Welcome!

The program will begin soon.

You will not hear audio until we begin.

Plugging and Abandoning Idle and Orphan Wells

IOGCC/SPE Webinar

2023 June 28

Panelists: Jonathan Heseltine, Matteo Loizzo, Samuel Rondon, and Gavin Snyder

Webinars

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Finding the ways that work

Plugging and Abandoning Idle and Orphan Wells

Jonathan Heseltine, Matteo Loizzo

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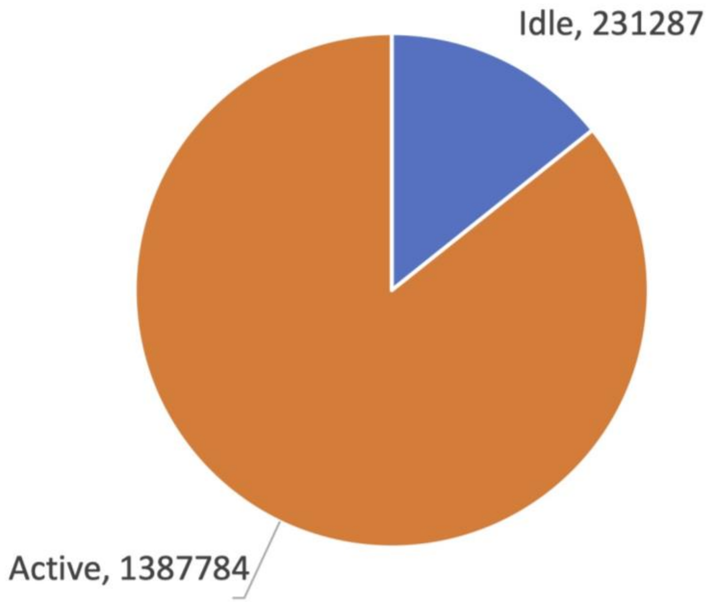
Idle wells, when is that?

- Operating
- Plugged and abandoned
- Idle → Schrödinger's well
  - Owner is around, or orphan well
  - Time-bound
    - Periodic approval after initial non-operational interval
    - Most of the 37 States and Provinces surveyed by IOGCC
      - Different approaches e.g., CA requires periodic MIT
    - Nudge to abandon



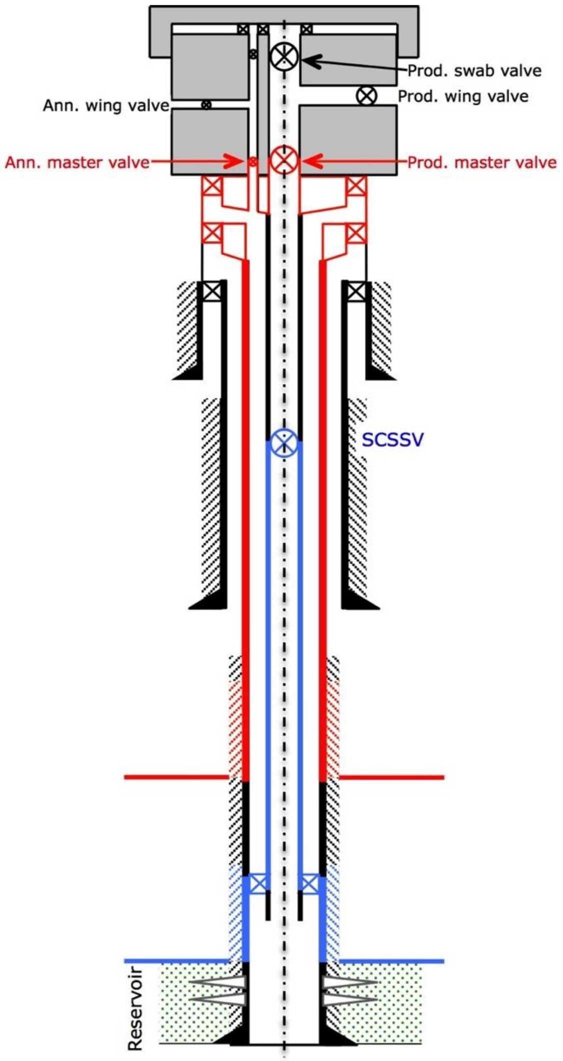
Source: IOGCC Idle and Orphan Oil and Gas Wells (2021). Total wells drilled and not plugged reported by 33 US states up to 2021. "Idle" wells count the approved ones, excluding the 92,198 documented orphan wells. The corresponding fraction of idle wells for the 4 Canadian provinces that reported them is 38%, vs. 14% in the USA.

Not all idle wells are the same

- Shut-in
  - Closed at the Christmas Tree or SSSV → can produce economically
    - Includes artificial lift wells with a shut-off pump
  - “*Well […] capable of production or injection by opening valves, activating existing equipment or supplying a power source*”, CO
    - Can become “inactive” after a certain time
- Temporarily abandoned (suspended)
  - Plug isolating the reservoir
  - Well Decommissioning Phase 1 if plug is permanent (OEUK WDG)

What's wrong with idle wells?

- Barrier system depends on steel → corrosion
  - Oxygen (O_2) for freshwater aquifers
    - Includes oxygenated saline aquifers in the Rockies, much more corrosive
    - External corrosion, in the absence of cement
    - Freeze-thaw cycles can help wreak havoc of conductors
  - Carbon dioxide (CO_2) for deeper aquifers
    - Hydrogen sulfide (H_2S) and Stress Corrosion Cracking
  - Microbiologically influenced corrosion (MIC)
    - Logs suggest a velocity of 0.3 mm y^{-1} (12 mils y^{-1}), after an induction of ~7 years
    - Nutrients
  - Is it really static?
    - Natural convection and viscous fluids
    - O_2 ingress in sub-hydrostatic wells
- No independent barriers with corrosion
- Water injector → biggest risk, but out of scope



Managing idle wells' corrosion

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- Understand the threats
  - External corrosion is rare → does it affects me?
- Eliminate corrosion
  - Oil
  - pH≥12 and biocide
  - Cathodic protection for structural casing
  - Material selection if H_2S is present → NACE MR0175
- When is the right time?
  - Wells are always shut in for an hour or two

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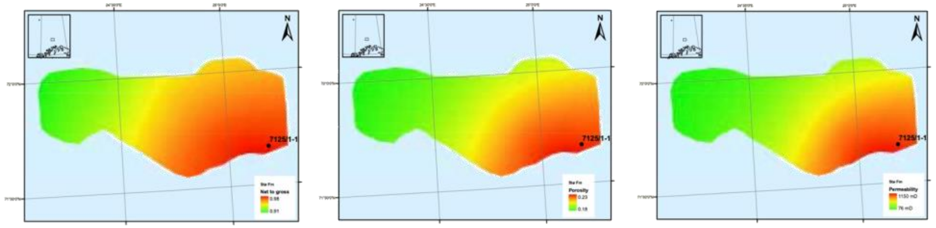
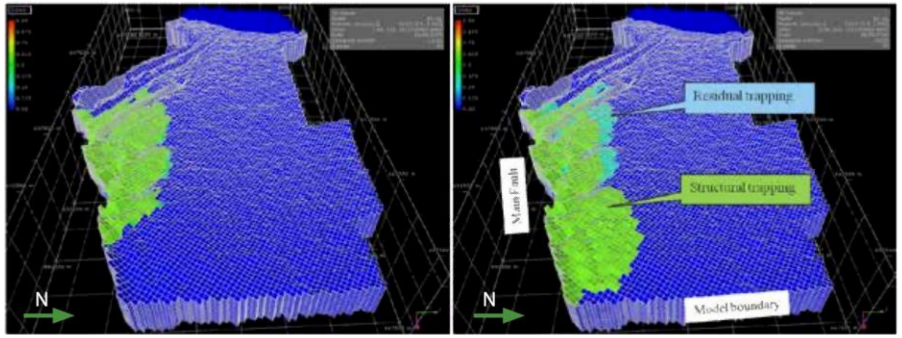
Area of Review

- *"Region surrounding the geologic sequestration project where USDWs may be endangered by the injection activity"*
  - 40 CFR 146.84, Class VI wells
    - Extends to all UIC wells, and fracked wells in some states
  - Reservoir modeling, history matching → continuous improvement
  - Plume and formation fluids
- *"Determine which abandoned wells in the area of review have been plugged in a manner that prevents the movement of carbon dioxide or other fluids that may endanger USDWs, including use of materials compatible with the carbon dioxide stream"*



Net/Gross values from 0,97-0,92 | Porosity varies from 20-24 % | Permeability is 1000mD in the well

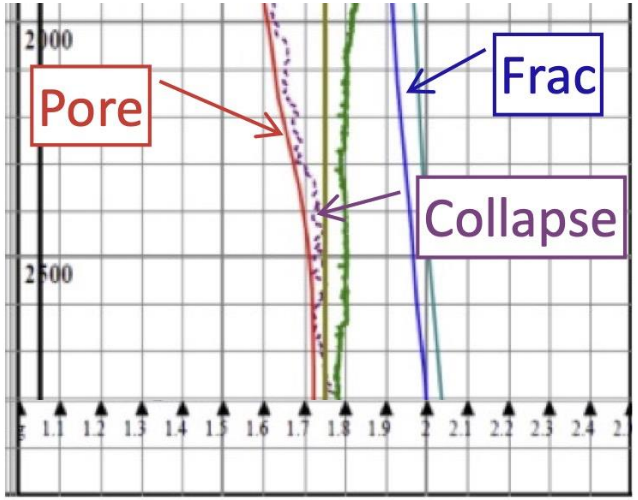


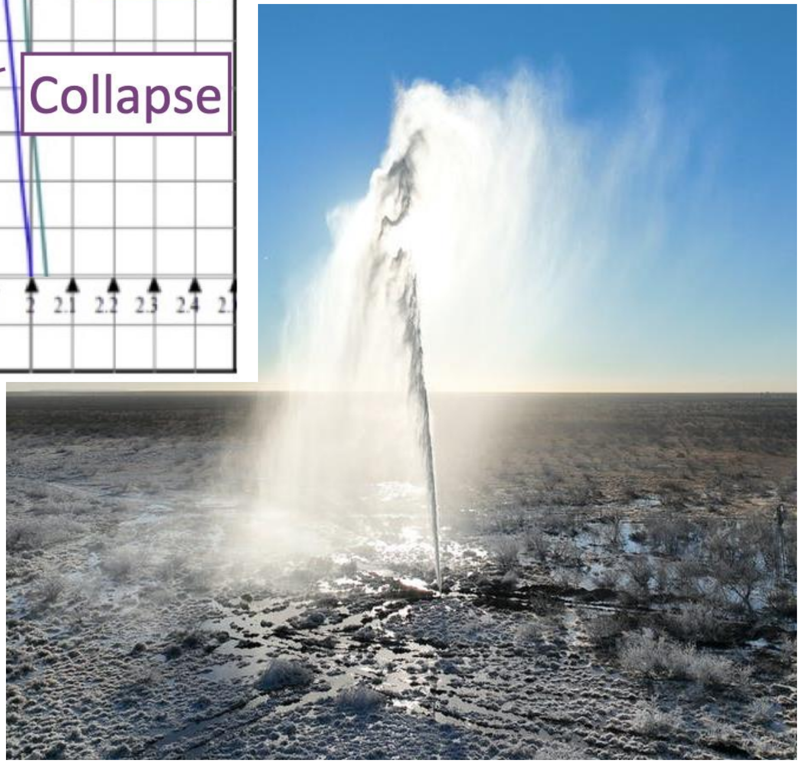
Distribution of injected gas (green) after end of injection (50 years), and after 1000 years of storage. North to the right.

Source: NPD, CO_2 Storage Atlas – Barents Sea (2019)

Plug to prevent movement

- Are barriers qualified now?
  - Will they be after CO_2 injection?
- Only two materials for P&A well barriers → rock and cement
  - Cement has no pressure rating
  - Caprock → Minimum Safe Abandonment Depth
    - Column of fluid (i.e., CO_2) in equilibrium with reservoir meets frac pressure
    - Higher pressure, lighter fluid → deeper MSAD





Source: TexasMonthly, 2022 Jan 12

Compatible with the CO_2 stream

- Class G/H cement carbonation
  - Lime to calcite → passivation
    - Density >15.4 ppg
    - Lime-free cement e.g., class L (Portland cement, gypsum, pozzolan) → no carbonation front
  - Likely scaling of microannuli
  - No dissolution ever observed
- *"Despite early concerns, a significant body of research suggests that while supercritical CO_2 is reactive with wellbore materials, it does not necessarily lead to a degradation of wellbore integrity"*
  - Pawar et al., 2015 (Los Alamos National Laboratory)
- *"Field studies suggest that in the presence of competent original cement, reactions with CO_2 do not adversely affect the cement's capability of preventing migration of CO_2"*
  - Iyer et al., 2022 (Norway's SINTEF)

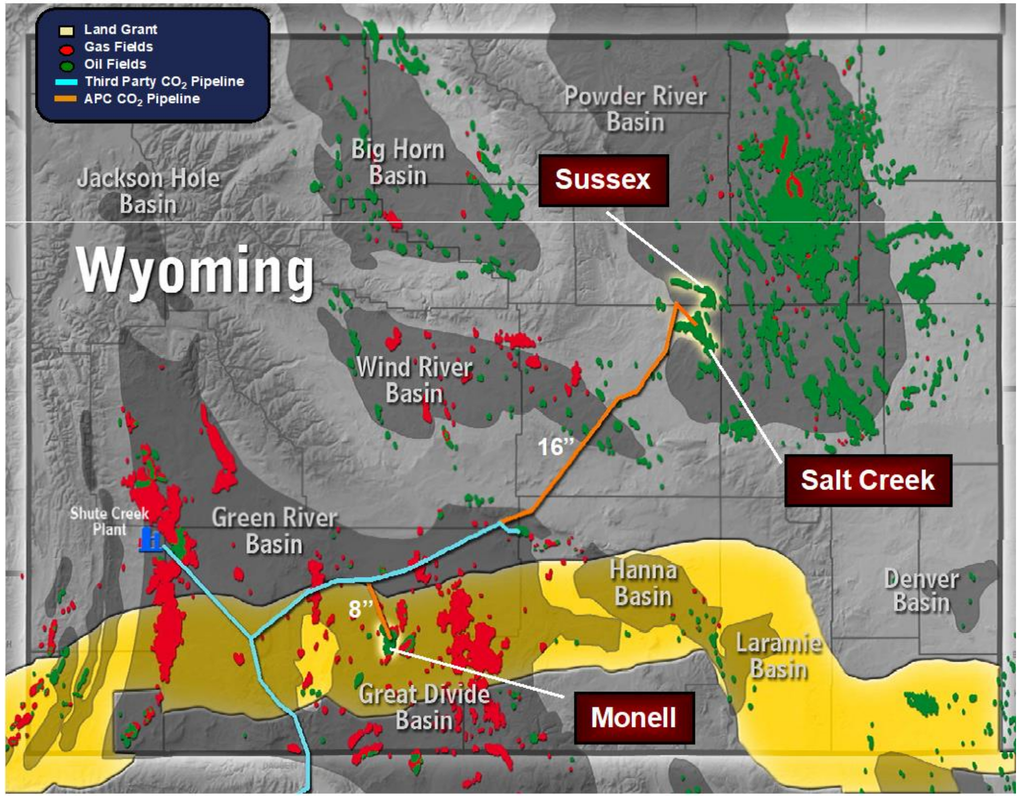
Source: Carey, J.W. et al. Cement with 30 years of CO_2 exposure. Int. J. GHG Control I (2007)

Legacy plugged wells in AoR

- Challenges
  - Little data
    - Scanned CBL, no PPFG
  - Grandfathered regulations
- Worst candidates → dry exploration wells
  - No properly qualified barriers
  - Rushed abandonment
  - Sometimes right on top of the anticline
- Material is not an issue if cement is competent

Dealing with legacy plugged wells

- Anadarko Salt Creek field (WY)
  - CO_2 flood
  - >4,000 wells drilled
    - ~70% earlier than 1930
    - >3,000 “questionably” P&A wells
- Keep ahead of CO_2 plume, re-enter and abandon properly
  - Section mill
  - Industrialize process → de-risk and eliminate waste



Source: Hendricks, K.(2009). Experiences in the Salt Creek Field CO_2 Flood. Presentation to the 5th Annual Wellbore Integrity Network Meeting

How to lower P&A Costs?

Webinars

↑ Streamline Admin/Reg Processes
↓ "Red tape"

↑ Knowledge Transfer
↑ Diagnostics
↑ Campaigns/ABC
↓ Uncertainty

↓ Liability
↓ Risk
↓ Emissions Cost

↓ Material Cost
↓ Waste

↑ Efficient Field Operations
↓ Equipment
↓ Fuel

↑ Barrier Performance
↓ # of remedial attempts
↑ Longevity

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Novel Barrier Materials & Methods

Webinars

- Materials
  - Solids-free composition, low viscosity, rheological properties allowing placement in small flow pathways
  - Superior mechanical properties (strength, flexibility) to withstand geological/operational stresses
  - Environmental resistance (chemical, corrosion, temperature)
  - Curing behavior (strength development)
  - Very low permeability
  - Expansion upon setting
  - Improved longevity
  - Lower CO_2 emissions during manufacturing

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Novel Barrier Materials & Methods

- Methods (enabling technology)
  - Rigless deployment
  - Less equipment, fuel, GHG emissions
  - Cross-trained crews, reduced labor
  - Treatment of remote wells
  - Flow path access
  - Placement, diversion
  - Downhole mixing
  - Wellbore cleanup
  - Fewer trips
  - Monitoring and diagnostics

Alternative Materials

Webinars

- Range
  - Conceptual → Commercialized
- Applications
  - Primary, remedial, plugging
  - Downhole environment
  - Geometry (flow path)
  - Well type
- No one-solution-fits-all

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Company	Product Name	Product Type	Category
BiSn Oil Tools	Wel-Lok M2M	Metal Alloy	Metal Alloy
Isol8 Ltd.	Fusion P&A	Metal Alloy	Metal Alloy
Wellstrom AS	M3 Bismuth Alloy	Metal Alloy	Metal Alloy
Seal Well Inc.	Bismuth	Metal Alloy	Metal Alloy
Panda Seal	Thermite/bismuth?	Metal Alloy	Metal Alloy
TS Nano	TSN-23	Nano modified resin	Resin
Wellcem AS	ThermaSet	Resin	Resin
M&D Industries (Ultraseal)	Liquid Bridge Plug	Resin	Resin
Western Petroleum Management	RITE-WAY	Resin	Resin
Cannseal (an Interwell Company)	IntegritySeal	Resin	Resin
Challenger Technical Services	MCDIS with Resin	Resin	Resin
Shear Fluids Ltd.	ShearSET, ShearPLUG	Resin	Resin
Halliburton	Welllock	Resin	Resin
Drytech	DRYflex Resin	Resin	Resin
Biosqueeze	Biomineralizing solution (CaCO3)	Biological	Pumpable Consolidating/Setting/Precipitating
Allonia	Biomineralizing solution (CaCO3)	Biological	Pumpable Consolidating/Setting/Precipitating
Italmatch	Xclude	Chemical Precipitate	Pumpable Consolidating/Setting/Precipitating
Resolute Energy Services	Assure	Expanding Polymer Grain	Pumpable Consolidating/Setting/Precipitating
Magnum Cementing / National Silicates	MPD-8 Geopolymer	Geopolymer	Pumpable Consolidating/Setting/Precipitating
SLB	EcoShield	Geopolymer	Pumpable Consolidating/Setting/Precipitating
Glass Technology Services / Vitritech	Glass-Based Solutions for Consolida	Glass	Pumpable Consolidating/Setting/Precipitating
Pluto Ground Technologies	Smartset	Magnesium oxysulfate cem	Pumpable Consolidating/Setting/Precipitating
BJT	SelectSeal	Magnesium oxysulfate cem	Pumpable Consolidating/Setting/Precipitating
SNF	Floset	Polymer Gel	Pumpable Consolidating/Setting/Precipitating
Schlumberger	D264 Nanosealant	Polyuronide polymer?	Pumpable Consolidating/Setting/Precipitating
Seal-Tite International	Pressure Activated Sealant	Pressure Activated Sealant	Pumpable Consolidating/Setting/Precipitating
TS Nano	TSN-21	Setting nanosealant	Pumpable Consolidating/Setting/Precipitating
Petroc	Pressure Activated Sealant	Supercritical CO2	Pumpable Consolidating/Setting/Precipitating
FloPetrol	SandAband AS	Unconsolidated Material	Pumpable Consolidating/Setting/Precipitating
Cama Geoscience	Quick Clay	Clay	In-situ
PQ Corp	Lithisil®25	Shale as a barrier	In-situ
TNO	Bentonite Plug	Shale as a barrier	In-situ
Interwell P&A	RockSolid	Thermite	In-situ
Well-Set P&A AS	Magnetorheological Blended Cemei	Advanced Cement	Advanced Cement
Carbon Upcycling Technologies	Cement Blend	Advanced Cement	Advanced Cement
Gittings-Grima	Graphene Enhanced Cement	Graphene additive	Advanced Cement
Winterhawk Well Abandonment	Casing Expansion Tool	Casing Expansion	Mechanical
Renegade Services	Local Expander	Casing Expansion	Mechanical
Welltec	WAB	Casing Expansion	Mechanical
Pragma Well Technology	Pragma M-Bubble	Expandable Plug	Mechanical
None - conceptual	Biochar	Biochar	Filter/Absorb/React
None - conceptual	Methanotrophic Bacteria	Biological	Filter/Absorb/React

Joint Industry Project

- Industry requires better understanding of materials and applications

01 | SELECT PRODUCTS

Select and rank innovative, effective and commercially viable sealing & barrier products. 5 selected.

02 | REVIEW

Summarize state-of-technology to determine testing requirements.

03 | LAB TESTING

Provide independent testing of the alternative materials for regulator and operator acceptance.

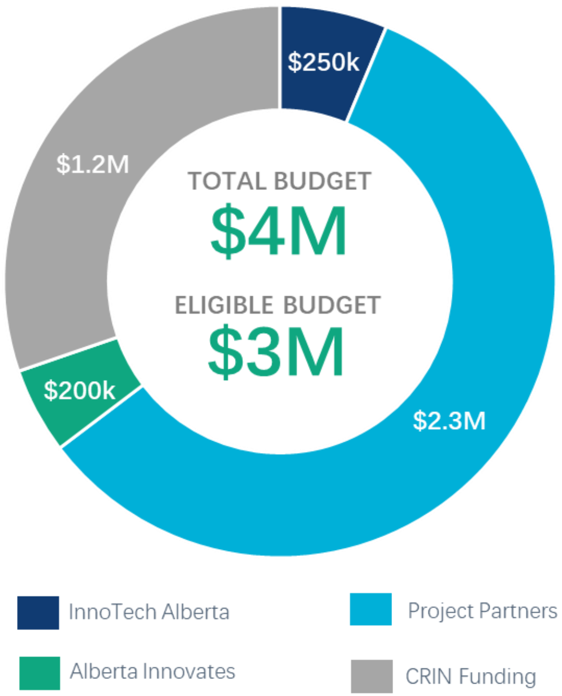
04 | FIELD TRIALS

Conduct several field trials per approved technology, to test the efficacy of the technology.

05 | DATA SHARING

Share field trial results with local and international operators to gain market acceptance of the products.

Example Joint Industry Project

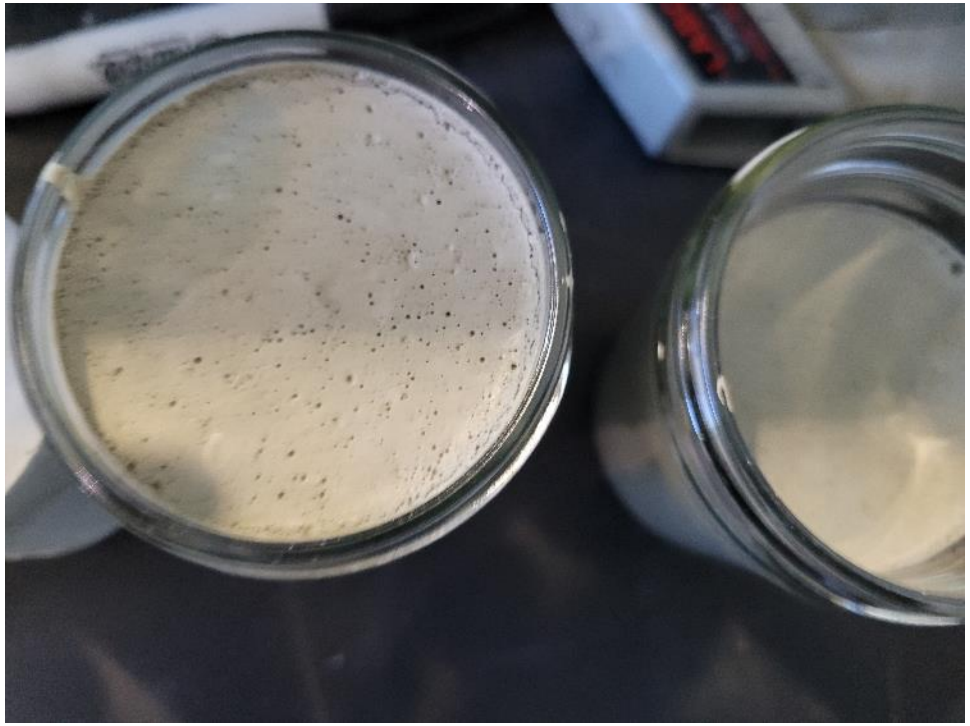


Lab Testing Objectives

- Regulator approval
- Operator knowledge & confidence
- Recommendations
  - Well characteristics (operating envelope)
  - Deployment practices
- TRL > 6 – material characterization complete
  - Lab trials → demonstration is simulated environment

Lab Testing - Benchtop

- Benchtop setting tests provide
  - Understanding of material handling, reaction, cured state, shrinkage
  - Effects of water, oil, paraffin contamination/contact
  - Displacement/contamination/ miscibility



Casing Plug Pressure Test

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- For suitable products
- Displacement of water-wet casing
- Cured under pressure, temperature
- Make-up water measured to infer shrinkage
- Pressure tested with water and/or gas
  - Typically to failure, observe leak paths

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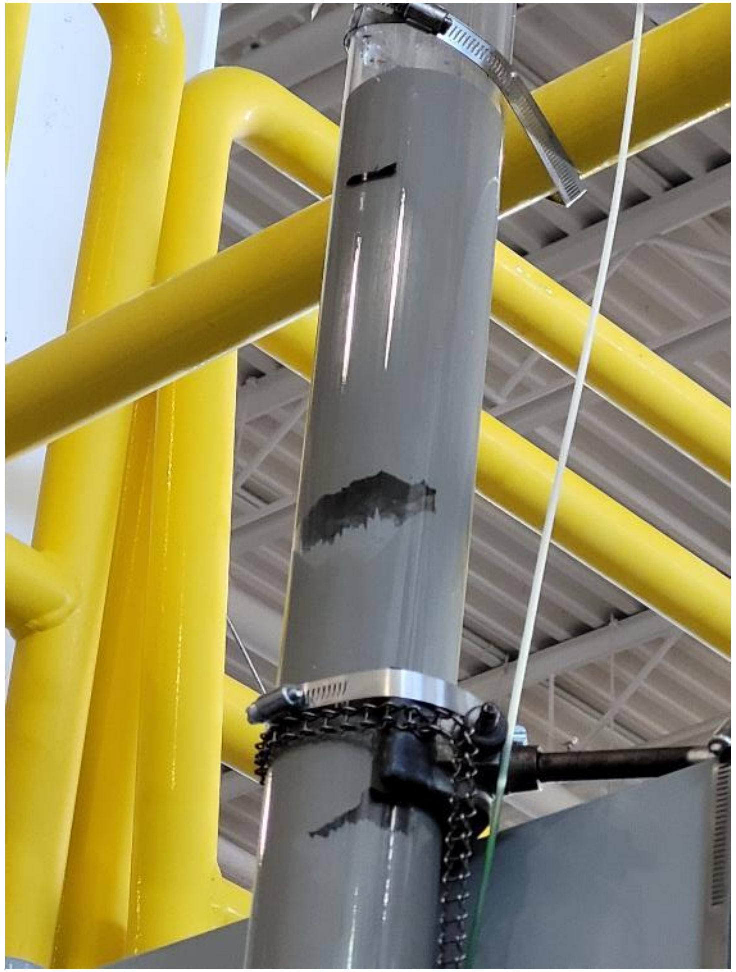
Core Injection ("squeeze")

- Injection into sand-pack and split cement cores, displacing water
- Effluent collected and monitored
- Curing under pressure
- Pressure tested with water and/or gas
- Cores sectioned to observe displacement efficiency

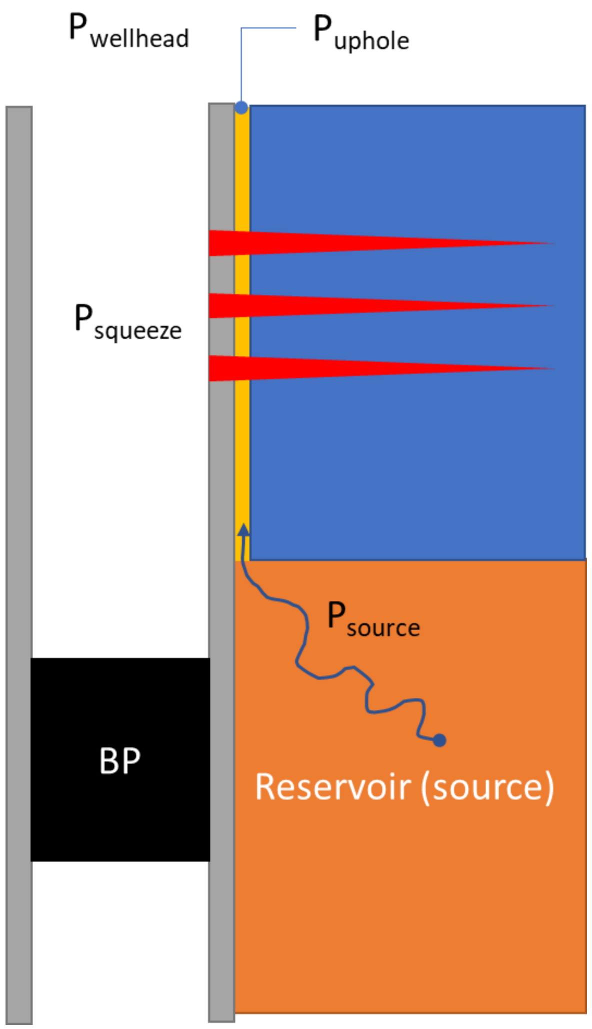
Gas Invasion

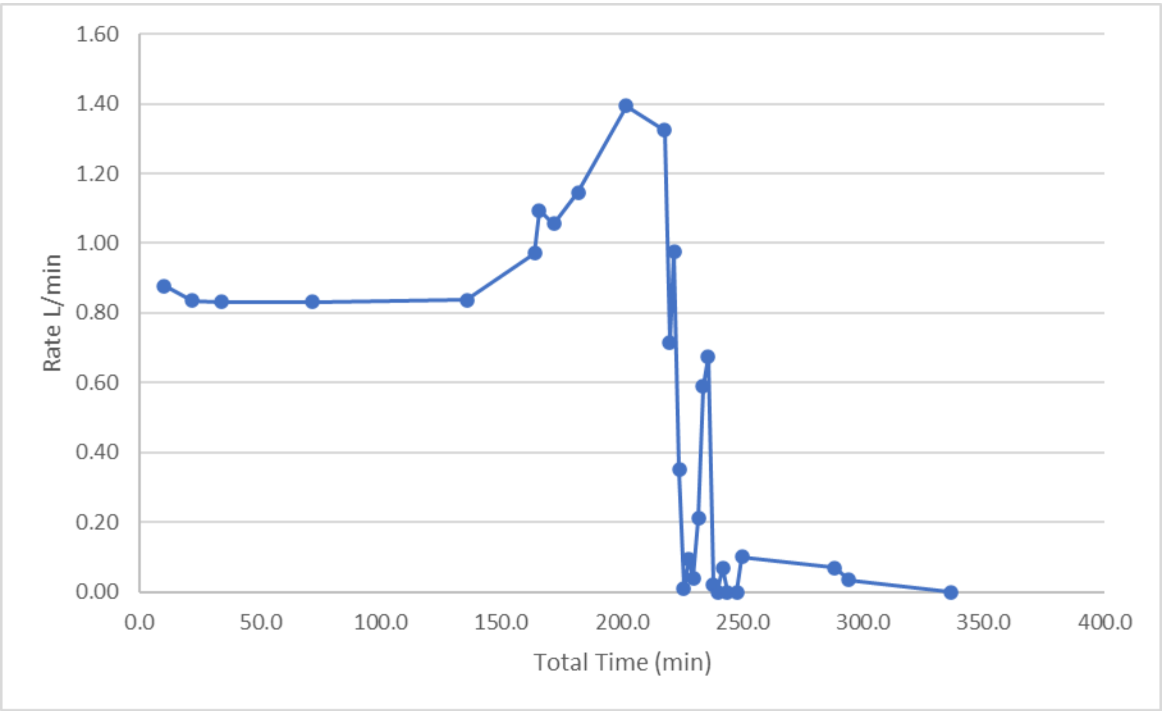
- Initial testing to examine effects of decreased hydraulic head during curing
  - Gas pressure at base of column of material
  - Inlet pressure @ head pressure
- Additional testing with pressure > hydrostatic (initial flow)



Gas Invasion

$P_{squeeze} > P_{source} > P_{uphole}$





Other Tests

- Endurance test
  - 200+ days in acidic brine, pressure, temperature
  - Relative test compared to Class G Portland cement and casing
- Casing shear-adhesion
- Core injection with gas flow

Field Trials

- Wells selected for consistency
- Well selection criteria
  - High degree of confidence in the leak source
  - Well-characterized baseline SCVF flow and build-up pressure
  - Inclination at target depth – less than 10 degrees
  - One production casing string (below SC): casing – cement - formation
  - Preferred 4.5-5.5" nominal OD casing size at target depth
  - Caprock at target depth (impermeable and competent formation)
    - Consideration of cement quality
  - Preferred area well remediation experience from offset wells
    - Minimize additional/unforeseen risks
- Limited variables can also limit qualification

Achieve More with Limited Resources

Webinars

↑ Streamline Admin/Reg

Regulatory Approval

↓ Red tape

↑ Knowledge Transfer

Collaboration/Sharing

↓ Uncertainty

↓ Liability

? Direct or Indirect Impact

↓ Emissions Cost

? Direct or Indirect Impact

↑ Efficient Field

Enabling Technologies

↓ Fuel

↑ Barrier Performance

Technical Performance

↑ Longevity

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Conclusions

- Many potential solutions for lowering costs and improving outcomes in well P&A
- No one-size-fits all barrier material/technology
- Lab trials proving material capabilities and cautions
- Field trials ultimately demonstrate technology
  - Numerous variables and unknowns
  - Limited number of wells, data points
- Further study
  - Other materials
  - Application envelopes
  - Barrier length requirements
  - Longevity
  - Additional field trials -or- full-scale simulation

Successful Large Onshore Well P&A Campaigns

Samuel Rondon, RBU Asset Retirement Engineer; Chevron USA Inc.
Gavin Snyder, RBU Asset Retirement Engineer; Chevron USA Inc.

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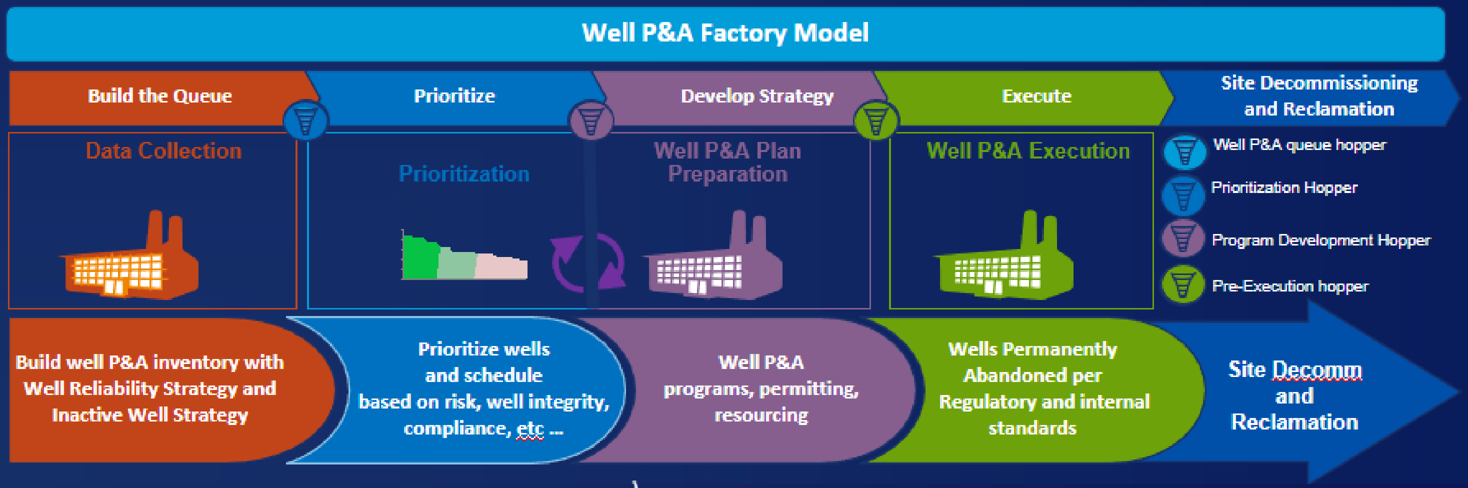
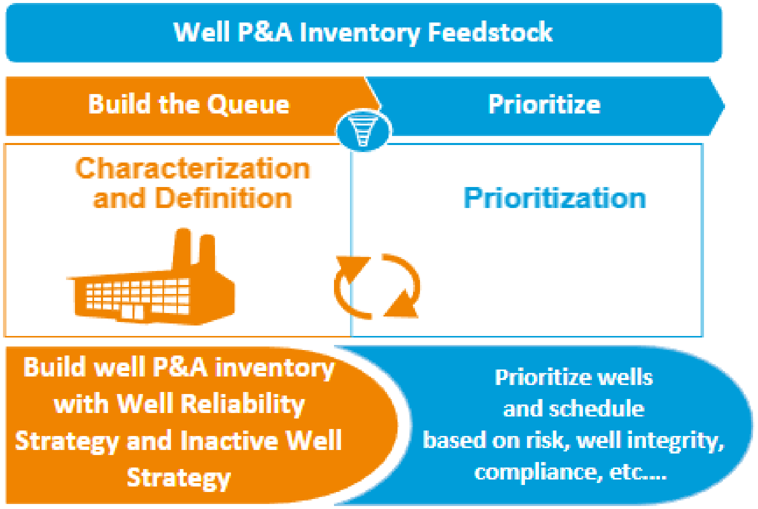


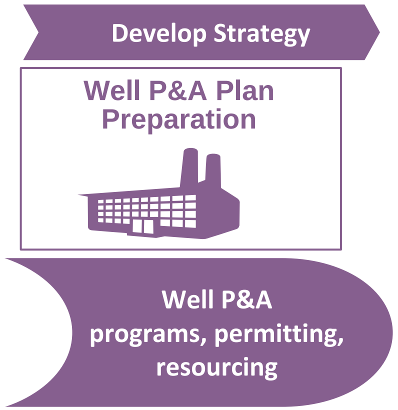
Initiation

- **Healthy Queue**- Important for business to be aligned on ARO strategy, properly funded and healthy queue of well inventory to abandon
  - Well Reliability Strategy
  - Idle/Inactive Well Strategy
- **Data Collection and Validation**- Accurate well data in a system of record to develop abandonment strategy and plans
- **Prioritization-** Prioritize well queue based on criteria such as regulatory compliance, Integrity risks, risk reduction, geography, efficiency, etc...



Ramp Up

- **Categorizing-** Categorize wells (bundle) wells with similar risk profiles, construction characteristics and abandonment designs
- **Playbooks-** Clearly document workflow processes, abandonment designs, costs and standard operating procedures for each category
- **Execution Strategy:**
  - **Campaign (Factory)** style planning and operations
    - Resourcing for high volume, fast-paced, and schedule driven operations
    - Cross functional engagement and collaboration
    - Separate strategy for managing outliers/problem wells to avoid bottlenecks
- **Resource strategy-** Sourcing for campaign (factory) style operations
    - Fixed cost contracts per well category
    - Bundled P&A package (rig, wireline, fishing and cementing)
    - One down- all down NPT



Maintain

- **Document** well abandonment operations in system of record
- **Assurance:**
    - Abandonment barriers verified for position and integrity
- **Performance** Tracking and Data Science
    - Set goals, KPIs, track them and make it visible
- **Continual Improvement-** Reduce cost and cycle time
    - New technology
    - Value Stream mapping of processes
    - Business Partner inclusion is critical

QUESTIONS / DISCUSSION