An Evaluation of Well Construction/Drilling/Conversion Methodologies Associated with Gas Storage Depleted Field Operations in the United States

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Introduction

Since the Aliso Canyon blowout, there is movement afoot to re-evaluate and re-assess gas storage operations in the United States.

This incident along with previous gas storage releases in Hutchinson, Kansas and Moss Bluff, Texas has lead to both state and federal agencies reviewing existing gas storage regulations to determine if regulatory requirements are adequate to ensure safe operations.
Natural Gas Storage History

According to the Energy Information Administration, as of 2015, there are 413 natural gas storage fields in the United States.

Approximately 79% of these gas storage fields are in depleted oil and natural gas reservoirs.

Many of these oil and natural gas reservoirs were originally drilled in the early to mid-1900s.

Source: Tomastik, 2016
Natural Gas Storage

Initial conversion of these depleted oil and natural gas fields to gas storage started with the Zoar field in New York in 1916.

Gas storage conversion of many of these fields commenced after World War II and continued across the United States as demand for natural gas increased.

Source: www.nationalfuelgas.com
Conversion of Old Fields to Storage

Conversion of older, depleted oil and natural gas wells to gas storage was not without problems.

Many of these older fields to be converted were developed for production in the early to mid-1900s.

Most of the well construction and cementing practices at that time were substandard compared with modern drilling and completion technologies.

Source: www.cmich.edu
Well Conversions to Gas Storage

Due to older well construction and cementing practices, most wells converted to gas storage undergo well workovers.

Well workovers can lead to remedial well construction and cementing operations as well as continued well integrity assessment.
The Aliso Canyon Gas Storage Field

Shallow oil production was discovered in 1938.

Discovery of the Sesnon-Frew gas storage zone in 1940.

Geology is structurally complex with a combination of bounded fault blocks, unconformities, and stratigraphic pinchouts.

The existing oil and gas production wells were drilled from the early 1940s to mid-1950s.

Additional wells completed in mid-1960s.


The Sesnon-Frew gas storage zone ranges from 7,000 to 9,000 feet in depth.

Since the late 1970s new wells have been drilled and completed as gas storage wells to replace older wells that have been plugged and abandoned.

Currently, there are a total of 114 wells in the storage field.

Field surface operating pressures as high as 3,000 psi.

Gas storage operations occurred through both tubing and production casing.
Current Map of Aliso Canyon Field

Source: DOGGR, 2016
Typically, the old oil and gas wells from the 1940s-1960s were completed with surface casing, production casing, and a liner.

Surface casing from 16” to 11-3/4” was typically set from depths of 500 to 1,000 feet and cemented.

Production casing (composite string of varying weights) ranged from 9-5/8” to 7” and was set from 7,000 to 9,000 feet and cemented.

Wells were completed with 5” or 5-1/2” liners that were either perforated, slotted, or gravel-packed through the gas storage zone.

Usually 2-3/8” or 2-7/8” tubing was run into the well.
Typical Old Well Construction

Source: DOGGR, 2016
New Gas Storage Well Completions

New gas storage wells have been drilled and completed in the field since the mid-1970’s to present.

Typical well construction has not changed too much:
- 13-3/8” Surface Casing set from 800 to 1,000 feet and cemented to the surface;
- 9-5/8” Production Casing set from 7,000 to 9,000 feet and cemented to the surface;
- 5-1/2” liner hung through gas storage zone;
- 2-7/8” tubing; and
- Some wells have been drilled directionally
Typical New Well Construction

Source: DOGGR, 2016
Gas Storage Operations

Many of the historic wells converted to gas storage have experienced extensive remedial workovers.

Workovers often included:
- Casing patches;
- Casing scraping;
- Squeeze cement jobs;
- Fishing jobs;
- Milling and reaming;
- Sidetracking; and
- Additional liner or liner replacement.

Source: ALL Consulting, 2016
Well Integrity Issues

Production casing showed evidence of corrosion from shallower zones, loss of well integrity due to leakage, and inadequate cement jobs.

Lack of consistent cased-hole geophysical logging methodologies, pressure testing, and well integrity assessment was apparent.

Source: DOGGR, 2016
Well Integrity Evaluation

Prior to the mid-2000s, most wells had annual temperature log surveys, occasional pressure testing, and some cement evaluation logging.

By the mid-2000s, noise logging was added and more cement evaluation logging on the newer wells was undertaken.

Source: DOGGR, 2016
Well Workover Issues

All well workovers required “killing” the well through the tubing prior to commencement of workover operations and installation of a blowout preventer.

Lack of additional main gate valve on the production casing for well control.

Non-optimized wellhead designs prevented work on wells under pressure, which could potentially lead to uncontrolled releases.
Well SS 25 Had This Problem

Source: DOGGR, 2016
Source: DOGGR, 2016
Examples of Wellhead – Old Vs. New

Source: DOGGR, 2016

Source: DOGGR, 2016
Snubbing Wellhead System

Source: Universal Wellhead Services, 2015

Source: ALL Consulting, 2016
Well Workover Under Pressure

Source: ALL Consulting, 2015

Source: ALL Consulting, 2015
Aliso Canyon New Requirements

Comprehensive safety review requires each of the 114 active wells either pass a battery of tests in order to resume gas injection/withdrawal operations or be taken out of operation and isolated from the underground gas storage reservoir.

The required tests to resume normal operations include:

- Casing wall thickness inspection;
- Cement bond log;
- Multi-arm caliper inspection;
- Pressure test;
- Temperature log; and
- Noise log.
Additional Requirements

Additionally, to resume operations, the operator is required to:

- Install and operate real-time pressure monitors;
- Operate with lowest possible operating pressure on tubing-casing annulus;
- Inject and withdraw only through interior metal tubing;
- Undergo testing of any downhole devices;
- Undergo testing of any downhole devices every six months;
- Comply with CA DOGGR Underground Injection Control regulations; and
- Establish a facility-wide emergency response and SPCC plans.
Current Well Safety Status

20 wells have passed all tests
36 wells have been taken out of service
58 wells have pending test results

Source: DOGGR, 2016
Evaluation of the Required Testing

An evaluation and assessment of some of the well integrity testing indicates some questionable testing protocols such as:

- Some logging procedures not following accepted industry standards for temperature and noise logging;
- Rather short logging times and no evidence of multiple logging passes; and
- Pressure testing different sections of production casing below normal operating pressures.

Source: DOGGR, 2016
Conclusions

As seen by this evaluation of a current gas storage field utilizing a depleted oil and natural gas field with a number of legacy wells, better efforts need to be considered when addressing well construction, cementing, workovers, and well head designs in many of the storage operations in the United States.

Well integrity evaluation and assessment will remain a critical factor in preventing future gas storage incidents in the United States.

Due to the Aliso Canyon incident, many changes in gas storage regulations on the federal and state level are forthcoming.
Contact and Citation Information

Citation Information: