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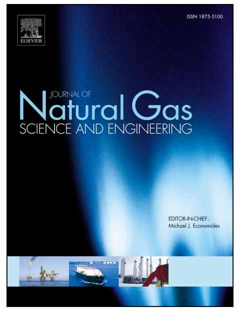


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ACCEPTED MANUSCRIPT

# Pressure Buildup Test Analysis in Wells with Sustained Casing Pressure

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## Abstract

When the well's casing head pressure cannot be permanently bled off with a needle valve, the casing is said to exhibit Sustained Casing Pressure (SCP). Rebuilding of surface pressure (pressure buildup – after closing the valve) results from migration of gas in the leaking cement sheath of the well's annulus. Problem of sustained casing pressure (SCP) has been widespread in the Gulf of Mexico and also reported in Canada, Norway, and other places. Regulations require 24-hr testing of SCP wells comprising pressure bleed-down followed with pressure buildup. In these tests, the rate of pressure buildup is indicative of the size of cement leak – prompt buildup implies larger leak on a relative scale with no quantification. Presented here is the first mathematical model for quantitative analysis of pressure buildup in SCP wells. The model simplifies transient gas flow in cement and ignores migration time of gas in the annular fluid column above the cement top. The simplification allows finding the size of cement leak and the depth and value of gas pressure source formation.

Also presented is validation of the model with actual field data from testing SCP wells. Matching the model to field data gives acceptable estimates of the gas-source formation depth and pressure, cement leak size, and expected maximum casing pressure value. The results also reveal a correlation between the pressure buildup-stabilization pattern and well parameters - cement leak size controls the pressure buildup rate, while the gas-source formation pressure controls the stabilized pressure value. Quantitative analysis of SCP buildup with the new model could be extremely useful as it provides values of three parameters (cement leak size, gas source formation depth and pressure) that are critically important for designing remedial treatment.

## Introduction

Problem of SCP has been common in the Gulf of Mexico (GOM). Over 11,000 casing strings in over 8000 wells have been reported with SCP [1]. The regulations promulgated by US Minerals Management Service, MMS, (presently, Bureau of Safety and Environmental Enforcement, BSEE) 30 CFR 250.517 require remedial operation on a well if any of its casing string has significant SCP problem.

MMS has also developed guidelines to tolerate small values of SCP – a departure from 30 CFR 250.517. However, wells with approved departure must be frequently tested so that severity of SCP could be monitored and controlled. Presently, testing of SCP is mostly qualitative and limited to arbitrary criteria for casing pressure buildup. Such information is insufficient for operators to quantitatively analyze SCP problem and prevent potential risks. Thus there is a need for improved analysis that could provide information on the parameters causing gas migration and SCP.

**Field Data Analysis.** We have analyzed casing pressure data from an offshore oilfield in the GOM [2] and compared the results with MMS data from the whole GOM [1]. Of 26 wells total, 22 wells (85%) have SCP problems. And by casing type, almost half of intermediate casings have SCP problem, followed by surface casings, production casings and conductor casings (Fig. 1). The statistical analysis shows the trend similar to that reported in literature [1] (Fig. 2), with exception of the intermediate casing strings. From further analysis by casing size, large casings are likely to have SCP problem (Fig. 3).

The SCP problem in terms of casing pressure values can be also sized. Among casings affected by SCP, about 50 percent of the production casings and 35 percent of the intermediate casings have SCP values less than 1000 psi. For the other casing strings, about 90 to 100 percent of the strings have SCP values less than 500 psi (Fig. 4).

### Reported Field Patterns of SCP Buildup

#### Typical SCP Buildup Pattern

We have analyzed historical data of casing pressure change from 38 casing string affected by SCP. Fig. 5 shows a typical pattern of SCP buildup. (Of the 38 casings with SCP, 82 percent displayed typical pattern of buildup.) By this pattern the casing pressure increases monotonically after the bleed-off at steadily-reduced rate until stabilizing at a certain constant value. In some cases, a small buildup rate may not change during the test as shown in Fig. 6. Such a low-rate incomplete buildup would be difficult to analyze. In this study, only typical patterns of SCP buildup are quantitatively analyzed.

#### Abnormal Behavior

Fig. 7 is an abnormal case. The well was shut in at about 500 days. The casing pressure record is scatted significantly. It is very difficult to identify any obvious trends from the data. Moreover, comparison of all casing pressures change vs. time in this well (Fig. 8) indicates a correlation, i.e. pressure communication between different casings. This could be the main reason for the erratic pressure data in Fig. 7.

#### Comparsion of Bleed-off and Buildup Patterns

Unlike pressure buildup, the bleed-off is very short. Usually, only two or three data points were recorded from the bleed-off (Fig. 9). It is difficult to analyze the bleed-off from such a few data. On the other hand, in a short time, the bleed-off behavior could be only affected by the compressibility of gas accumulated at the wellhead and that of mud below. Testing of bleed-off can only provide partial information on well parameters. Therefore, this study concentrated on analyzing SCP buildup after the bleed-off.

## Mechanism of SCP Return after the Bleed-off

The most significant cause of SCP in the outer casing strings, outside of the production casing, is gas migration outside wells due to poor cementing. In the database of MMS, 50% of the casing strings exhibiting SCP are outer strings outside the production casing (Fig. 2).

Gas migration is classified into two distinct groups – "early" and "late". The former can be defined as those that are related to aspects of the actual cementing operation i. e. slurry

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