PROJECT TITLE: **WARI 1801 – CEMENT ALTERNATIVES**

MONTHLY REPORT NUMBER**:** **02**

MONTH OF REPORT: **FEBRUARY 2019**

THIS REPORT:

RECOMMENDED PROCEDURES

FOR THE QUALIFICATION OF CHEMICAL CEMENT ALTERNATIVES

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EXECUTIVE SUMMARY

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Following the identification and summary of Chemical Cement Alternative testing protocols as captured in previously submitted Report-01, Wilkie Enterprises evaluated various procedures per protocol. These procedures were reviewed with seventeen organizations, with the aim of ascertaining the Chemical Cement Alternatives testing capability and capacity to execute the procedures within the Province of Alberta. This Report, therefore, details and justifies recommended procedures for the understated protocols to be adopted for the Province:

I. Safety and Toxicology during storage, handling and transportation
II. Leaching toxicity
III. Groundwater protection
IV. Field Pilot Protocol
V. Bonding to casing, cement and formation
VI. Effects of products on the wellbore (i.e. corrosion, limits wellbore access, etc.)
VII. Longevity of the product in wellbore conditions with evidence supporting the expected longevity
VIII. Product integrity under anticipated adverse conditions (example interaction with H2S or diesel products)
IX. Field deployment verification protocol

In selecting the preferred procedures, Wilkie Enterprises focused on risk reduction associated with the performance of the Chemical Cement Alternatives by:

a) Sequencing the procedures and testing activities in proper order and
b) Addressing potential failure modes of the Alternative

ACKNOWLEDGEMENTS

We do acknowledge the following individuals for their insight in the completion of this milestone:

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6) Fred Wassmuth, Team lead Tight Oil & Water Flooding group at Innotech
7) Grant Farion at Trican Energy Services
8) Spencer Homer President at SealWell
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10) Curtis Eickhoff, Ph.D., Senior Environmental Toxicologist at Nautilus Environmental
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12) Mike MacDonald, Development Chemist at National Silicates
13) Matt Hopkins of SNF
14) Andrew Louden, CEO at Isol8
15) Con Diewart at Dynamic Well Supply and Technical Services
16) Colin Witt, Senior Cementing Engineer at Stingray Solutions

TABLE OF CONTENTS

Contents

List of Tables

List of Figures

INTRODUCTION

Wilkie Enterprises was contracted by PTAC to deliver the following:

- Identify, approach Stakeholders and develop standardized testing protocols for the approval of Chemical Cement Alternatives in the Province of Alberta
- Deliver a roadmap, complete with capable vendors and industry partners, to provide an achievable, repeatable, consistent testing process for Chemical Cement Alternatives.

The detailed scope of work comprises the following work packages:

Work Package	The Work
1	Verify current Chemical Cement Alternative protocols used by the major industry Stakeholders in Alberta
2	Research and identify Chemical Cement Alternative testing protocols used in the oil and gas industry of other provinces and major international markets
3	Review all identified protocols and recommend (and justify) standardised testing for each protocol based on: a) Industry best practice b) Test duration for each protocol c) Cost Estimate for each protocol
4	Upon review of all of the above information, recommend (and justify) a standard value for each property, where applicable, for all identified protocols
5	Propose criteria for approving laboratories for Chemical Cement Alternative protocols testing (if non-existent)
6	Identify and evaluate laboratories or facilities for conducting Chemical Cement Alternative protocol testing
7	Propose a list of “Approved Laboratories” for the above testing protocols
8	Propose a format for test reporting to the AER
9	Develop and submit Final Report

Table 1: Work Packages

Having submitted Report #1 that covered the work in Work Packages 1 & 2, this report covers the work done in Work Package 3.

In executing Work Package 3, Wilkie Enterprises reviewed all identified standardized testing for the following protocols identified in Report #1:

I. Safety and Toxicology during storage, handling and transportation
II. Leaching toxicity
III. Groundwater protection
IV. Field Pilot Protocol
V. Bonding to casing, cement and formation
VI. Effects of products on the wellbore (i.e. corrosion, limits wellbore access, etc.)
VII. Longevity of the product in wellbore conditions with evidence supporting the expected longevity
VIII. Product integrity under anticipated adverse conditions (example interaction with H2S or diesel products)
IX. Field deployment verification protocol

Following the review, relevant testing facilities in Alberta were identified and subject matter experts therein were consulted for cost estimates, test duration and industry best practice for the respective tests. This information was used in justifying standardized testing for each protocol.

METHODOLOGY FOR WORK PACKAGE 3

As referenced in the prior Report, key stakeholders involved in the use of Chemical Cement Alternative in Alberta recommended a United Kingdom (UK) Oil and Gas document titled "Guidelines on Qualification of Materials for the Abandonment of Wells" as a framework for Standardized Testing of Chemical Cement Alternatives.

The document identified the following Chemical Cement Alternatives listed in the Table 2 below

Type	Chemical Cement Alternatives	Examples
A	Modified Cements/ ceramics (non-setting)	Pozzolanic cements, slag, phosphate cements, hardening ceramics, geopolymers
B	Grouts (non-setting)	Sand or clay mixtures, bentonite pellets, barite plugs, calcium carbonate and other inert particle mixtures
C	Thermosetting polymers and composites	Resins, epoxy, polyester, vinylesters, including fibre reinforcements
D	Thermoplastic polymers and composites	Polyethylene, polypropylene, polyamide, PTFE, PEEK, PPS, PVDF and polycarbonate, including fibre reinforcements
E	Elastomeric polymers and composites	Natural rubber, neoprene, nitrile, EPDM, FKM, FFKM, silicone rubber, polyurethane, PUE and swelling rubbers, including fibre reinforcements
F	Formation	Claystone, shale, salt
G	Gels	Polymer gels, polysaccharides, starches, silicate-based gels, clay based gels, diesel/clay mixtures
H	Glass	Solid impermeable silicate glass
I	Metals	Bismuth Alloys
J	Modified in-situ materials	Chemical Cement Alternatives formed from casing and / or formation through thermal or chemical modification

Table 2: Chemical Cement Alternatives [1]

The document further listed:

a) Critical Parameters related to potential failure modes of the Alternatives and
b) Their significance to the Alternatives' integrity.

The Alternative Properties to be tested are listed in the Table 3 below:

Critical Parameters (Applicable Protocol Number)	Definition	Units	Importance of the Property to the Chemical Cement Alternative Testing
Permeability (V)	Measure of the ability of a porous material to transmit fluids under a pressure differential.	Darcy	Provides an estimate of the lag time between placement and breakthrough and release rate of fluid below a given length of material under a set pressure differential
Diffusion coefficient (V)	Proportionality constant between the gradient of concentration driving the diffusion process and the corresponding flux of the moving fluid	m^2s^{-1}	Provides an estimate of the lag time between placement and breakthrough and release rate of fluid below a given length of material under a set concentration differential

Absorption (V, VI)	Mass of fluid taken up by porosity within a substance	% mass/ % vol.	Allows an indication of swelling, from which resulting stresses may be projected
Chemical Resistance	Indication of reactivity of a material. Described with terms non resistant, limited resistance, resistant		Allows an indication of the degree to which properties of the material may change
Volume Change (V, VI)	Change in volume	strain or % by vol.	Variable required to calculate stresses from expansion or shrinkage
Modulus of elasticity (VII)	Uniaxial stress over uniaxial strain.	Pressure	Variable required to determined degree of deformation under a given pressure, and under temperature change
Poisson's ratio (VII)	Ratio of lateral strain to axial strain under uniaxial stress	None	Variable required to determine lateral deformation under a given pressure and under temperature change
Cohesion (VII)	Describes a granular material's cementation strength between grains under shear stress.	Pressure	Variable required to determine shear failure
Internal friction angle (VII)	Describes a granular material's ability to increase load-capacity or shear stress with confinement	Degrees	Variable required to determine reduction in ultimate compressive strength and loss in cohesion
Hydrostatic yield (VII)	Stress applied uniformly in all directions when plastic deformation happens	Pressure	Above this threshold material will undergo irreversible plastic deformation causing loss of cohesion and load-bearing capacity. Provides indication of pore collapse in granular materials
Tensile Strength (VII)	Threshold at which failure occurs under a tensile load	Pressure	Describes maximum tensile stress
Unconfined compressive strength (VII)	Threshold at which failure occurs under axial compressive stress	Pressure	Maximum compressive stress that a Chemical Cement Alternative can withstand
Hardness (VII)	Describes a material's resistance to surface deformation		QA/QC control test. For some materials, provides indication of yield strength in shear
Shear bond strength (V, VII)	Threshold at which bond between two materials fails under shear loading	Pressure	Variable required to calculate pressure differential value resulting in the movement of Chemical Cement Alternative
Tensile bond strength (V, VII)	Threshold at which bond between two materials fails under tensile loading	Pressure	Maximum tensile at the Chemical Cement Alternative casing interface prior to failure
Creep (VII)	Linear deformation over time at a set load	Strain rate/time %/s	Provides an estimate of the ultimate dimensional change of a Chemical Cement Alternative under a given pressure differential or other load
Fatigue life	Threshold number of stress cycles of a given property prior to failure		Provides an indication of longevity at a specified cyclical stress regime.
Decomposition temperature (VII)	Threshold temperature at which Chemical Cement Alternative begins to thermally decompose for a given pressure and environment composition	Temperature	Provides an indication of the degree of deterioration and gives a prediction of maximum operating temperature of the material
Density (II)	Mass per unit volume	Mass per unit volume	QA/QC test. Provides an indication of the likelihood of Chemical Cement Alternative moving due to differences between densities of Chemical Cement Alternative and well fluids

Table 3 Critical Parameters of Chemical Cement Alternatives and Their Relevance [1]

Wilkie Enterprises approached a total of seventeen (17) organizations in the Oil and Gas Industry with expertise in determining the Critical Parameters listed in Table 3. The organizations are broken down as follows:
Ten (10) Service based organizations.

Three (3) Engineering Testing Facilities: Innotech, C-FER Technologies and Dynamic Well Services
Two (2) Universities: University of Calgary, University of Alberta.
Two (2) Technical Institutes: Northern Alberta Institute of Technology (NAIT) and Southern Alberta Institute of Technology (SAIT)

Upon due technical consultation with the organisations listed above, Wilkie Enterprises condensed and reviewed all possible practices per protocol and recommends the understated procedures.

PRESENTATION OF RECOMMENDED PROCEDURES

This section of the report outlines the recommended procedures and standardized tests for each Protocol.

Protocol I: Safety and toxicology during storage, handling and transportation

Protocol Objective:
To ensure that toxic elements of the Chemical Cement Alternatives are safely and properly handled during transportation and storage.

Number of Procedures Evaluated: Four (4) – See details in Appendix Table 6

Recommended Procedure:
Adopt the following steps:

1) Follow directions on storage, handling and transportation from the Material Data Sheet
2) Follow safety and toxicology protocol for the Chemical Cement Alternative from Material Data Sheet
3) If not available, follow the safety and toxicology protocol of the individual chemicals prior to and post-setting, by visiting list in section 26.8.1.3 of "An Industry Recommended Practice (IRP) for the Canadian Oil and Gas Industry, IRP 26 Wellbore Remediation" [2].
4) Ensure adequate ventilation during product preparation

Justification:
Each of the four procedures complement each other by filling the gaps existing in the other three; such that when taken together they provide the complete procedure for the protocol.

Protocol II: Leaching toxicity
Protocol III: Groundwater protection

Objectives for the two (2) Protocols Above:

Chemical Cement Alternatives should not contaminate groundwater with harmful substances during deployment (curing) or through deterioration.

Number of Procedures Evaluated: Four (4) – See details in Appendix Table 7 and Table 8

Recommended Procedure:

Adopt the following steps:

1) Determine the toxicity of the product from an extensive literature review.
2) Following this, determine the wellbore depth where the product will be placed.
3) Calculate the dispersion potential of toxicants from the product in its uncured and cured form.
4) The final outcome is unconditional acceptance, conditional acceptance or non-acceptance.

The procedure is detailed in Figure 1 below.

Justification:

A similar procedure is being used by the AER subject matter experts to evaluate toxicity of Chemical Cement Alternatives in remedial wellbore applications. Procedure has proved practical and satisfactory.

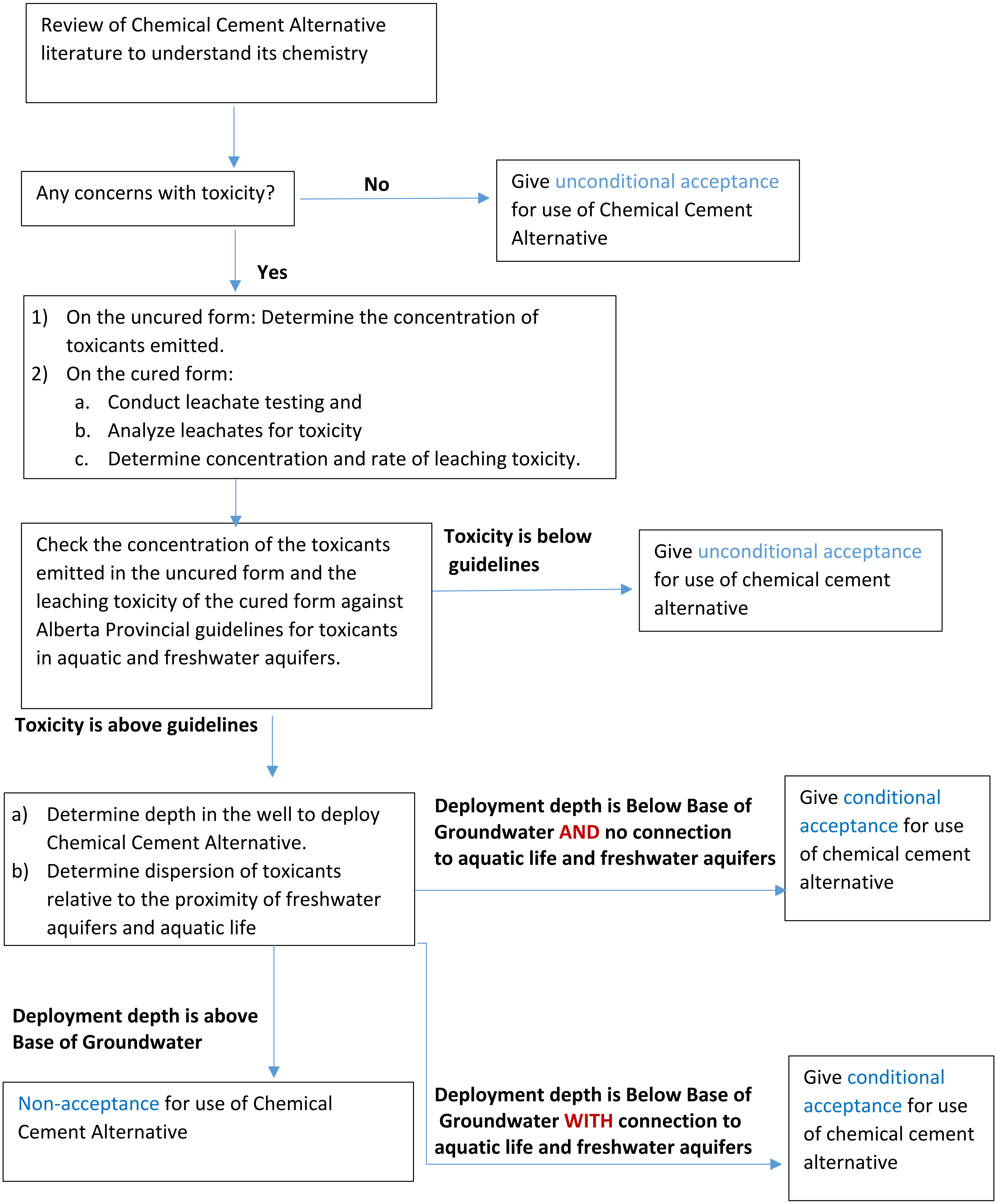

Figure 1: Toxicity Testing Approval Process for Chemical Cement Alternatives

Protocol IV: Field Pilot Protocol

Protocol Objectives:
To ensure that the Chemical Cement Alternative meets its design specifications during field tests

Number of Procedures Evaluated: Sixteen (16) – See details in Appendix Table 9

Recommended Procedure:
Adopt all the 16 procedures as follows:

1) Establish anticipated downhole conditions based on current knowledge
2) Model placement techniques
3) Model the effect of varying loads and external influences
4) Ensure that the material has appropriate properties that allow it to displace the existing fluids and form a continuous sealing medium even when contaminated
5) Consider retaining pre-mixed and blended post-set sample for future evaluation
6) Function test (see Appendix 8 for an example [1])
7) Confirm effectiveness of placement techniques with previous yard trials
8) Determine the extent of material contamination during placement
9) Minimize setting time (when practical) and/or maintain sufficient surface pressure when transitioning from liquid into solid to prevent escape of fluid and loss of the integrity of the Chemical Cement Alternative
10) Conduct in situ testing and verification of the Chemical Cement Alternative
11) Ensure Chemical Cement Alternative can be removed in the event that well re-entry is required
12) Develop success/failure criteria for tests after placement
13) Conduct long term monitoring
14) Document product operating envelope to prevent degradation as a result of future operations in the reservoir
15) Utilize tools like acoustic transducers to determine extent of deterioration
16) Consider collaborating with other organizations to share costs

Justification:
Each of the sixteen procedures complement each other by filling the gaps existing in the other fifteen; such that when taken together they provide the complete procedure for the protocol.

Protocol V: Bonding to casing, cement and formation
Protocol VI: Effects of products on the wellbore (i.e. corrosion, limits wellbore access, etc.)
Protocol VII: Longevity of the product in wellbore conditions with evidence supporting the expected longevity
Protocol VIII: Product integrity under anticipated adverse conditions (example interaction with H2S or diesel products)

Objectives for the four (4) Protocols above:

To ensure the integrity (and performance) of the Chemical Cement Alternatives will last over the entire abandonment life of the well.

Number of Procedures Evaluated: One hundred and fifty (150) See details in Appendix Table 10 to Table 20

Recommended Procedure:

A systematic approach focused on reducing the risk associated with Chemical Cement Alternatives by providing evidence that the failure modes of the Alternative have been identified and testing activities are relevant and complete. This Qualification Process is broken down as follows (see Figure 2):

1) Establish The Basis for Qualification of the Chemical Cement Alternative

   Objective: To test and ascertain the understated functional specifications of the Chemical Cement Alternative.
   1. Sealing: Provide sealing against movement of fluids
   2. Maintain Position: The Chemical Cement Alternative should not move along the wellbore or laterally
   3. Placeability: The Chemical Cement Alternative should be able to be placed at required depth
   4. Durability: The Chemical Cement Alternative should not lose integrity over time
   5. Removal: The Chemical Cement Alternative should be able to be removed
   6. Environmentally Safe: The Chemical Cement Alternative should not be harmful to the environment as deemed by the AER.

2) Conduct Chemical Cement Alternative Assessment

   Objective: To determine which components of the Chemical Cement Alternative that requires qualification and to identify uncertainties and challenges
   1. Conduct composition analysis of the Chemical Cement Alternative
   2. Assess degree of novelty
   3. Identify the main challenges and uncertainties
   4. Refer to Section 7, Technology Assessment, [3]for a detailed breakdown of each step

   Note: Uncertainty in performance primarily comes from novel components. The application area and novelty of the Chemical Cement Alternative affects the uncertainty associated with its implementation. The testing procedures should reduce uncertainty by providing empirical evidence in the areas with the greatest uncertainties.

Application Area	Degree of Novelty of Technology		
	Proven	Limited Field History	New or Unproven
Known	1	2	3
Limited Knowledge	2	3	4
New	3	4	4

Table 4: Example Novelty Categorization [3]

   In the example above,
   1. No new technical uncertainties
   2. New technical uncertainties
   3. New technical challenges
   4. Demanding new technical challenges

3) Conduct Threat Assessment

   Objective: To identify relevant failure modes with associated failure mechanisms for the novel components of the Chemical Cement Alternative and to assess the affiliated risks.

1. Refine the Chemical Cement Alternative composition assessment from the second category, if necessary
2. Define various probabilities and consequences of failure (risk = probability x consequence)
3. Define low, medium and high risk using a risk matrix
4. Identify all potential failure modes and rank according to risk
5. Develop a failure mode register containing the associated risks
6. Refer to Section 8, Threat Assessment [3], for a detailed breakdown of each step

Note: Medium and high risk failure modes are considered critical. Table 3 is a list of Critical Parameters related to potential failure modes for Chemical Cement Alternatives. See section 5, Potential Functional Failure Modes and Root Cause [1], for a list of common failure modes for Chemical Cement Alternatives.

Also note, Quantitative Failure probability shall be based on:

1. Test Results
2. Numerical Analysis using recognised methods
3. Documented relevant experience
4. Engineering judgement by qualified personnel

4) Develop Chemical Cement Alternative Qualification Plan

Objective: To provide the evidence needed to address the failure modes identified in step three (3) of the Qualification Process

1. Analyze and select detailed qualification methods (refer to Appendix Table 10-Table 20 for a list of Experimental Work Plans)
2. Justify success criteria for all qualification methods
3. Utilize conventional engineering methods to provide safety margins accounting for underlying uncertainties of each failure mode
4. Refer to Section 9, Selection of Qualification Methods [3], for a detailed breakdown of each step

Note: The Qualification Plan must include a function test and a program for ageing testing. See Section 8.0, Experimental Work Plan [1]. Also, all qualification activities should account for the impact of uncertainties in the Critical Parameters. See Section 9.3, Parameter Effects and Models [3].

5) Execute Chemical Cement Alternative Qualification Plan

Objective: To document the performance margins for the failure modes of concern

1. Conduct theoretical analysis and calculations where practical to record fulfillment of the specifications and margins against failure modes [1]
2. Verify theoretical calculations with experiments
3. Conduct standardized testing and suggested methods for each Chemical Cement Alternative as identified in Appendix Table 10-Table 20 to address outstanding medium and high risk failure modes.
4. Collect and document the data obtained from the qualification activities
5. Ensure traceability to allow an independent review of test specifications, apparatus and quality assurance.

6. Refer to Section 10, Execution of the Technology Qualification Plan [3], for a detailed breakdown of each step

6) Conduct Performance Assessment

Objective: To assess whether the evidence obtained from the Chemical Cement Alternative Qualification Plan satisfies the functional requirements.

1. Verify that the qualification activities have been completed and that the acceptance criteria were met
2. Perform a sensitivity analysis of key parameter effects
3. Assess the confidence of the qualification evidence
4. Compare the failure probability for each failure mode of concern against the functional specifications
5. Refer to Section 11, Performance Assessment [3], for a detailed breakdown of each step

Justification:
Global procedure for the development of standardized tests as per the document titled "Recommended Practice Technology Qualification DNVGL-RP-A203" by Det Norske Veritas GL, a global quality assurance and risk management company.

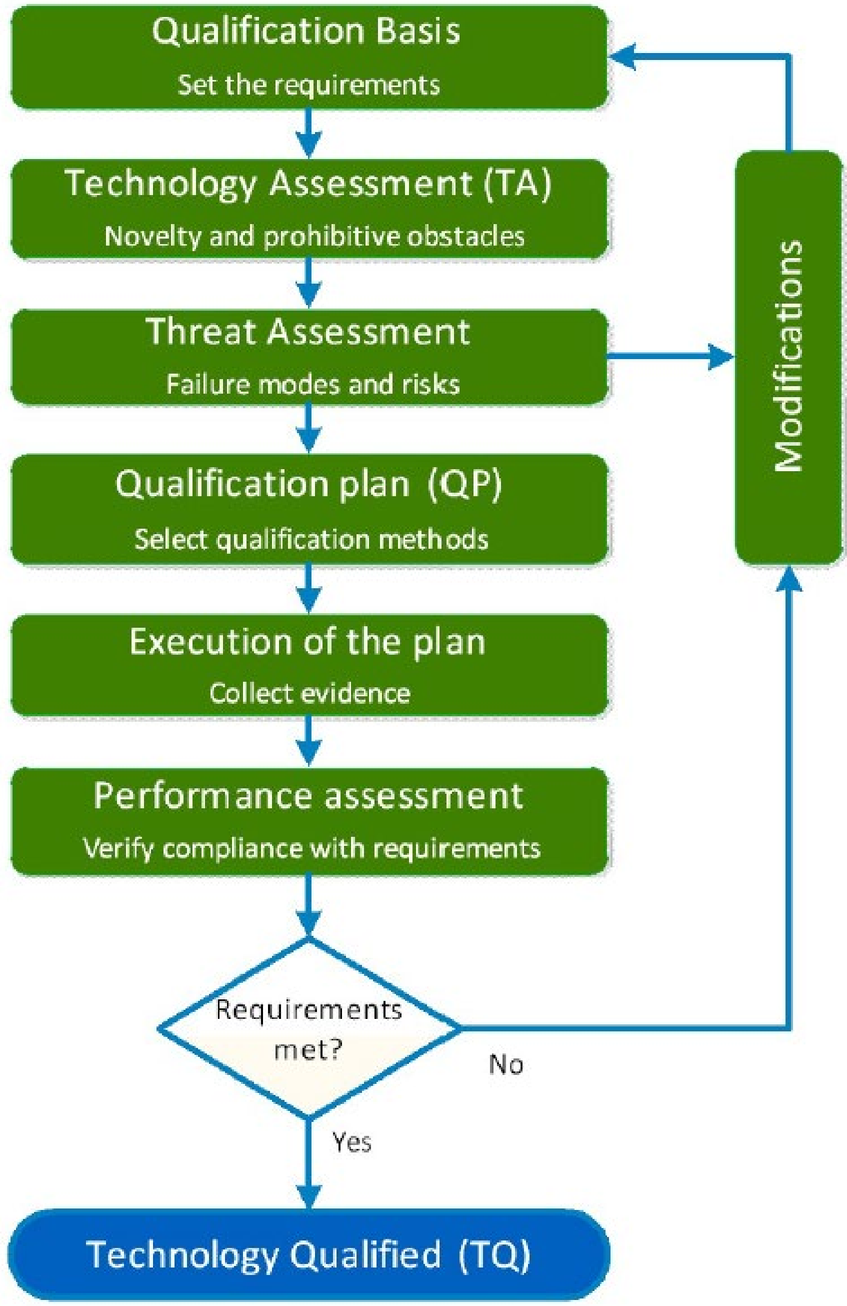

Figure 2: Qualification Process for Chemical Cement Alternative

DOCUMENTATION REQUIRED FOR PROTOCOLS V TO VIII

Documentation presented by the vendor for the Chemical Cement Alternative should contain all the information required to assess its novel components. All evidence used to justify its qualification should be present. These include:

1. Functional specification of the Chemical Cement Alternative
2. Chemical Cement Alternative material specifications with documentation of its performance in the intended operating conditions. This includes traceability from the specifications to manufacturing and assembly.
3. Failure mode register including required personnel competency
4. Assumptions made in final Threat Assessment
5. Evidence used by the vendor in the Qualification Process
6. List of Qualification methods and their justification
7. Safety margins to specified minimum performance requirements, failure modes.
8. Limiting values
9. System reliability
10. Records of document revisions stating content of revision

Note: Refer to Section 2.3, Documentation Requirements and Confidentiality [3], for a detailed breakdown of each step

Protocol IX: Field Deployment Verification

Protocol Objectives:
To ensure that the Chemical Cement Alternative meets its design specifications during field deployment.

Number of Procedures Evaluated: Fourteen (14) – See details in Appendix Table 21

Recommended Procedure:
Eleven (11) of the fourteen (14) procedures are recommended for adoption as follows:

1) Determine Displacement efficiency with relevant wellbore fluids
2) Evaluate and prevent slumping of plugging materials components in relevant wellbore fluids. Component size can be critical meaning tests may be required at different scales. Computer simulations may assist in understanding the behavior as long as the output is verified.
3) Minimize setting time (when practical) and/or maintain sufficient surface pressure when transitioning from liquid into solid to prevent escape of fluid and loss of the integrity of the Chemical Cement Alternative
4) Verify that the Chemical Cement Alternative has been successfully placed
5) Ensure Chemical Cement Alternative can be removed in the event that well re-entry is required
6) Verify that the product blend is not altered from what was tested or accepted for use
7) Review life expectancy of product against accepted wellbore materials such as casing cement, packers, cast iron, fiberglass, etc.
8) Document product operating envelope to prevent degradation as a result of future operations in the reservoir
9) Consider retaining pre-mixed and blended post-set sample for future evaluation
10) Develop success/failure criteria for testing after product placement
11) Consider collaborating with other organizations to share costs

Justification:
Each of the eleven (11) procedures complement each other by filling the gaps existing in the other ten (10); such that when taken together they provide the complete procedure for the protocol. The three (3) procedures eliminated were redundant and are already captured in Protocols V to VIII.

NEXT MILESTONE DELIVERABLES

As per the contract, the next Milestone is to complete Work Package-4 by March 29th, 2019. The objective of this Work Package is to recommend (and justify) a standard value for each property, where applicable, for all identified protocols.

SCHEDULE "A" MILESTONE AND INVOICING SCHEDULE

Payment Milestones	Work Package	Proposed Completion Date	Actual Completion Date				Anticipated Completion Date			
1. Meetings with Stakeholders and development of categories and protocols required per category.	1	Nov 30, 2018			Jan 31, 2019					
2. Develop list of current Chemical Cement Alternative protocols per category in Alberta	1	Dec 31, 2018			Jan 31, 2019					
3. Develop list of current Chemical Cement Alternative protocols per category outside Alberta	2	Jan 31, 2019			Jan 31, 2019					
4. Propose best practice protocols	3	Feb 28, 2019				Feb 28, 2019				
5. Propose standard value per property (where applicable)	4	Mar 31, 2019					Mar 31, 2019			
6. Develop criteria for approving of laboratories for Chemical Cement Alternative testing	5	Apr 30, 2019						Apr 30, 2019		
7. Develop list of "Approved Laboratories" for testing protocols	6 & 7	May 31, 2019							May 31, 2019	
8. Provide format for test reporting to the AER	8	May 31, 2019							May 31, 2019	

9. Final Report	9	Jun 30, 2019								Jun 30, 2019

Table 5: Milestones and Work Packages Schedule

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APPENDIX

SUMMARY OF CHEMICAL CEMENT ALTERNATIVES PROTOCOLS

I. Safety and toxicology during storage, handling and transportation

Protocol Objective:

To ensure that toxic elements of the Chemical Cement Alternatives are safely and properly handled during transportation and storage.

Existing Protocol as used by SealWell	Protocol as recommended by DACC
- Follow Material Data Sheet directions on storage and transportation - Ensure adequate ventilation during product preparation	- Check the Material Data Sheet and identify the safety and toxicology protocol for the Chemical Cement Alternative. - When not available, follow the safety and toxicology protocol of the individual chemicals prior to and post-setting, by visiting list in section 26.8.1.3 of "An Industry Recommended Practice (IRP) for the Canadian Oil and Gas Industry, IRP 26 Wellbore Remediation" [2].

Table 6: Safety and Toxicology Protocols for Chemical Cement Alternatives

II. Leaching toxicity

Protocol Objective:

Chemical Cement Alternatives should not contaminate subsurface formations with harmful substances during deployment (curing) or through deterioration.

Existing Protocol as used by Matrix Drilling Solutions	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator
- See leachate test method Revision 1b under "Methods of Testing" of Appendix below.	- Measurement of Density During Ageing Testing in "Guidelines on Qualification of Materials for the Abandonment of Wells" [1] - Measurement of Change in Dry Mass After Ageing Testing in "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]

Table 7: Leaching Toxicity Protocols for Chemical Cement Alternatives

III. Groundwater Protection

Protocol Objective:

Chemical Cement Alternatives should not contaminate groundwater with harmful substances during deployment (curing) or through deterioration.

Existing Protocol as used by Matrix Drilling Solutions	Protocol as recommended by National Silicates
- See leachate test method – Revision 1b under "Methods	- See PSAC and CAPP database of toxicity test

of Testing" of Appendix below. -See Element Materials Technology "Water Analysis Testing" [3] for a list of constituents requiring measurement after Chemical Cement Alternative contacts groundwater in a lab setting (prior to field pilot tests)	results for mud additives for a list of constituents requiring measurement after Chemical Cement Alternative contacts groundwater in a lab setting (prior to field pilot tests)

Table 8: Groundwater Protection Protocols for Chemical Cement Alternatives

IV. Field Pilot Protocol

<u>Protocol Objective:</u>

To ensure that the Chemical Cement Alternative meets its design specifications during field tests.

Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator	Protocol as recommended by DACC
- Establish anticipated downhole conditions based on current knowledge - Function test as identified in Appendix 8 performed by Shell Global Solutions in "Guidelines of the Qualification of Materials Used in the Abandonment of Wells" [1]. See also lines 291-299 of same document. - Model placement techniques - Confirm effectiveness of placement techniques with previous yard trials - Determine the extent of material contamination during placement - Ensure that the material has appropriate properties that allow it to displace the existing fluids and form a continuous sealing medium even when contaminated - Conduct in situ testing and verification of the Chemical Cement Alternative - Model the effect of varying loads and external influences - Conduct long term monitoring - Utilize tools like acoustic transducers to determine extent of deterioration - Ensure Chemical Cement Alternative can be removed in the event that well re-entry is required - Minimize setting time (when practical) and/or maintain sufficient surface pressure when transitioning from liquid into solid to prevent escape of fluid and loss of the integrity of the Chemical Cement Alternative	- Document product operating envelope to prevent degradation as a result of future operations in the reservoir. - Consider retaining pre-mixed and blended post-set sample for future evaluation - Develop success/failure criteria for tests after placement - Consider collaborating with other organizations to share costs

Table 9: Field Pilot Protocols for Chemical Cement Alternatives

V. Bonding to casing, cement and formation

VI. Effects of products on the wellbore (i.e. corrosion, limits wellbore access, etc.)

VII. Longevity of the product in wellbore conditions with evidence supporting the expected longevity

Objectives for the three (3) Protocols above:
To ensure the integrity (and performance) of the Chemical Cement Alternatives will last over the entire abandonment life of the well.

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator
PERMEATION TESTING		
V	Nitrogen Permeability	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V	Diffusion coefficient	Not required
INTERACTION WITH FLUID		
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C
V, VI	Absorption	Not required
DIMENSIONAL STABILITY		
Expansion/Swelling		
V, VI	During hardening	API RP 10B-5 ring test
V, VI	Hardened	API RP 10B-5 ring test
Shrinkage		
V, VI	During hardening	API RP 10B-5 ring test
V, VI	Hardened	API RP 10B-5 ring test
V, VI	Differential thermal expansion	ASTM E228
V, VI, VII	creep	ASTM C512-10
MECHANICAL TESTING		
VII	Triaxial testing	Not required
VII	Cohesion	Not required
VII	Poisson's ratio	Not required
VII	Internal friction angle	Not required
VII	Hydrostatic compressive yield	Not required
VII	UCS	API RP 10B-2
VII	Tensile strength	ASTM C496
VII	Elastic modulus	ASTM C469
VII	Hardness	ASTM E384
OTHER		
V, VII	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VII	Tensile bond strength	Not required
VII	Decomposition temperature	Not required
II	Density	ASTM C 138
V, VI, VII	Stress relaxation	Not required

Table 10: Testing Protocols for Modified Cements/ ceramics (non-setting)

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator
PERMEATION TESTING		
V	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V	Diffusion coefficient	Not required
INTERACTION WITH FLUID		
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C
V, VI	Absorption	Not required
DIMENSIONAL STABILITY		
Expansion/Swelling		
V, VI	During hardening	Not required
V, VI	Hardened	Not required
Shrinkage		
V, VI	During hardening	Not required
V, VI	Hardened	Non – identified
V, VI	Differential thermal expansion	ASTM E228
V, VI, VII	creep	Not required
MECHANICAL TESTING		
VII	Triaxial testing	Not required
VII	Cohesion	Not required
VII	Poisson's ratio	Not required
VII	Internal friction angle	Not required
VII	Hydrostatic compressive yield	Not required
VII	UCS	Not required
VII	Tensile strength	Not required
VII	Elastic modulus	Not required
VII	Hardness	Not required
OTHER		
V, VII	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], recommended that substrate rugosity measurements done as per ASTM D7172
V, VII	Tensile bond strength	Not required
VII	Decomposition temperature	Not required
II	Density	Pressurized mud balance
V, VI, VII	Stress relaxation	Not required

Table 11: Testing Protocols for Grouts (non-setting)

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator	Existing Protocol as used by Matrix Drilling Solutions
PERMEATION TESTING			
V	Nitrogen Permeability	Not required	See "Cement Plug Testing: Weight vs. Pressure Testing to Assess Viability of a Wellbore Seal Between Zones" [4] (VA, USA) for perm testing
V	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of	

		Materials for the Abandonment of Wells” [1]	
INTERACTION WITH FLUID			
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	
V, VI	Absorption	Not required	
DIMENSIONAL STABILITY			
Expansion/Swelling			
V, VI	During hardening	See section 8.4.1 of “Guidelines on Qualification of Materials for the Abandonment of Wells” [1]	
V, VI	Hardened	See section 8.4.1 of [1]	
Shrinkage			
V, VI	During hardening	See section 8.4.2 of “Guidelines on Qualification of Materials for the Abandonment of Wells” [1]	
V, VI	Hardened	See section 8.4.2 of [1]	
V, VI	Differential thermal expansion	ASTM E228	
V, VI, VII	creep	ISO 899-1	
MECHANICAL TESTING			
VII	Triaxial testing	Not required	API 10 A (AB, CA)
VII	Cohesion	Not required	
VII	Poisson’s ratio	Not required	See “Cement Plug Testing: Weight vs. Pressure Testing to Assess Viability of a Wellbore Seal Between Zones” [4] (VA, USA)
VII	Internal friction angle	Not required	
VII	Hydrostatic compressive yield	Not required	
VII	UCS	API RP 10B-2	API 10 A “COSS 2018-18” [5] (AB, CA), ASTM D695 “Tensile, Flexural, and Compression Testing of Two-Part Polymer Resin” [6](GA, USA), See “The Effect of Waterborne Epoxy Resin Emulsion on the Physical Properties of Oil Well Cement” [7](China)
VII	Tensile strength	ISO 527-1	ASTM D638 “Tensile, Flexural, and Compression Testing of Two-Part Polymer Resin” [6] (GA, USA),
VII	Elastic modulus	ISO 527-1	API 10 A “COSS 2018-18” [5] (AB, CA), ASTM D638 “Tensile, Flexural, and Compression Testing of Two-Part Polymer Resin” [6] (GA, USA), See “Cement Plug Testing: Weight vs. Pressure Testing to Assess Viability of a Wellbore Seal Between Zones” [4] (VA, USA)

VII	Hardness	See section 8.4.2 of [1]	
OTHER			
VII	Flexural strength		ASTM D790 & D670, flexural strength "Tensile, Flexural, and Compression Testing of Two-Part Polymer Resin" [6] (GA, USA)
V, VII	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], recommended that substrate rugosity measurements done as per ASTM D7172	"Cement Plug Testing: Weight vs. Pressure Testing to Assess Viability of a Wellbore Seal Between Zones" [4] (VA, USA), See "The Effect of Waterborne Epoxy Resin Emulsion on the Physical Properties of Oil Well Cement" [7](China) (China)
V, VII	Tensile bond strength	Not required	
VII	Decomposition temperature	TGA/DTA/DSC measurement	
II	Density	ISO 1183-1	
V, VI, VII	Stress relaxation	Not required	

Table 12: Testing Protocols for Thermosetting polymers and composites

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator
PERMEATION TESTING		
V	Nitrogen Permeability	Not required
V	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
INTERACTION WITH FLUID		
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C
V, VI	Absorption	Not required
DIMENSIONAL STABILITY		
Expansion/Swelling		
V, VI	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VI	Hardened	See section 8.4.1 of [1]
Shrinkage		
V, VI	During hardening	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], may need to investigate thermal shock
V, VI	Hardened	See section 8.4.2 of [1]
V, VI	Differential thermal expansion	ASTM E228
V, VI, VII	creep	ISO 899-1
MECHANICAL TESTING		
VII	Triaxial testing	Not required
VII	Cohesion	Not required
VII	Poisson's ratio	Not required
VII	Internal friction angle	Not required
VII	Hydrostatic compressive yield	Not required
VII	UCS	ISO 604
VII	Tensile strength	ISO 527-1

VII	Elastic modulus	ISO 527-1
VII	Hardness	ISO 868
OTHER		
V, VII	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], recommended that substrate rugosity measurements done as per ASTM D7172
V, VII	Tensile bond strength	Not required
VII	Decomposition temperature	TGA/DTA/DSC measurement
II	Density	ISO 1183-1
V, VI, VII	Stress relaxation	Not required

Table 13: Testing Protocols for Thermoplastic polymers and composites

Subject (Applicable Protocol Number)	**Property**	**Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator**
PERMEATION TESTING		
V	Nitrogen Permeability	Not required
V	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
INTERACTION WITH FLUID		
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^0C
V, VI	Absorption	Not required
DIMENSIONAL STABILITY		
Expansion/Swelling		
V, VI	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VI	Hardened	See section 8.4.1 of [1]
Shrinkage		
V, VI	During hardening	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VI	Hardened	See section 8.4.2 of [1]
V, VI	Differential thermal expansion	ASTM E228
V, VI, VII	creep	ISO 899-1 / ASTM D395
MECHANICAL TESTING		
VII	Triaxial testing	Not required
VII	Cohesion	Not required
VII	Poisson's ratio	ISRM suggested method
VII	Internal friction angle	Not required
VII	Hydrostatic compressive yield	Not required
VII	UCS	BS EN ISO 604
VII	Tensile strength	BS EN ISO 527-1
VII	Elastic modulus	BS EN ISO 527-1
VII	Hardness	ISO 868
OTHER		
V, VII	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], recommended that substrate rugosity measurements done as per ASTM D7172
V, VII	Tensile bond strength	Not required
VII	Decomposition temperature	TGA/DTA/DSC measurement

II	Density	ISO 1183-1
V, VI, VII	Stress relaxation	ASTM D395 and NORSOK M710

Table 14: Testing Protocols for Elastomeric polymers and composites

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator
PERMEATION TESTING		
V	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V	Diffusion coefficient	Not required
INTERACTION WITH FLUID		
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C
V, VI	Absorption	Not required
DIMENSIONAL STABILITY		
Expansion/Swelling		
V, VI	During hardening	Not required
V, VI	Hardened	ISRM suggested method
Shrinkage		
V, VI	During hardening	Not required
V, VI	Hardened	ISRM suggested method
V, VI	Differential thermal expansion	ASTM E228
V, VI, VII	creep	ASTM C512-10
MECHANICAL TESTING		
VII	Triaxial testing	ISRM suggested method
VII	Cohesion	ISRM suggested method
VII	Poisson's ratio	ISRM suggested method
VII	Internal friction angle	ISRM suggested method
VII	Hydrostatic compressive yield	ISRM suggested method
VII	UCS	ISRM suggested method
VII	Tensile strength	ASTM C496
VII	Elastic modulus	ASTM C469
VII	Hardness	Not required
OTHER		
V, VII	Shear bond strength	Not required
V, VII	Tensile bond strength	Not required
VII	Decomposition temperature	Not required
II	Density	Not required
V, VI, VII	Stress relaxation	Not required

Table 15: Testing Protocols for Formation

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator	Protocol as recommended by National Silicates
PERMEATION TESTING			
V	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	
V	Diffusion coefficient	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	
INTERACTION WITH FLUID			

II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	
V, VI	Absorption	Absorption index	
DIMENSIONAL STABILITY			
Expansion/Swelling			
V, VI	During setting	Not required	
V, VI	Set	Not required	
Shrinkage			
V, VI	During setting	See Section 8.4.2 of “Guidelines on Qualification of Materials for the Abandonment of Wells”	
V, VI	Set	See Section 8.4.2 of “Guidelines on Qualification of Materials for the Abandonment of Wells”	
V, VI	Differential thermal expansion	ASTM E228	
V, VI, VII	creep	Not required	
MECHANICAL TESTING			
VII	Triaxial testing	Not required	
VII	Cohesion	Not required	
VII	Poisson’s ratio	Not required	
VII	Internal friction angle	Not required	
VII	Hydrostatic compressive yield	Not required	
VII	UCS	Not required	
VII	Tensile strength	Not required	
VII	Elastic modulus	Not required	
VII	Hardness	Not required	
OTHER			
VI	Corrosion		API Recommended Practice 13B-1.
V, VII	Shear bond strength	See Section 8.6 of “Guidelines on Qualification of Materials for the Abandonment of Wells” [1], recommended that substrate rugosity measurements done as per ASTM D7172	See “Improving Cement Bond in the Appalachian Basin With Adjustments to Preflush and Spacer Design” [8] (OH, USA), See ““The Cement-to-Formation Interface in Zonal Isolation” [9] (KL, Malaysia)
V, VII	Tensile bond strength	Not required	
VII	Decomposition temperature	TGA / DTA / DSC	See ““High-Temperature Plug Formation With Silicates” [10] (TX, USA) & “Advanced Cements for Geothermal Wells” [11]
II	Density	Not required	
V, VI, VII	Stress relaxation	Not required	

Table 16: Testing Protocols for Gels

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator
PERMEATION TESTING		
V	Nitrogen Permeability	Not required
V	Diffusion coefficient	Not required
INTERACTION WITH FLUID		

II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C
V, VI	Absorption	Not required
DIMENSIONAL STABILITY		
Expansion/Swelling		
V, VI	During hardening	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VI	Hardened	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
Shrinkage		
V, VI	During hardening	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VI	Hardened	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VI	Differential thermal expansion	ASTM E228, may need to investigate thermal shock
V, VI, VII	creep	Not required
MECHANICAL TESTING		
VII	Triaxial testing	Not required
VII	Cohesion	Not required
VII	Poisson's ratio	Not required
VII	Internal friction angle	Not required
VII	Hydrostatic compressive yield	Not required
VII	UCS	API RP 10B-2
VII	Tensile strength	Not required
VII	Elastic modulus	ASTM C469
VII	Hardness	ASTM E384
OTHER		
V, VII	Shear bond strength	See Section 9.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V, VII	Tensile bond strength	Not required
VII	Decomposition temperature	Not required
II	Density	ASTM C138
V, VI, VII	Stress relaxation	Not required

Table 17: Testing Protocols for Glass

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator	Existing Protocol as used by SealWell
PERMEATION TESTING			
V	Nitrogen Permeability	Not required	
V	Diffusion coefficient	Not required	

INTERACTION WITH FLUID			
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C	
V, VI	Absorption	Not required	
DIMENSIONAL STABILITY			
Expansion/Swelling			
V, VI	During hardening	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	
V, VI	Hardened	See Section 8.4.1 of [1]	
Shrinkage			
V, VI	During hardening	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], may need to investigate thermal shock	
V, VI	Hardened	See Section 8.4.2 of [1]	
V, VI	Differential thermal expansion	ASTM E228	See Section 4 of "Remediating sustained casing pressure by forming a downhole annular seal with low melt point eutectic metal" [12] (AB, CA)
V, VI, VII	creep	ISO 204	
MECHANICAL TESTING			
VII	Triaxial testing	ISRM suggested method	
VII	Cohesion	Not required	
VII	Poisson's ratio	ISRM suggested method (triaxial) or ASTM E1876	
VII	Internal friction angle	Not required	
VII	Hydrostatic compressive yield	ISRM suggested method	
VII	UCS	ASTM E9	
VII	Tensile strength	ISO 6892-1	
VII	Elastic modulus	ISO 3312 or ASTM E9	
VII	Hardness	ASTM E18, ASTM E10 or ASTM E384	
OTHER			
Corrosion		ISO 1516/NACE MR0175	See "CCEMC Project C110113: Permanent Sealing of GHG Emitting Wells" [13] (AB, CA)
V, VII	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], recommended that substrate rugosity measurements done as per ASTM D7172	See "Remediating sustained casing pressure by forming a downhole annular seal with low melt point eutectic metal" procedure conducted in Halliburton lab in Duncan [12] (OK, USA)
V, VII	Tensile bond strength	Not required	
VII	Decomposition temperature	TGA/DTA/DSC measurement	
II	Density	ISO 3369	
V, VI, VII	Stress relaxation	Not required	

Table 18: Testing Protocols for Metals

Subject (Applicable Protocol Number)	Property	Protocol as recommended by Shell, Conoco Phillips & Alberta Energy Regulator
PERMEATION TESTING		
V	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]
V	Diffusion coefficient	Not required
INTERACTION WITH FLUID		
II, VIII	Dry Mass	Measurement of mass after drying to constant mass at 105^0C
V, VI	Absorption	Not required
DIMENSIONAL STABILITY		
Expansion/Swelling		
V, VI	During hardening	Not required
V, VI	Hardened	ISRM suggested method
Shrinkage		
V, VI	During hardening	Not required
V, VI	Hardened	ISRM suggested method
V, VI	Differential thermal expansion	ASTM E228
V, VI, VII	creep	ASTM C512-10
MECHANICAL TESTING		
VII	Triaxial testing	ISRM suggested method
VII	Cohesion	ISRM suggested method
VII	Poisson's ratio	ISRM suggested method
VII	Internal friction angle	ISRM suggested method
VII	Hydrostatic compressive yield	ISRM suggested method
VII	UCS	ISRM suggested method
VII	Tensile strength	ASTM C496
VII	Elastic modulus	ASTM C469
VII	Hardness	Not required
OTHER		
V, VII	Shear bond strength	Not required
V, VII	Tensile bond strength	Not required
VII	Decomposition temperature	Not required
II	Density	Not required
V, VI, VII	Stress relaxation	Not required

Table 19: Testing Protocols for Modified in-situ materials

VIII. Product integrity under anticipated adverse conditions (example interaction with H2S or diesel products)

Protocol Objective:

To ensure lifetime integrity (and performance) of the Chemical Cement Alternatives in the worst downhole conditions

Stakeholder	Recommended Protocol
National Silicates	- See procedure described in Field Test Results of a New Silicate Gel System that is Effective in Carbon Dioxide Enhanced Recovery and Waterfloods" [14]
SealWell	- See comprehensive corrosion testing conducted by the University of Calgary

	in Appendix A of "CCEMC Project C110113: Permanent Sealing of GHG Emitting Wells" [13]
SNF	- See procedure described in "More Than 12 Years' Experience With a Successful Conformance-Control Polymer-Gel Technology" [15] and ""Acrylamide-Polymer/Chromium (III)-Carboxylate Gels for Near Wellbore Matrix Treatments" [16]
Shell, ConocoPhillips, AER	See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]

Table 20: Protocols for Chemical Cement Alternatives Under Adverse Conditions

IX. Field deployment verification

Protocol Objective:

To ensure that the Chemical Cement Alternative meets its design specifications during field deployment.

Stakeholder	Recommended Protocol
SealWell	- Conduct unsteady state heat transfer modelling with multiphysics program, such as COMSOL, and consult with firms such as AltaSim Technologies to execute program ""CCEMC Project C110113: Permanent Sealing of GHG Emitting Wells" [13] - See Section 6 of "CCEMC Project C110113: Permanent Sealing of GHG Emitting Wells" [13]
Shell, ConocoPhillips, AER	- Determine Displacement efficiency with relevant wellbore fluids - Evaluate and prevent slumping of plugging materials components in relevant wellbore fluids. Component size can be critical meaning tests may be required at different scales. Computer simulations may assist in understanding the behavior as long as the output is verified. - Minimize setting time (when practical) and/or maintain sufficient surface pressure when transitioning from liquid into solid to prevent escape of fluid and loss of the integrity of the Chemical Cement Alternative - Verify that the Chemical Cement Alternative has been successfully placed - Ensure Chemical Cement Alternative can be removed in the event that well re-entry is required - Account for thermal expansion differences between casing and material during setting reactions. Cracking and de-bonding may result post set if this is significant. For thermal expansion testing see ASTM E228 coefficient of thermal expansion.
DACC	- Verify that the product blend is not altered from what was tested or accepted for use - Review life expectancy of product against accepted wellbore materials such as casing cement, packers, cast iron, fiberglass, etc. - Document product operating envelope to prevent degradation as a result of future operations in the reservoir - Consider retaining pre-mixed and blended post-set sample for future evaluation - Develop success/failure criteria for testing after product placement

	- Consider collaborating with other organizations to share costs

Table 21: Protocols for Field Deployment Verification of Chemical Cement Alternatives