Using casing annular packers to prevent shallow gas migration to surface in shale wells

New research suggests that methane contamination blamed on fracking is actually due to cement integrity issues that can be inexpensively controlled.

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Efforts in many cities, states and countries to ban hydraulic fracturing as an oil and gas production method have been driven in part by a few well-publicized reports of high methane content observed in drinking water near shale production operations. Although methane gas is not regulated in drinking water—not being considered harmful to drink—this gas is a concern because it can accumulate and potentially cause suffocation and/or explosions.

One recent study sampled drinking water in Pennsylvania and New York and reported nearly 17 times as much methane in drinking water sources within 0.6 mi (1 km) of newly drilled, completed and fractured shale gas wells compared with sources located more than 1 mi (1.6 km) away. Assuming that the testing was conducted in a valid process, these results would qualify as definitive information that linked drilling and completion of some shale gas wells to increased methane content in shallow aquifers. However, the same study reported that no chemicals used in hydraulic fracturing fluids were detected in drinking water samples. This suggests that, contrary to fracking opponents’ claims, the newly created fractures are not extending thousands of feet upward into the shallow freshwater aquifers.

A number of industry studies suggest that shallow gas migration, from formations far above the fracture-stimulated shale formation, may be responsible for the occasional aquifer contamination that has widely been blamed on fracking in shale oil and gas operations. The inexpensive addition of a mechanical device, specifically an inflatable or swellable casing annular packer, to control annular fluid movement after cement displacement can improve cement integrity and greatly reduce or eliminate the possibility of annular gas migration that could potentially enter drinking water formations, leak to the surface or create sustained casing pressure. This article presents examples of this application and argues that the use of casing annular packers should be evaluated and included in any well drilling program risk analysis.
CEMENT INTEGRITY

The typical oil or gas well is constructed by drilling through thousands of feet of rock and cementing in place multiple strings of casing. In shale wells, the vertical section generally terminates near the target reservoir, and the well path is then turned horizontally and penetrates thousands of feet into the shale formation. An additional casing string or liner is then run into the well and the horizontal segment is separated into multiple producing zones through various methods such as cement or packers. The space between different casing string sizes, or between the casing and the formation, is called the annulus. Cement is used to fill the annulus between different casing string sizes, for stability and to provide pressure barriers; the integrity of the cement is critical in controlling the pressure and the flow of the various fluids in the well.

Thousands of these types of wells have been safely drilled, completed and produced worldwide. Only a few specific geographic areas are experiencing the water aquifer contamination problem. An improved understanding of the regional geology can better define the potential sources of unwanted gas flow, and wellbore completion equipment can be designed to prevent contamination of drinking water aquifers.

Efforts to define the cause of elevated methane levels are still underway, but one problem that has plagued oil and gas drilling for some time is a lack of cement integrity. This loss of control can occur during the initial completion, during the high-pressure fracturing process or later in the life of the well due to corrosion or tectonic movement.

Gas migration through the annulus is generally considered a major contributing factor in the lack of cement integrity during initial completion. Numerous studies have been conducted and articles written as to the causes of this migration. Multiple solutions to prevent the occurrence have been presented.

In one study designed to investigate the reasons for this initial gas migration, multiple pressure gauges were placed on the outside of casing and hardwired to the surface to allow monitoring of annular pressure at various depths in the well during critical operations—while circulating, while displacing cement and during the cement curing process. After displacing cement and bumping the plug, pressure in the annulus declined, Fig. 1a. In the cases where the annular pressure fell below formation pressure near the gauge, loss of hydraulic bond was observed during the completion phase, in many cases requiring costly repair before producing the well. If left untreated, this poorly bonded area would allow gas flow from higher-pressure zones to lower-pressure zones in the well.

Figure 1b shows the annular pressure response when a casing packer was run and an annular seal was achieved immediately after plug bump. In this case, the annular pressure below the casing annular seal declined rapidly to a level that was less than the nearby formation pressure. Gas flow was determined by neutron log analysis as an accumulated pocket underneath the annular seal. As the decline and flow occurred very early in the curing process, equilibrium pressure was achieved quickly at the formation face. This rapid pressure equalization provides a better environment for the development of high-quality cement, eliminating conditions for long-term gas flow or fluid loss. The objective was achieved: a cured cement column without flow channels.

CASING ANNULAR PACKERS

Solutions to controlling annular gas migration are available from many different service companies; to be effective, these solutions must be custom-engineered for the geological and environmental conditions present. Mechanical devices with elastomeric seals such as inflatable or swellable casing annular packers are commonly used. Chemical formulations used to improve cement properties can also be successful under certain well conditions.

In several geographic areas of unconventional resource development, thin, shallow formations containing non-commercial levels of methane gas are encountered in the vertical well section, Fig. 2. These shallow formations are often considered a contributing factor to the occurrence of annular gas migration and/or the lack of cement integrity in the intermediate casing strings. In an unreported, recent study of wells in Pennsylvania’s Marcellus shale, seven of 10 wells exhibited poor cement integrity of intermediate casing. In the same development area, the operator elected to use casing packers as a method of controlling annular gas migration. With this method, the operator achieved a 100% success rate of maintaining cement integrity before and after drilling and completion.

In multiple wells where a full-length production casing has been run in the horizontal section, there are still indications that nearby drinking water sources contain higher methane levels than normal. This data further suggests that the methane source may be from the naturally occurring, thin formations in the vertical section of the well. If these formations contain methane, they have po-
The packer with a disturbed region immediately below it, Fig. 3b. Analysis of the neutron log determined that the area contained a high level of gas. In another case study, an E&P area in Indonesia had encountered severe annular gas flow problems for years. The problems ranged from less-severe sustained casing pressure to rig evacuations, blowouts and even multiple rig fires. Due to the severity of the problem, the operator adopted the use of a mechanical control method in 2001. Since then, more than 300 wells have been successfully drilled and completed, with minor annular flow problems in only three of the wells. All three of these problems were repaired with inexpensive and effective standard intervention programs. No annular flow was severe enough to require rig evacuation, and no blowouts were experienced.

In two other areas (the Gulf of Mexico and the Gulf of Thailand) where operators experienced catastrophic annular flow problems, casing annular packers were added to the completion program, and now wells are successfully drilled and completed with no annular gas flow, sustained casing pressure or other problems. The recent introduction of casing packers constructed with swellable elastomers simplifies the completion process and has greatly improved cement integrity in a wide variety of wells. This device is now accepted as a reliable stand-alone zonal isolation method in horizontal sections to allow selective fracturing of individual zones.

The addition of packers with swellable elastomers provides a self-healing capability to the hydraulic integrity of the annuli and is particularly applicable where applied pressures during frac treatments and production cycles are potentially sufficient to crack the cement sheath that is meant to be a pressure seal.

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LITERATURE CITED

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