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A DECADE OF MODERNIZATION (FOLLOWING A 111-DAY BLOWOUT)

Alan J. Walker, Engineering Advisor

Energy & Geosciences Institute (EGI)

University of Utah

EGI Energy & Geoscience Institute egi.utah.edu THE UNIVERSITY OF UTAH

California Department of Conservation

formerly DOGGR, Division of Oil, Gas, and Geothermal Resources

currently CalGEM, Division of Geologic Energy Management

California Department of Conservation

Agenda

- Introduction
  - Public impact
  - Video by independent investigator
  - Regulatory and participating agencies
- Aliso Canyon blowout
  - Well design
  - CONTROL-CEMENT-CONFIRM
- Outcome, recovery, regulations
- Major lessons learned

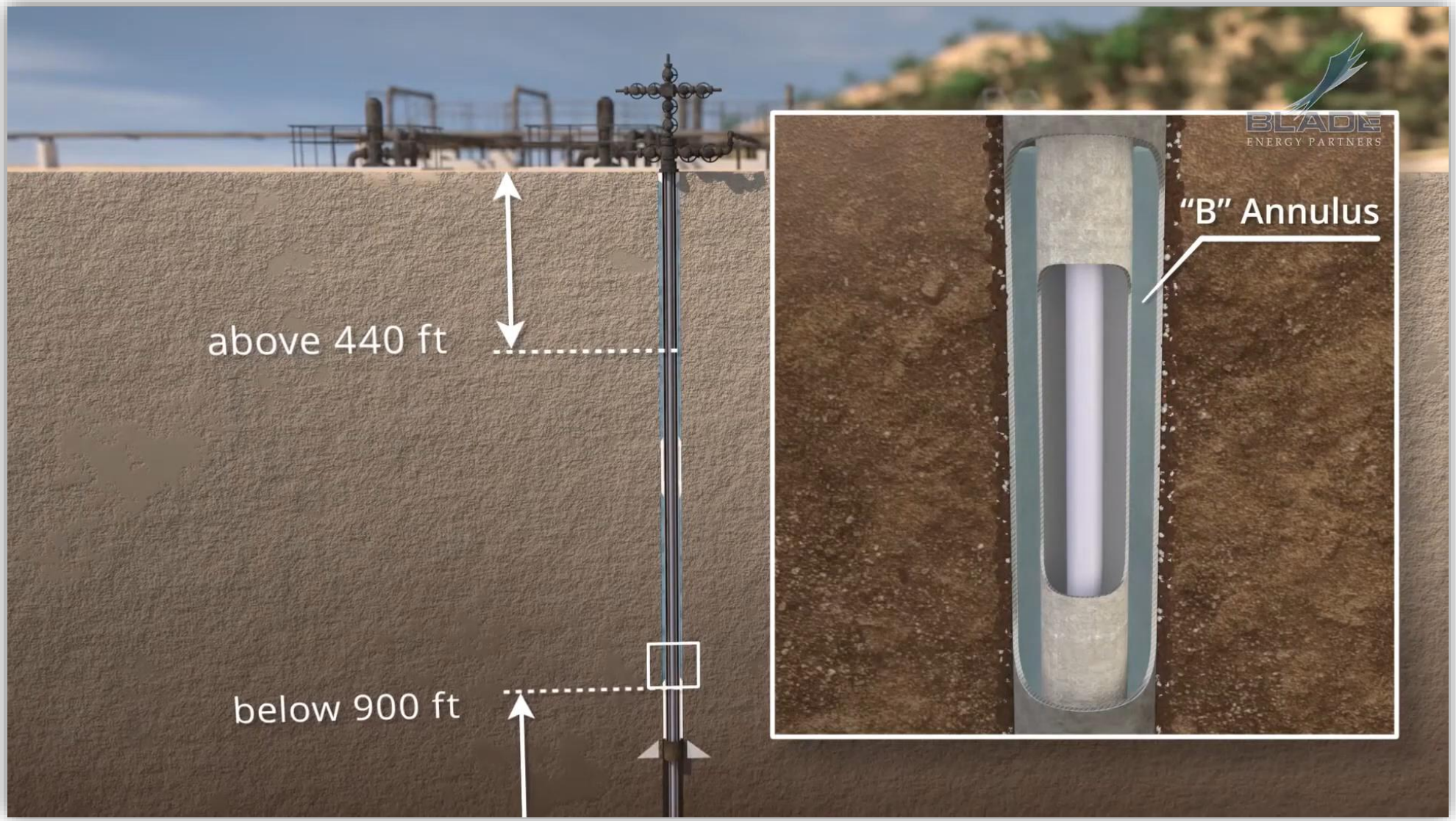
Blowout at Standard Sesnon 25, Aliso Canyon

- Aliso Canyon – 30 miles from Los Angeles
  - Gas storage well blowout
  - Largest US methane leak
  - Five billion cubic feet of natural gas of 85 BCF inventory
  - Approximately 45 MMCF/Day
  - 8,000 CA residents relocated
  - Two elementary schools closed for four months
- Emergency Declaration by Governor
- 111 days to bring under control

SS25 Public Impact

- State of Emergency declared by Governor of California
- Federal, state, and local agencies, over 40
- Significant Community Impact
  - Relocation cost >$700 million
  - ~8,000 residents relocated during holidays
  - 2 Elementary schools temporarily closed
- Environmental: released ~ 5 Bcf natural gas
- Legal
- Community groups and NGOs activated

VIDEO by investigator 1:42 to 4:36 of 6:17



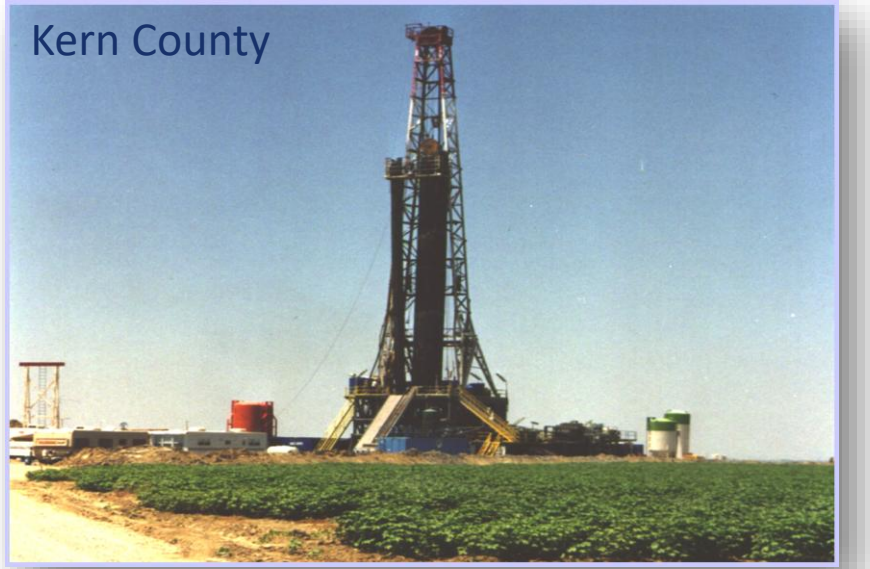
Division of Oil, Gas, and Geothermal Resources (DOGGR), now CalGEM

- Created in 1915 – currently in Department of Conservation
- Overseas drilling, operations, closure
  - Life, health, property, and natural resources
  - Water
  - Energy reservoirs
- Approximately 310 personnel
  - 73% engineers and geoscientists
  - 27% management, planners, support, and administration

Drilling and Production Locations

Photos courtesy CalGEM

Kern County



Santa Barbara

Los Angeles

Kern River

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Participating Federal Agencies

SoCalGas
A Sempra Energy utility

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Participating Federal and State Agencies

SoCalGas
A Sempra Energy utility

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Federal, State, and Local Agencies

SoCalGas
A Sempra Energy utility

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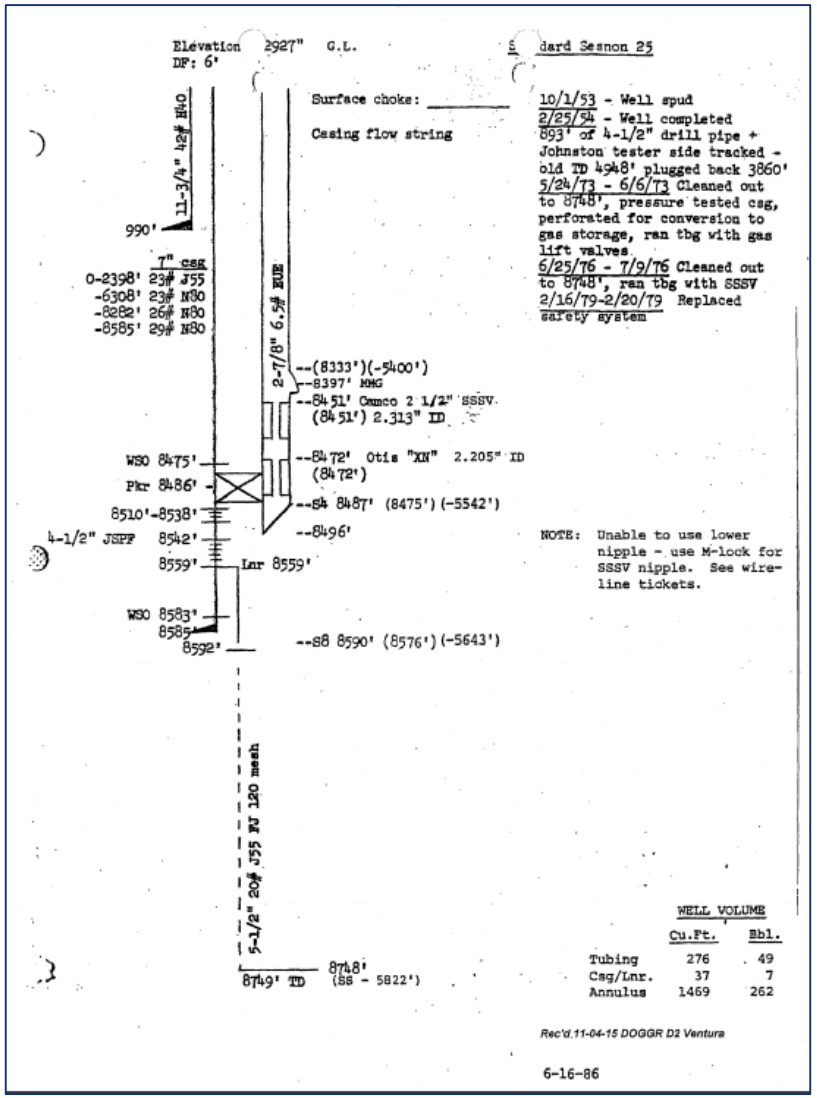
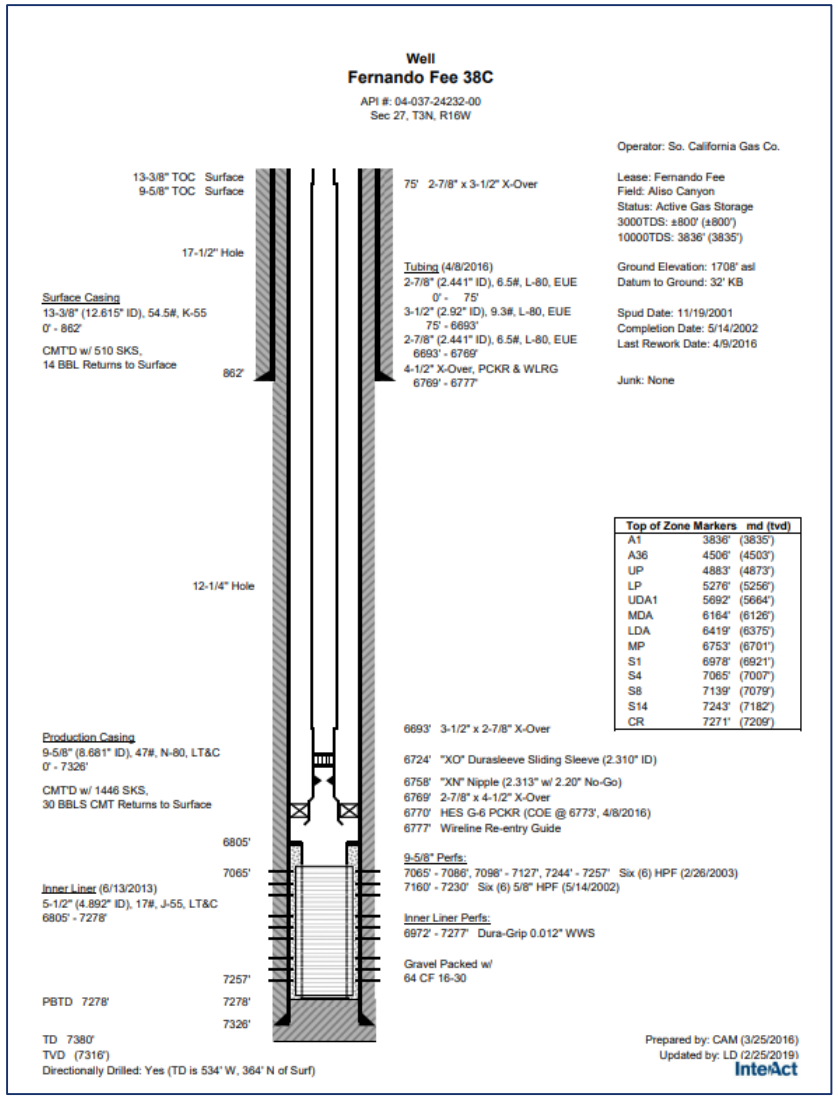
Standard Sesnon 25
(Pre-Blowout)



Fernando Fee 38C
(Currently Active)



Pipe Burst Pressure – Barlow's – Safety

Burst Pressure = (2 x Strength x Wall Thickness)/Outside Diameter

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Standard Sesnon 25 well in Oct 1953

Converted oil well

Working pressure (Pr) is 3,600 psi

Casing 7" J55 23 pounds/foot

Wall = 0.31 inches

Pb = 2 x 55,000 x 0.31 / 7.00 = 4,871 psi

Pr = 3,600 psi

Safety margin = Pb – Pr = 1,271 psi

Pb downrated = Pb X 0.85 = 4,140 psi

Fernando Fee 38C well in Nov 2001

Gas storage well by design

Working pressure (Pr) is 3,600 psi

Casing: 9 5/8" N80 47 pounds/foot

Wall= 0.47 inches

Pb = 2 x 80,000 x 0.47 / 9.625 = 7,813 psi

Pr = 3,600 psi

Safety margin = Pb – Pr = 4,213 psi

Pb downrated = Pb x 0.85 = 6,641 psi

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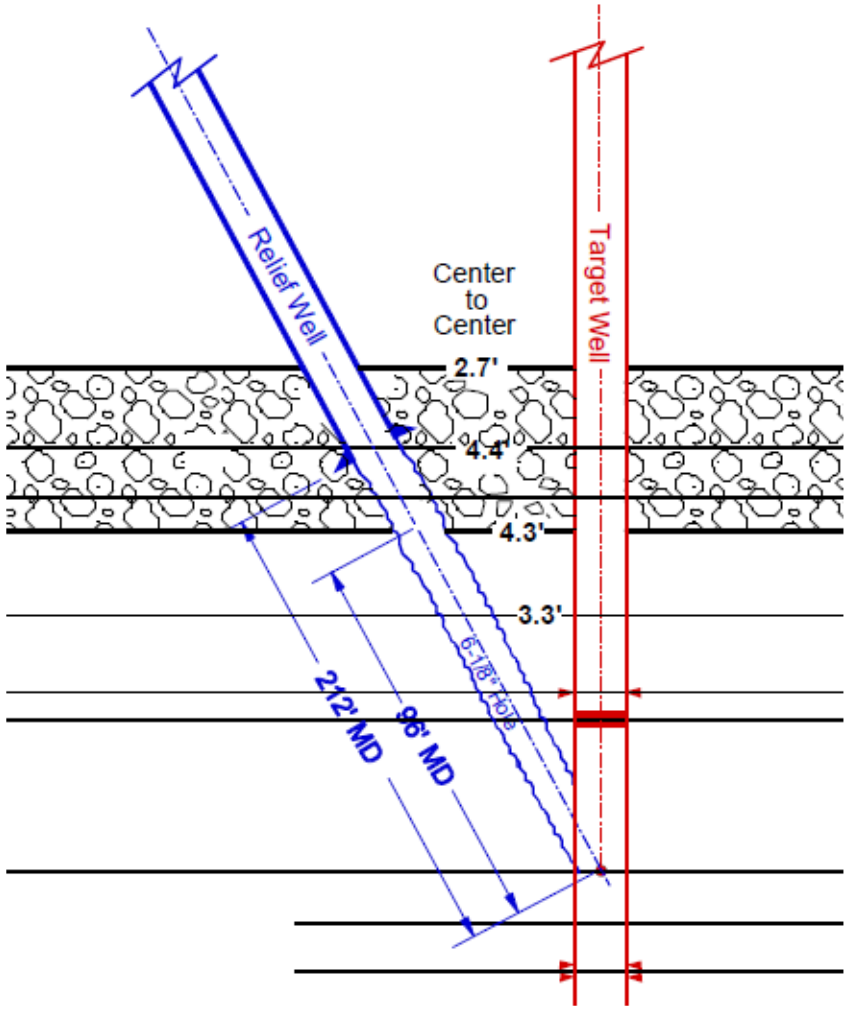
SS25 Top Down Well Control Attempts

- Seven top down well control attempts
  - Heavy barite mud
  - Lost circulation materials
  - Ball sealers
  - Steel balls
  - Golf balls
  - Woody plugging agents
  - Junk shots
- Successive attempts eroded opening

Relief well #2, foreground
Porter #39 A - Relief Well #1, background

Porter #39 A (Relief Well #1) Intercept Plan



CONTROL-CEMENT-CONFIRM

- CONTROL: Well was controlled within 5 minutes of intercept with drilling mud
- CEMENT: Three stages
  - After 24 hours of stable pressures, cement from total depth (TD) to open reservoir perforations
  - After 24 hours cement from reservoir up to ~6,500 feet
  - After 24 hours, plug back relief well
- CONFIRM: Three days of testing
  - Shot fluid level – no change in 60 minutes
  - Temperature and noise log – no unexplained anomalies & top of cement in tubing = 8199’ MD
  - Cement bond log - annular TOC = 7610’ MD
  - Positive pressure test, held 900 psi for 70 minutes, loss = 0.75%

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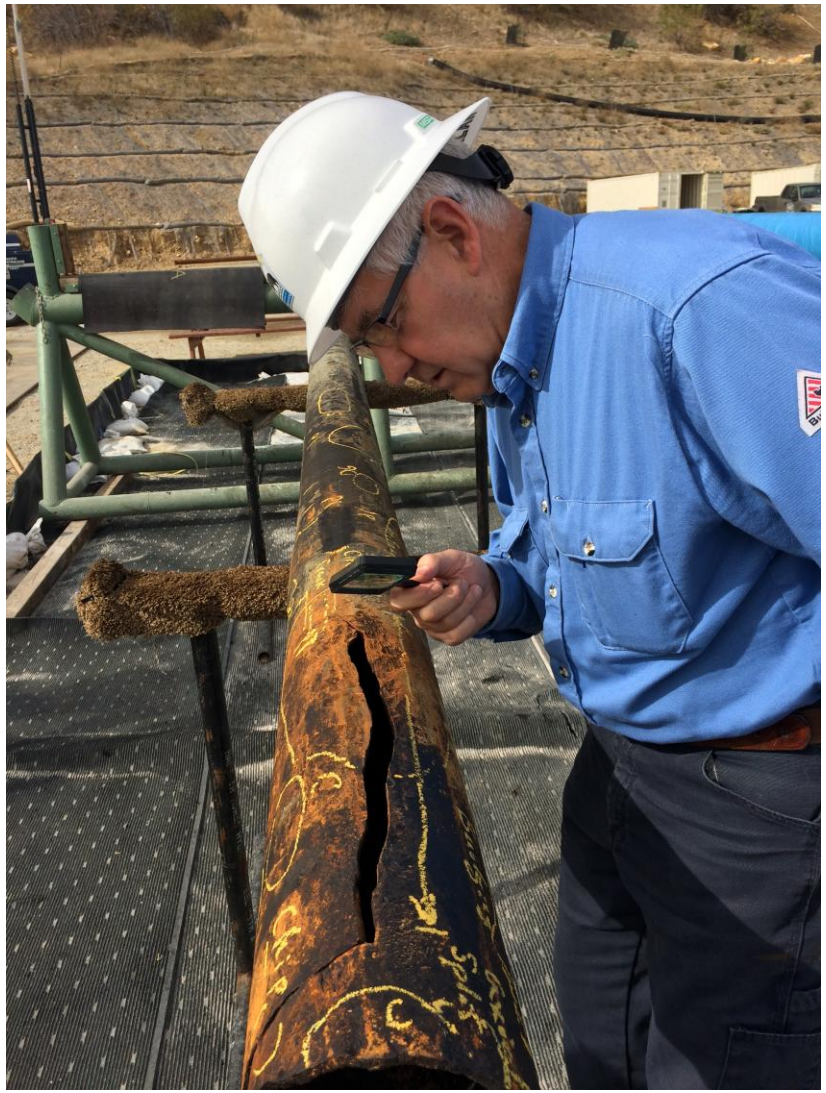
Aliso Canyon Concurrent Safety Review

- 114 gas storage injection and withdrawal wells
- 100% noise and temperature logs
- Transparency – DOGGR website
  - Safety Testing and Review Requirements
  - Test Results of Aliso Canyon Wells
  - Emergency Orders and Regulations
  - Maps, every log used, reports
- Decision point
  - Plug and abandon permanently or
  - Plug in tubing and fluid in tubing and annulus or
  - Conduct full suite of tests to return to injection and withdrawal

Safety Review, Battery II & Resumption

- All injection and withdrawal wells
  - Casing inspection, caliper logs, and cement bond log
  - Positive pressure test to 115% of allowable operating pressure
- Operator resumed injection after regulatory approval
  - All wells either P&A'd, isolated from the reservoir, or passed all tests
  - After public workshop and comment period in February 2017
  - Tubing only production, with minimal pressure annulus
  - And approval by DOGGR and the Public Utilities Commission
- 66 wells passed all Battery II tests and returned for injection and withdrawal service
- 48 wells permanently plugged and abandoned

SS-25 Casing at 890 feet



New Underground Gas Storage Regulation

- Development Principles
  - Transparency
  - Broad Audience
    - Industry Experts
    - National Labs
    - Public
  - Proactive vs Reactive
  - Evidence -based criteria
  - Risk Based Decisions
    - Quantitative
    - Qualitative
- Initial Proposal July 2017
- Content and Results
  - Risk Management
  - Compliance Schedule
  - Emergency Response
  - Project Data
  - Records Management
  - Well Construction
  - Mechanical Integrity
  - Monitoring
  - Decommissioning
- Final Text May 2018
- Effective October 2018

Risk Management Plans – All UGS Projects

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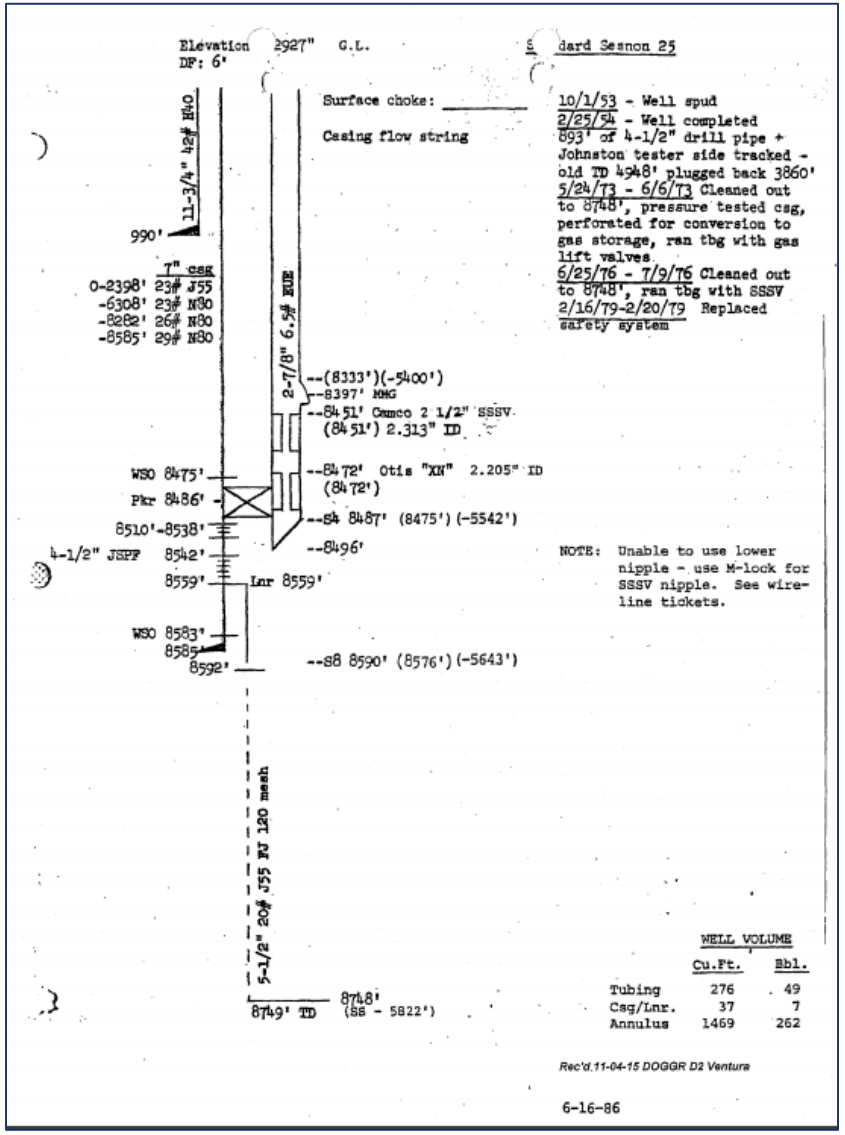
Identify potential threats and hazards

- Ongoing verification of individual and every well's mechanical integrity
- Corrosion monitoring and evaluation
- Protocols for evaluation of wells and facilities
- Ongoing verification of reservoir integrity
- Evaluation of geologic hazards and natural disaster threats
- Prioritization of risk mitigation efforts



Well Construction-all UGS Projects

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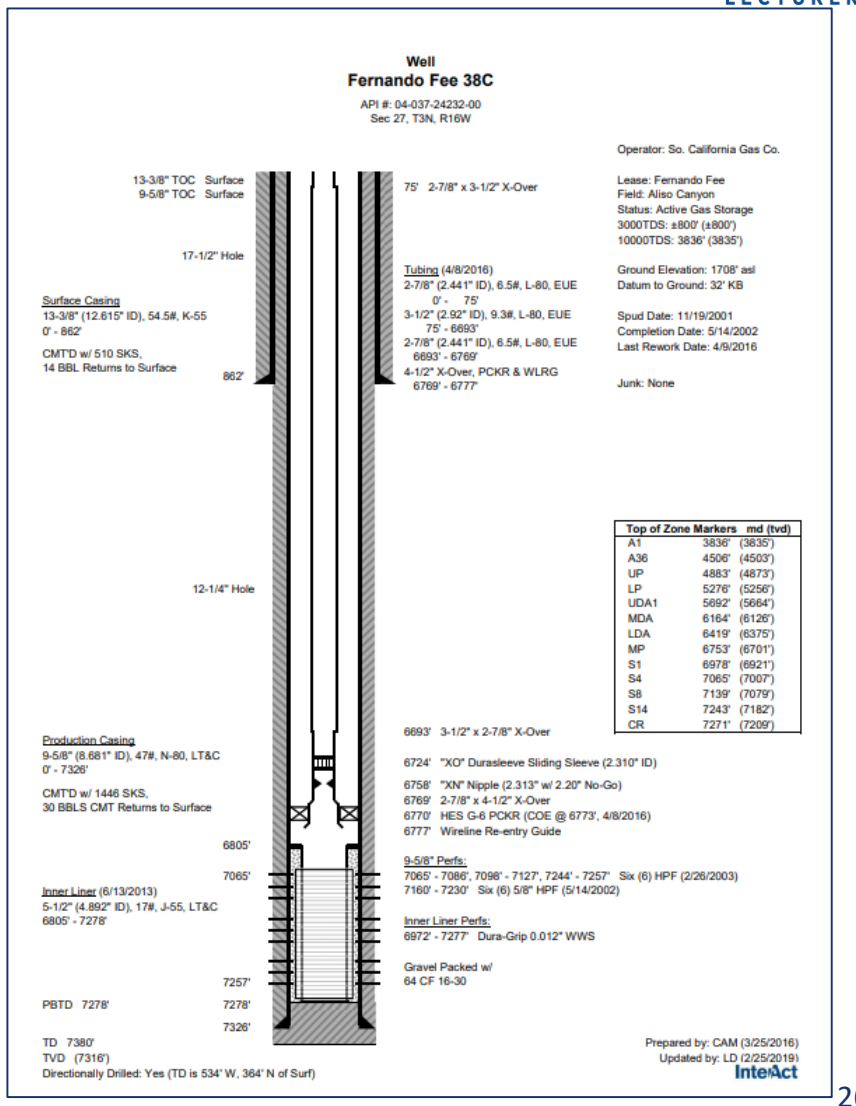
"The operator shall ensure that a single point of failure does not pose an immediate threat of loss of control of fluids and to make certain that integrity concerns with a gas storage well are identified and addressed before they can become a threat to life, health, property, or natural resources."



VIDEO by investigator 5:00 to 6:07 of 6:17

Continued Studies – Never Waste a Crisis

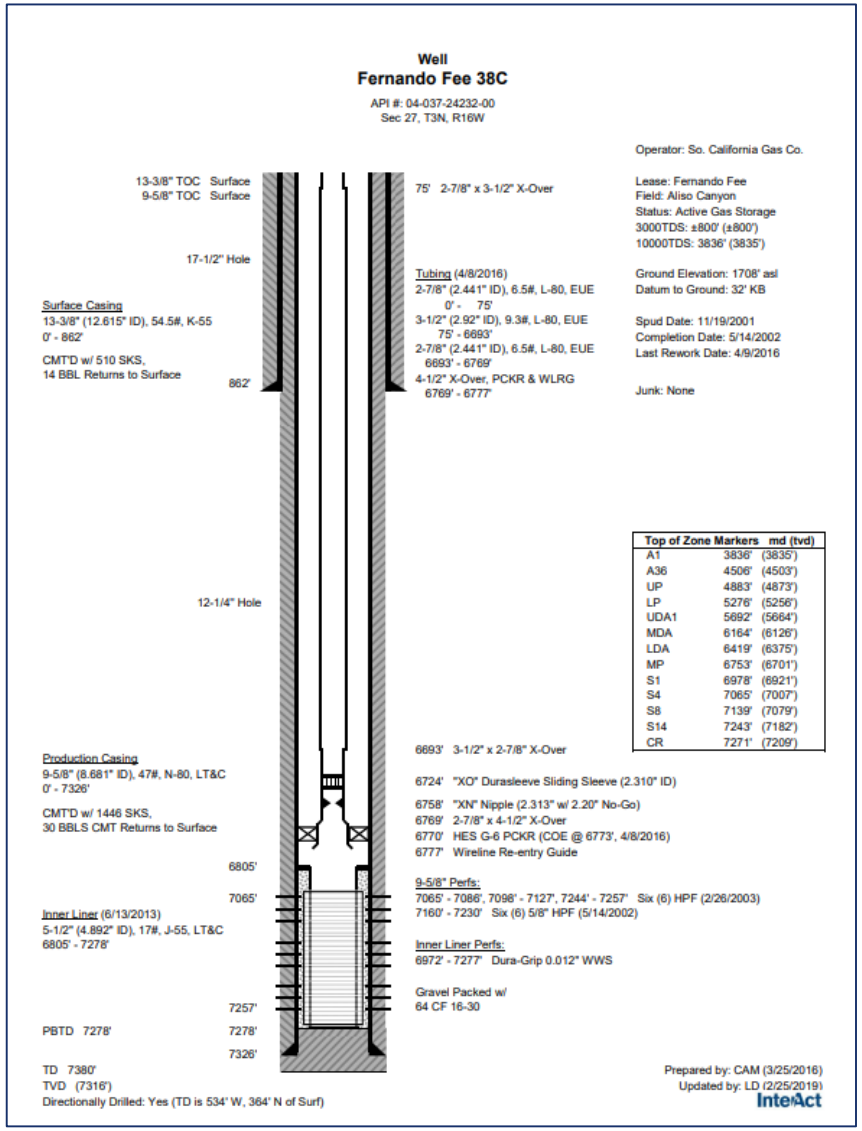
- Seismic Risk Analysis
  - Landslide Hazard
  - Slope Stability
  - Wellhead Integrity
  - Reservoir Geomechanics
  - Seismic Hazard (PSHA)
  - Fault Displacement (PFDHA)
  - Wellbore Integrity
  - Scale Modelling 1:10
  - Well Failure Modelling
  - Gas Migration Model

- Root Cause Analysis
  - Blade Energy
  - CPUC Report
  - DOGGR Report

Photo courtesy of CalGEM

Conclusions / Lessons Learned

- Never Waste a Crisis
- Initiate Joint Agency Incident Command Early
- Develop Proactive Regulation
  - Evidence based
  - Flexibility to modify
  - Management of Change
  - Risk Management Plans
- Promote a Safety Culture
  - Management of Change
  - Root Cause Analysis training
  - Special skill training, i.e. HRVT logs, thermography
- Maintain Redundancy



Sources of Information

- California Department of Conservation
  - Geologic Energy Management Division (CalGEM)
  - Geologic Survey (CGS)
- California Public Utility Commission
- Southern California Gas Company (SoCal Gas)
- Blade Energy
- U.S. Department of Energy National Laboratories
  - Sandia (SNL)
  - Lawrence Livermore (LLNL)
  - Lawrence Berkeley (LBNL)

Thank you! Questions?

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