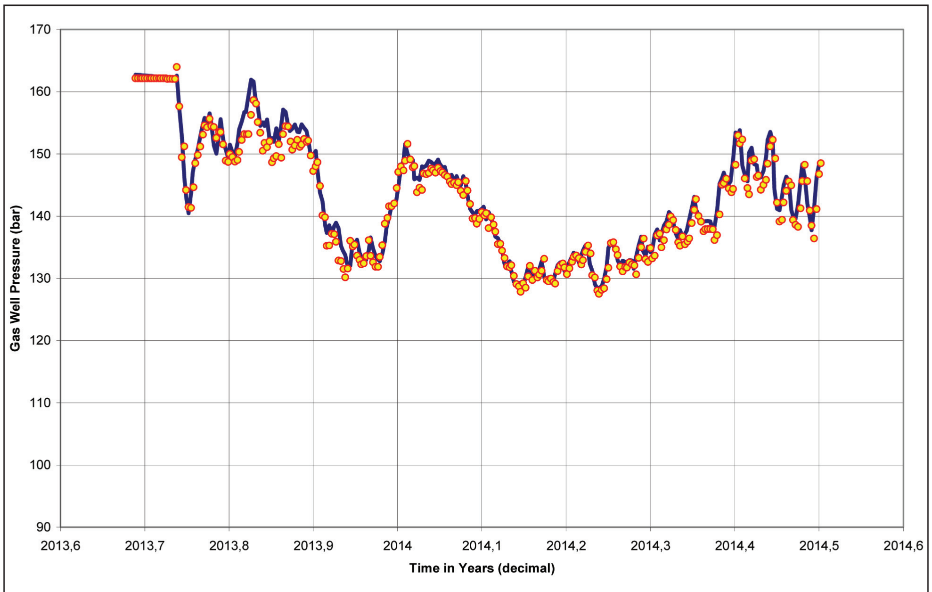

Fig. 4 Measured (dots) and calculated (line) gas well head pressure

volume. The calculations are made in small time steps of 1 hour or less.

Debrining

CavBox was already installed for the debrining process of the cavern. The gas injection rates and the brine rates were retrieved from the SCADA every 15 minutes and the cavern pressure, casing shoe pressure, the temperatures and the well head pressures were calculated.

In Figures 2 and 3 and the gas and brine well head pressure development is shown. For the brine pressure no reliable data were available due to a failure of the pressure gauge.

Storage Operations

For storage operations the program was extended and embedded in the NomiX environment. The input data for history calculation and predictions were provided by the system as well as the start of the program. The calculation of a year cycle (time step size 1 hour) takes a few seconds.

In Figure 4 the pressure match of historical production is shown with respect to well head pressure and in Figure 5 calculated and measured well head temperatures. In Figure 6 the correlation between measured and calculated data is shown. The correlation is quite good and the error is in the range of 1%. It should be noted that the measured pressures as well the rates were daily averages and that the match would improve if hourly data were taken.

Integration in NomiX

Today's cavern gas storages are assets that are closely linked to the markets. These markets become more and more volatile. Any order of gas volumes (nominations) from or to the market is named by an energy trader. He trades directly with the market and errors are not permitted and are penalized severely. Thus each energy trader needs to cope with new challenges before realizing a deal:

- Are there enough capacities to inject the nominated amount of gas?
- Can the nominated amount be produced without damaging the caverns?
- Is all equipment available which is needed to process the nomination (e. g. compressors)?

These questions are essential for highly flexible but safe nomination operations. They are essential technical questions, whereas a trader is an expert in marketing and sales-related questions. He does not need all the technical background information. Instead, he must only see a green light if his nomination can be processed or a red light if not. The fact that traders are constantly requiring better prediction accuracy has made it necessary to integrate the process engineering system into the prediction simulations (subsurface and surface). This is because the availability and design limits of the system components have a significant effect on the performance (capacity and deliverability) of the gas storage. The number of components needed for injection or withdrawal as well as an exact description of the conditions at the different process sections within the station need to be predicted.

On the basis of the know-how within the companies SOCON and GreyLogix, the software – entitled NomiX [1] – can precisely predict the feasibility of gas quantity nominations with regard to rock mechanics, thermodynamics and specifics of the installation and make this information available to the gas trader and/or station manager (Fig. 7). The procedure can be performed as required by a mere click, whilst NomiX promotes reliable, economic multi and high cyclic operation of storage caverns. As the facility in Zuidwending is designed to allow flexible reaction to sudden changes in gas demand, a customized NomiX version was already implemented. Thus it was reasonable to include the supervision of cavern A7 in this environment.

On behalf of and in cooperation with SOCON and GreyLogix, W. Littmann (CRE) has developed CavBox based on planned nominations of gas or energy quantities. The whole simulation software is as the entire storage system divided into different processing sections. During injection, withdrawal and standstill the following elements are taken into account:

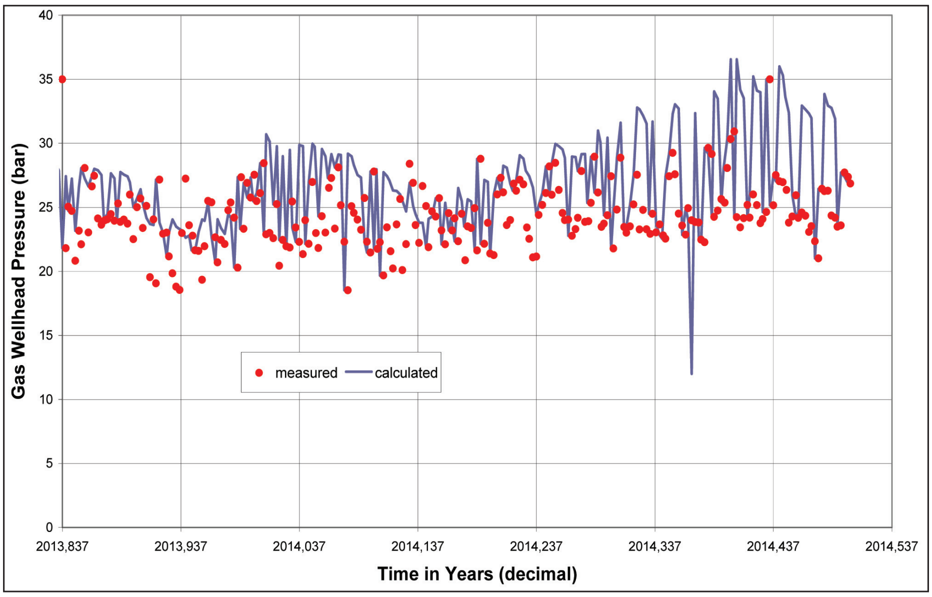

Fig. 5 **Measured (dots) and calculated (line) gas well head temperature**

– CavBox simulates cavern A7 – which is partly filled with brine – and creates a link-up with the cavern simulation of CavBase
– CavBase simulates the other gas filled caverns and checks the subsurface restrictions of all five caverns
– After checking the subsurface restrictions the results are given back to NomiX, which corresponds permanently with the DCS, creating nominations for a so-called “time remaining calculation” and handles the interfaces.

Due to NomiX manual interventions or calculations are superseded. The Zuidwending version is designed as a database-based distributed application for unmanned operation, which generates defined alarms in the event that time-remaining values are too low or in event of failures.

The authors wish to thank N.V. Nederlandse Gasunie and Energy Stock B.V. for their support

References

[1] Brodersen, F., Vosbeck, K., Kemper, J.,NomiX, A solution to focus on sales-related questions without disregard of cavern restrictions, Solution Mining Research Institute, Fall 2012, Technical Conference, Bremen, Germany.
[2] Krieter, M., Reitze, A., von Tryller, H., The Development of Natural Gas Caverns as a Trading Tool and the Consequences, SMRI Fall Meeting, Leipzig, Germany, 2010.

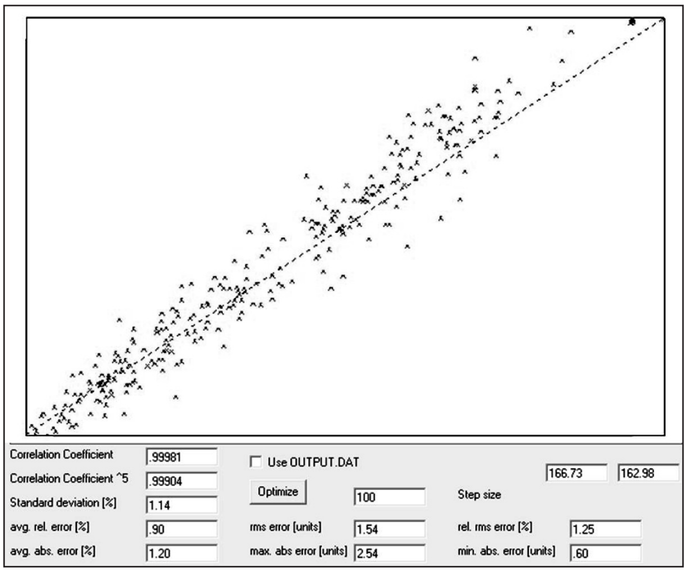

Fig. 6 **Correlation between measured and calculated well head pressure**

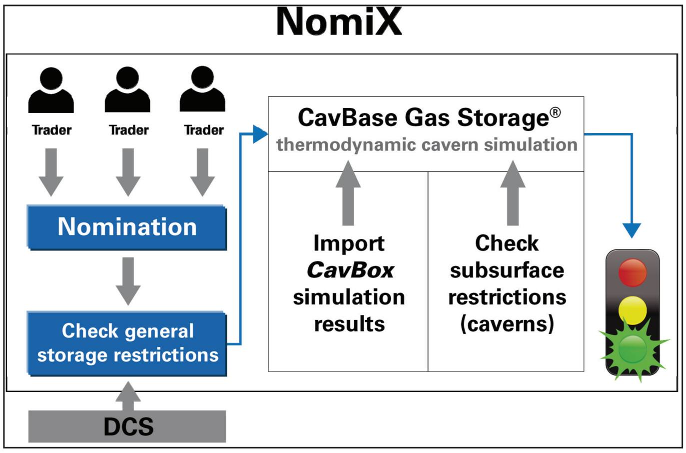

Fig. 7 **Principle of the NomiX structure [1]**