Experiments to Better Understand Pennsylvania's Gas Migration Problem*

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Abstract

The Marcellus shale-gas play represents a significant energy resource for the northeastern United States. The scale of the development associated with the expansion of the gas industry is noticeable in all aspects of the economies where this activity is occurring. It should be no surprise that potential unwanted events can negatively affect development of this scale and scope.

Introduction

Arguably, one of the greatest threats to environmental protection during development is integrity of the wellbores, especially in the upper portion of the drill hole where groundwater aquifers are prevalent. As such, the Pennsylvania Department of Environmental Protection (PA DEP) requires significant engineering controls for the wellbore in deep Marcellus gas wells. One focus of these controls is on the performance of cements used to isolate the fluids and gases contained within the wellbore from the surrounding rock formations. Pennsylvania regulations require oil and gas well operators to prevent the migration of gas or other fluids into sources of fresh groundwater (§ 78.81) (a) (2)).

Gas Migration

For the purposes of this discussion, gas migration is synonymous with combustible gas (typically methane and ethane) flowing into an annular space during primary cementing operations. This gas has the potential to alter the physical properties of the cement. More precisely, formation gas has the ability to "invade" the cement when it is transitioning from a liquid to a gelled state. In these cases, the operator is required to:

- Permanently cement surface and coal-protective casing prior to drilling into the strata known to contain, or likely contain, oil or gas (§ 78.83 (e)).
- Use gas block additives and low fluid loss slurries in association with surface casing and coal-protective casing cement jobs (§ 78.85 (a) (5)) in areas of know shallow gas producing zones to prevent annular flow through the cement.

Alternatively, gas migration can occur when operators do not entirely remove the drilling mud from the wellbore prior to cementing. In these instances, some of the mud remains along the wellbore skin. The residual drilling mud can facilitate the development of gas-flow paths along the wellbore annulus. PA DEP regulations do require operators to ensure an adequate cement bond between the casing and the formation via wellbore conditioning (§ 78.83 (c) and 78.83c. (a)), but annular gas flows still do occur.

Geologic Settings

Prevention of gas migration can be a particular challenge in certain geologic settings. For example, in Pennsylvania's northern tier Marcellus region, certain gas-bearing sandstones in the upper portion of the wellbore have been known to emit gas with measurable flow and pressure. Similar conditions are observed in association with southwestern Pennsylvania's abundant coal beds.

In these settings, where gas has the potential to flow from the rock formation into a wellbore, the integrity of the curing cement can be threatened. This phenomenon may have occurred in a small number of Pennsylvania's Marcellus wells. The petroleum industry recognizes the deleterious impact of gas injection during the placement of the slurry used to isolate the drill holes from the groundwater aquifers. However, it appears that the corrective actions taken are varied and their effectiveness unclear.

Discussion

Both the PA DEP and a number of gas-producing companies operating in Pennsylvania have been working to reduce the occurrence of gas migration through cemented annular spaces. In addition, the PA DEP is currently in the process of finalizing its quarterly well integrity-testing program, one aspect of which centers around the evaluation of annular gas flow through cement. PA DEP, in a similar fashion to all regulatory agencies responsible for managing oil and gas development, will use available data to identify areas of the current regulations where enhancements may be beneficial.

The gas companies and their suppliers have brought in drilling and cementing experts from all over the world to find new processes and techniques to prevent (a) gas migration through the cement, and (b) gas movement along the annulus of the wellbores. In addition, all of the major oil and gas service companies formulate and produce cement mixtures that lessen the potential for formation gas migrating into the cement as it cures and hardens.

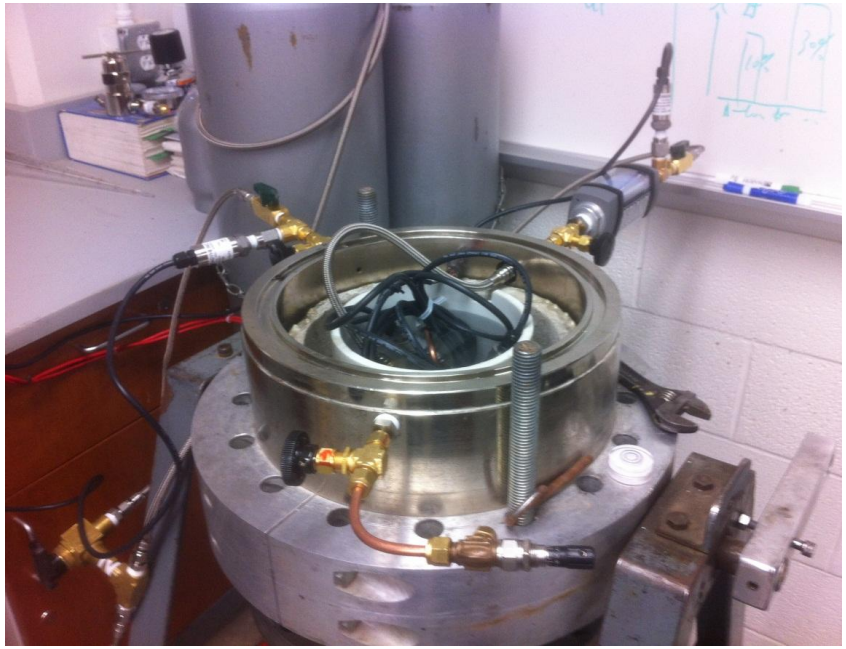
A potential for improvement in the development of the Marcellus shale gas play exists and centers on an enhanced understanding of how gas migration manifests itself under different cement placement conditions. Currently we can only indirectly measure the success of these efforts, i.e. no gas flow/pressure at the wellhead, no complaints of contamination from nearby wells and springs, etc. Geophysical logging methods are improving but they are not currently capable of producing definitive information about the existence of annular pathways in the cement.

Current uncertainties increase the need to understand:

- Conditions during cement placement - Hence the requirement by the PA DEP to maintain a cement job log which contains -- mix water temperature and pH, type of cement with listing and quantity of additive types, the volume, yield and density in pounds per gallon of the cement and the amount of cement returned to the surface, if any. Cementing procedural information must include a description of the pumping rates in barrels per minute, pressures in pounds per square inch, time in minutes and sequence of events during the cementing operation (§ 78.85 (f)).
- How varying wellbore gas-flow and pressure conditions impact cement performance. Since the collection of this information under field conditions is quite difficult to collect, a laboratory test chamber capable of simulating down hole conditions has been developed (Figure 1).

Conclusions

Initial project work was funded by the University of Pittsburgh's Center for Energy. Currently, the project is being performed as part of the National Energy Technology Laboratory's Regional University Alliance (NETL-RUA), a collaborative initiative of the NETL, under the RES contract DE-FE0004000. It is our aim to generate information on how the cement in the wellbore annulus is being affected by gas migration. This is accomplished by simulating in-situ conditions within a test chamber under a wide range of temperatures and pressures. Gas flows are injected through a simulated sandstone material into the cement as it cures. After each test, a series of forensic analysis are performed to map the migration paths of the injected gas within the cement. In addition, the permeability and mechanical properties, i.e. strength, stiffness, Poisson's ratio, etc., are being determined for each test condition. Once a better understanding of these processes is achieved, additional engineering solutions will insure that gas is not entering annular pathways in the wellbore and permitting cross-strata communication.



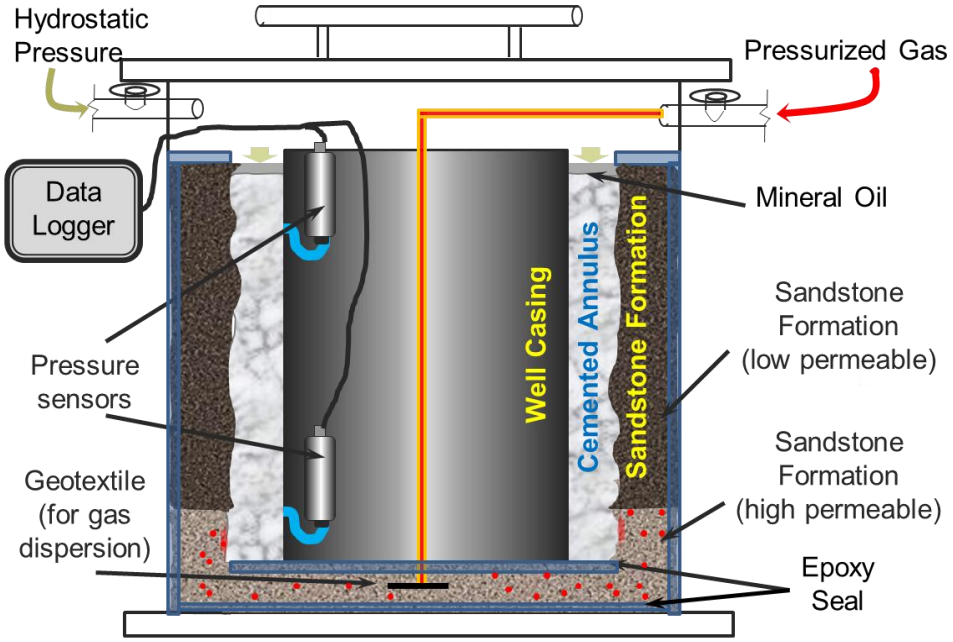


Figure 1. Picture and drawing of laboratory test chamber.