

Joint Legislative Oversight Hearing

Senate Committee on Natural Resources and Water and Joint Legislative Committee on Emergency Management

What Caused the Southern California Gas Company's 2015 Blowout at Aliso Canyon? *A Closer Look at the History of the Field and the Emergency Response*

Background Paper

Root cause analysis of the "SS-25" well leak

Introductory Comment. This paper is a high level overview of the independent third-party root cause analysis conducted to understand the cause of the natural gas leak from a vintage gas storage well at the Aliso Canyon gas storage facility that started in late 2015 and lasted for almost four months before finally being plugged. This industrial accident wreaked havoc on the surrounding communities and caused reverberations that continue to today. Numerous federal, state, and local government agencies were involved in the response to the leak and its impact on the storage facility's neighbors. This legislative oversight hearing will focus on the aspects of the leak and the response to the leak under the jurisdiction of the two legislative committees, the Senate Natural Resources and Water Committee and the Joint Legislative Committee on Emergency Management, convening the hearing. Therefore, this paper is not a comprehensive account of the leak and its aftermath, and will focus, in particular, on actions and information specific to the well itself. A companion paper will address emergency response. Some additional information not germane to these committees' jurisdiction is included for context.

This paper includes an overview of the leak, and the results of the root cause analysis of the leak. A discussion of changes in state law and regulation since the leak, and the current status of the facility follow.

The 2015 gas well leak at the Aliso Canyon gas storage facility. On October 23, 2015, a natural gas leak from a gas storage well (the "Standard Sesnon 25" well or "SS-25") was discovered at the Southern California Gas Company's (SoCal Gas') Aliso Canyon natural gas storage facility (facility) located in northeastern Los Angeles County. The facility is the largest in the western United States. The SS-25 well, originally drilled in 1953 and converted to gas storage service in 1973, is located uphill from and approximately 1-1/4 miles away from homes in the Porter Ranch community.

Over the course of several attempts to “kill” the well, the SS-25 leak became a blowout. Almost four months later, the leak was declared stopped on February 18, 2016 following a successful kill attempt using a newly-drilled relief well. The Air Resources Board’s (ARB’s) final estimate is that 109,000 metric tons of methane, a potent greenhouse gas, were emitted to the atmosphere from the leak. While it was occurring, the leak was estimated to constitute about 20% of total statewide methane emissions, and to be approximately equivalent to the annual greenhouse gas emissions of 600,000 cars. The leak received local, national and international news coverage.

The SS-25 leak caused severe disruption in the surrounding communities. Over 8,000 households relocated at some point during the leak (at SoCal Gas’ expense) and the Los Angeles County Department of Public Health and the local air quality regulator (the South Coast Air Quality Management District (AQMD)) received thousands of health and odor complaints between them. The Los Angeles Unified School District relocated two schools temporarily. News reports also cited losses for local businesses.

Since the SS-25 leak was stopped and despite clean-up efforts, public health complaints have continued in the surrounding community. While methane concentrations downwind during the leak did not reach levels thought to be dangerous, many can smell the added odorants (i.e. mercaptans) at extremely low concentrations. These odorants are associated with short-term health effects including nausea, dizziness and respiratory distress. These are among the ailments reported to authorities.

Multiple branches and levels of government were involved in the response to the leak and its aftermath. On January 6, 2016, then-Governor Brown issued a Proclamation directing various state entities to oversee SoCal Gas’ actions to stop the leak, protect public safety, ensure accountability and strengthen oversight of natural gas storage facilities. The Legislature passed and the Governor signed into law multiple bills seeking to address the SS-25 leak and help prevent a similar leak from occurring again. Regulators also required SoCal Gas to conduct multiple technical studies in order to improve understanding of the risks posed by the Aliso Canyon gas storage facility, and to have an independent third party perform a root cause analysis of the SS-25 leak.

Root Cause Analysis. Blade Energy Partners (Blade) performed the root cause analysis of the SS-25 leak. This work included a review of well records as well as the extraction and metallurgical testing of parts of the well. The main root cause analysis report was released on May 16, 2019, and four supplementary reports were subsequently released. All documents are now available on the website of the California Public Utilities Commission (CPUC) (<https://www.cpuc.ca.gov/aliso/>).

SS-25 well schematic. In order to understand the root cause analysis, it is useful to understand the different components of the well. A schematic of the well is shown on the figure excerpted from Blade’s report. A gas storage well is constructed from a combination of metal tubes of different lengths inserted into a hole drilled into the ground. Of particular interest, the surface casing, which extends from the surface to

990 feet depth, is 11-3/4" in diameter. It is cemented along its entire length to the surface. Inside this is the production casing that is 7" in diameter. The production casing extends from the surface to 8,748 feet deep. The bottom 1700 feet of the production casing is cemented in place. The production casing is not cemented from about 7000 feet depth to the surface. Modern construction requirements generally require the production casing to be cemented along its entire length to the surface. SS-25 was built before this modern well construction method was required. Inside the production casing is tubing which is 2-7/8" in diameter. The gap between the surface casing and the tubing is referred to as the annulus.

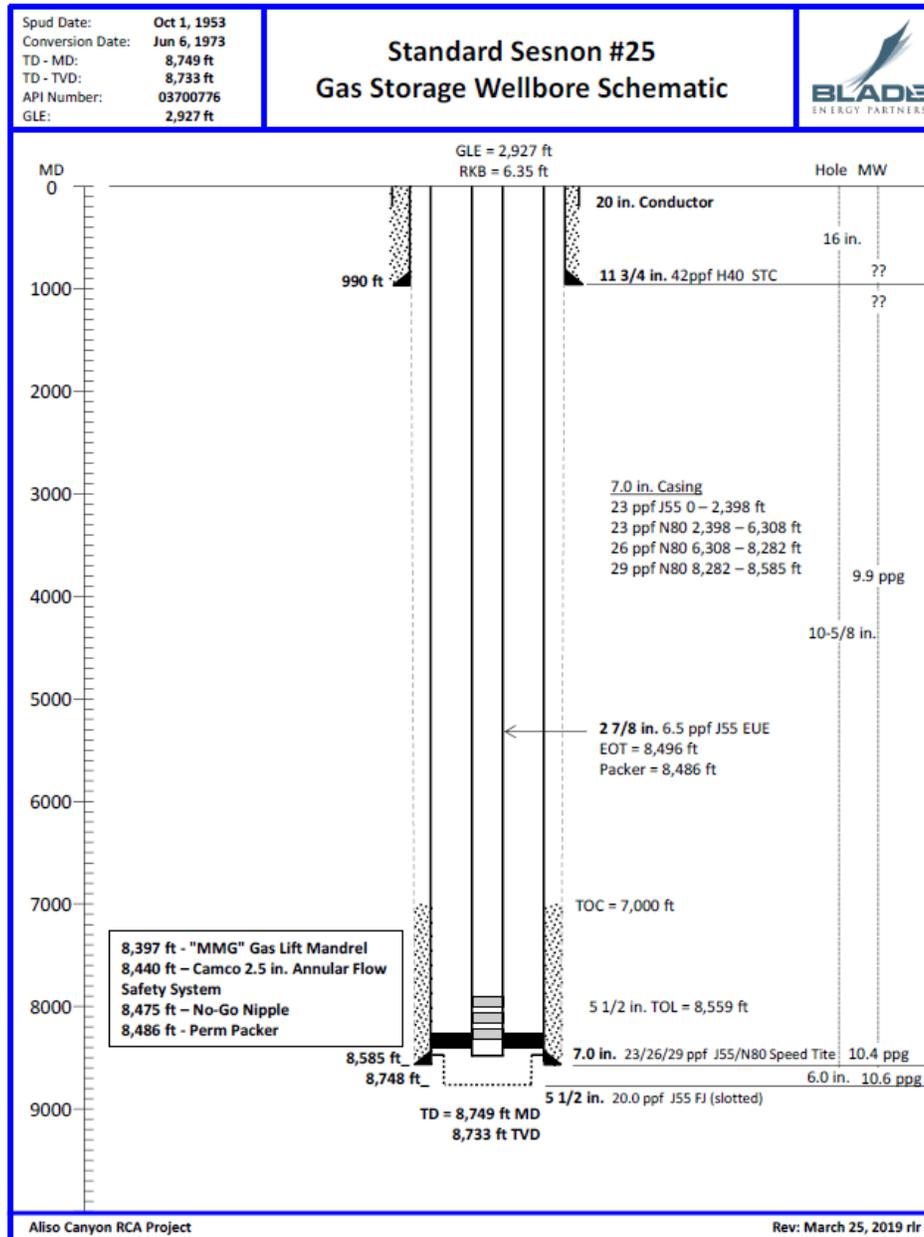


Figure 9: SS-25 Wellbore Schematic in February 1979

Figure from the Blade Energy Partner's Root Cause Analysis.

Aliso Canyon gas storage facility. At the time of the leak, there were approximately 114 gas storage wells capable of injecting and/or withdrawing natural gas from the facility's reservoir. In the early 1970s, a depleted existing oil reservoir was converted to use as a gas storage reservoir. Many existing oil wells serving the depleted reservoir were converted to gas storage service at the time. In 2015, forty-eight of the gas storage wells at Aliso Canyon were originally drilled in 1954 or earlier (about 40% of the wells in gas storage service). This was not unusual at the time as almost half of the 420 total wells in gas storage service in the state were at least 40 years old. The Aliso Canyon gas storage facility won at least 26 consecutive Outstanding Lease Maintenance Awards from the Division of Oil, Gas, and Geothermal Resources (division), the state's oil and gas well regulator, though 2009.

What Blade found. In reviewing records for the SS-25 well and other wells at the facility, and after evaluating the recovered portions of the well, Blade found the following:

- Testing of the SS-25 well's integrity showed no anomalies prior to the 2015 leak. The testing required at that time by the state's oil and gas well regulator, the Division of Oil, Gas, and Geothermal Resources (division), was not proactive, but reactive. The testing method would show leaks, but not identify in advance where leaks were likely to occur.
- However, other Aliso Canyon gas storage wells had numerous casing leaks. Blade reviewed records for 124 wells and identified 63 well casing leaks and 36 other types of failures. Approximately 40% of the gas storage wells reviewed had casing failures. No evidence of failure investigations were found.
 - One well file showed evidence of possible external casing corrosion, but no documentation was found. Two other wells had experienced underground blowouts which were successfully controlled by pumping heavy well kill fluids into the well.
- In 1988, SoCal Gas had a two-year plan to determine the mechanical condition of the casing of 20 wells from the 1940s-1950s. SS-25 was included on this list, but had a low priority. Over the two years, SoCal Gas measured the well thickness of 7 of these wells and discovered wall losses of 20 – 60%. Corrosion was also discovered. It is unclear if follow-up work to understand the source of corrosion was undertaken. Although it was on the list, SS-25 was not investigated.
- In 2014, SoCal Gas proposed moving from a reactive well maintenance program to a more proactive one when it proposed a six-year "Storage Integrity Management Plan" (SIMP) to the CPUC as part of its General Rate Case submission.
 - The goal of the SIMP was to "proactively identify and mitigate potential storage well safety and/or integrity issues before they result in unsafe conditions for the public or employees."

- **The direct cause of the SS-25 leak was an axial rupture of the 7” in diameter production casing due to external microbial corrosion caused by the presence of groundwater at a depth of about 900 feet.**
 - The leak started in the early morning and was discovered approximately 12 hours later.
 - The first rupture subsequently induced other cracks and failures to occur by various mechanisms.
 - No internal corrosion of the casing was observed.
 - The groundwater was from surface runoff. Over the years, it had replaced the drilling fluid that was originally pumped between the casing and the wellbore.
- **An additional direct cause of the leak was the failure to kill the well.**
 - The “top kills” (pumping heavy well fluids down the well from the wellhead) were unsuccessful because the density of the fluid used was too light, and the pump rates were inadequate. These errors both stemmed from inaccurate assessments of the parameters of the leak. The flow rate of the gas was inaccurately estimated.
 - Blade also determined that no “transient” modeling of well conditions was performed for the first 6 well kill attempts. According to Blade, this transient modeling method is widely used and a necessary part of addressing a leak like this. If detailed modeling had been conducted, the well could have been successfully killed starting in mid-November 2015. By the time of the last well kill attempt from the top (#7 in late December 2015), appropriate transient modeling was been conducted but the condition of the well had deteriorated substantially by then. This last top kill attempt was terminated without control being achieved.
- **The principal root causes of the leak are as follows:**
 - There was a history of inadequate follow-up investigation to the well failures that had occurred at the Aliso Canyon field.
 - Despite finding extension corrosion on several wells, no investigation of the causes of this corrosion was performed, and the potential relevance of these findings to other wells was not fully investigated.
 - No risk assessments focused on wellbore integrity management were performed.
 - There was no dual mechanical barrier system for the wellbore. A single point of failure could result in a leak.

- There was no requirement or policy to regularly inspect the wall thickness of production casing. Then-existing regulations identified leaks only.
- There were no well-specific well control plans or plans that considered transient kill modeling.
- There was no understanding of groundwater depths related to surface casings and wells.
- There were no systematic practices to protect casings against external corrosion. Additionally, there was no recognition of the particular risks to vintage wells that were not cemented to the surface.
- There was no real-time continuous pressure monitoring to help identify when leaks occurred.

State response to the 2015 leak. At the state level, there are two principal regulators of the Aliso Canyon gas storage facility – the CPUC and the division. The gas storage facility itself is under the primary jurisdiction of the CPUC, and the gas storage wells are under the division’s jurisdiction.

Both the CPUC and the division were actively involved in the response to the leak. The division’s supervisor issued a series of orders to SoCal Gas during the leak directing efforts to control the well, including requiring the relief well ultimately used to plug the leak to be drilled. During the leak, the supervisor also ordered a moratorium on injections into the facility’s wells, and required gas withdrawals to reduce reservoir pressure and thus reduce the leak rate, among other things.

The Legislature passed two gas storage bills in the months following the leak. The first, SB 380 (Pavley, Chapter 14, Statutes of 2016), was Aliso Canyon natural gas storage facility-specific. The second, SB 887 (Pavley, Chapter 673, Statutes of 2016), applied to all gas storage wells in the state. SB 380 extended the injection moratorium at the facility until certain conditions were met and required that all gas storage wells at the facility undergo specified integrity testing or be temporarily or permanently removed from service. SB 887 provided a statutory framework for revised natural gas storage well regulation by the division including, among other things, leak monitoring, proactive well testing requirements, the use of tubing only to inject and withdraw gas, and that no single point of failure would result in a loss of well control. SB 887 also directed the Air Resources Board (ARB) to include underground gas storage facilities in its regulation of emissions from oil/gas production facilities.

After SB 887 became law, the division promulgated new gas storage well regulations that went into effect on October 1, 2018. These new regulations are considerably more rigorous than the regulations in effect during the SS-25 leak, and institute a proactive and risk-based approach to well regulation. These include:

- Improved data and reporting requirements,
- A focus on hazard identification, risk management and quantitative assessments of risk,
- Added physical features (i.e. well construction) and operating requirements to help prevent leaking to the atmosphere,
- Worker training requirements, and
- Improved testing and monitoring requirements, among others.

The division received expert input from several national laboratories in this effort and also benefited from a technical study performed by the California Council on Science and Technology (CCST) at then-Governor Brown's behest. Much of the CCST report's recommendations for improved regulation were incorporated in the division's new regulations. The experts at the national laboratories helped in developing the new well integrity testing requirements and in interpreting the results of these tests.

Current status of the Aliso Canyon gas storage facility. The facility was authorized to re-start injections and operate at a reduced capacity in July 2017. Withdrawals were only authorized in limited circumstances if energy supply and electrical reliability was at risk in the area from potential gas shortages. Withdrawals appear to have occurred on less than 20 instances since, generally during relatively extreme winter weather.

As of July 24, 2019, 66 gas storage wells serving the facility have passed a comprehensive battery of well integrity tests and have returned to operation. Twenty-one wells have been permanently plugged and abandoned. An additional 26 wells have been plugged and abandoned, but site restoration work is still in process. Efforts to successfully plug one remaining well remain underway. Due to safety considerations, the division authorized a deadline extension beyond the one year specified in SB 380 for the plugging and abandonment of wells being permanently removed from service. According to the division, SoCal Gas has not sought any permits to drill new gas storage wells.

Daily leak testing of all gas storage wells is now required. There is also fenceline monitoring for emissions from the facility. Since the storage facility returned to service, there have been news reports of relatively small leaks of short duration from equipment at Aliso Canyon, including from the failure of an aboveground pipeline.

Seismic analysis. In response to concerns raised by the community and experts at the national laboratories, in 2017 the division required SoCal Gas to evaluate the potential geologic, seismic, and geomechanical hazards at the Aliso Canyon gas storage facility. The Santa Susana Fault System runs through the field and the major 1994 Northridge earthquake was reportedly responsible for a well failure at the facility. In March 2019, SoCal Gas submitted a series of analyses in response. While SoCal Gas' experts found the risks presented by landslides and earthquakes manageable, the division has

not yet completed its review, with the assistance of national lab personnel, of these studies.

Additional relevant information.

- Both the division's and the CPUC's investigations of the SS-25 leak continue. Their reports are expected by the end of the year and will utilize the results of Blade's root cause analysis.
- The CPUC opened the proceeding required by SB 380 to investigate the feasibility of minimizing or eliminating the use of the Aliso Canyon gas storage facility while still maintaining energy and electric reliability in the region in February 2017. The proceeding is projected to be completed by August 2020.
- Due to a series of transmission pipeline outages, the capacity of pipelines serving the Los Angeles area remains limited. Line 235-2 is projected to return to service on August 29, 2019 and has been delayed several times. Line 4000 is at reduced capacity (as similar to Line 235-2) until Line 235-2 returns to service and then it will be removed from service for maintenance and repair. Line 3000 remains at a reduced operating pressure. The reduced transmission pipeline capacity is, in part, attributed to significant spikes in spot gas prices in the Los Angeles area in the past year.
- A revised gas withdrawal protocol was approved by the CPUC in late July 2019 to provide somewhat more flexibility to meet the energy needs of the Los Angeles Basin.
- In late June 2019, the CPUC opened an investigation to consider penalties against SoCal Gas for the Aliso Canyon gas storage well leak. It also opened an additional investigation to investigate the organizational culture, and whether safety is adequately prioritized, among other areas of investigation.

Recent related legislation

SB 463 (Stern, 2019) would require the division to review its gas storage well regulations in view of the independent root cause analysis of the SS-25 well leak, among other things. (*This bill is pending before the Assembly Appropriations Committee.*)

SB 1370 (Stern, 2018) would have removed the specific exclusion for the maintenance of natural gas storage wells from SB 4. (*This bill died on the Assembly floor.*)

SB 801 (Stern, Chapter 814, Statutes of 2017) makes several requirements of energy utilities serving ratepayers in the Los Angeles Basin to support energy reliability where it has been affected by reductions in storage gas capacity and gas deliverability resulting for the 2015 leak at the Aliso Canyon storage facility.

SB 57 (Stern, 2017) would have required the gas injection moratorium to remain in place at the Aliso Canyon gas storage facility until the independent root cause analysis of the SS-25 well leak was completed. (*This bill died on the Senate floor.*)

SB 888 (Allen, Chapter 536, Statutes of 2016) directed how penalty funds assessed for the Aliso Canyon gas leak be expended, and required climate change impacts from gas storage facility leaks be fully offset, as specified, among other things.

SB 887 (Pavley, Chapter 673, Statutes of 2016) provided a statutory framework for revised natural gas storage well regulation by the division including, among other things, leak monitoring, new well testing requirements and that a single point of failure does not pose an immediate threat for a loss of control of well fluids.

SB 380 (Pavley, Chapter 14, Statutes of 2016) established Aliso Canyon natural gas storage facility-specific law governing testing criteria, requirements to be met prior to re-starting injections at the facility and required a CPUC proceeding to examine the feasibility of shutting down or minimizing the use of the facility due to the 2015 gas leak.