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

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THIS REPORT:

STANDARDS FOR THE QUALIFICATION OF CHEMICAL CEMENT ALTERNATIVES IN THE PROVINCE OF ALBERTA

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SEP 6th, 2019

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1.0 EXECUTIVE SUMMARY

This Standard was developed by Petroleum Technology Alliance Canada (PTAC) and reviewed by the Alberta Energy Regulator (AER). The AER reserves the right to give final approval for the use of any Chemical Cement Alternative in wellbore remediation operations in the Province of Alberta, thus all applications must be submitted to them. PTAC will propose adoption of this Standard to the AER.

This Standard addresses the protocols for testing the properties and their acceptance thresholds of the following Chemical Cement Alternatives prior to use in wellbore remediation applications in the Province of Alberta.

Table 1: Chemical Cement Alternatives [1]

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

The Chemical Cement Alternative testing protocols addressed are:

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

Upon evaluation of various procedures per protocol as practiced in other parts of the global industry, selection of procedures per protocol for the Province of Alberta were based on:

a) Identifying and mitigating potential handling, transportation, in-situ deployment and environmental risks that may be associated with the Chemical Cement Alternative.
b) Following the logical steps in determining the key properties and characterization of the Chemical Cement Alternatives.

The critical properties (parameters) of the Alternatives identified in Table 1 above are listed in Appendix I. The values for use in accepting or rejecting Chemical Cement Alternatives is benchmarked against the current property values for Portland Class G cement for the following reasons:

1) The AER has established Portland Class G cement as the primary abandonment isolation product. Like Portland cement, all the Chemical Cement Alternatives, with the exception of gels and grouts, produce a solid phase end product.
2) Therefore, it is only reasonable to use property values of this product as the benchmark for Chemical Cement Alternatives in order to not subject the Alternatives to a higher or lower standard than currently accepted.
3) Although gels and grouts do not produce a solid phase end product with a substantial mechanical strength, for some of its properties (like permeability, fluid interaction, dimensional stability) the values of Portland class G cement are good benchmarks.
4) Since gels and grouts do not possess sufficient mechanical strength, for some of its properties (like creep, unconfined compressive strength, hardness and tensile strength, etc.) the values of Portland class G cement are not good benchmarks. However, it is industry practice not to test for these properties in gels and grouts.

The procedure for qualifying laboratories for testing the properties of Chemical Cement Alternatives is presented in this Standard. Also included is the format for reporting the laboratories' Test Results.

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2.0 PROTOCOLS, APPLICABLE PROCEDURES AND ACCEPTABLE VALUES

This document outlines the standard procedures and tests for each Protocol.

Protocol I: **Bonding of products to casing, cement and formation**
Protocol II: **Effects of products on the wellbore (i.e. corrosion, limits wellbore access, etc.)**
Protocol III: **Longevity of the product in wellbore conditions**
Protocol IV: **Product integrity under anticipated adverse conditions**

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.

Protocols 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 1):

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 from the wellbore if re-entry is required
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 [2], 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.

Table 2: Example Novelty Categorization [2]

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

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 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 [2], for a detailed breakdown of each step

Note: Medium and high risk failure modes are considered critical. Table 3 in Appendix I is a list of Critical Properties (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.

4) Develop Chemical Cement Alternative Qualification Plan

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

1. Analyze and select detailed qualification methods (refer to Appendix II Table 5 – Table 14 for a list of Experimental Work Plans and Protocols V-VIII of this standard)
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 [2], for a detailed breakdown of each step
5. Low risk failure modes may be concluded based on qualitative assessments by qualified personnel.

Note: The Qualification Plan must include a function test and a program for ageing testing. For a function test setup see the first topic in Appendix II-A. A function test should begin with a small scale setup that serves as a screening process prior to more expensive larger scale experiments. In general, testing in smaller diameter tubes gives better results than testing in larger diameter tubes [7]. If an Alternative fails a leak test at the smaller scale, there is no need to test at a large scale. 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 Properties (Parameters). See Section 9.3, Parameter Effects and Models [2].

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 II Table 5 – Table 14 and Protocols V-VIII of this standard 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 [2], 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 property (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 [2], for a detailed breakdown of each step

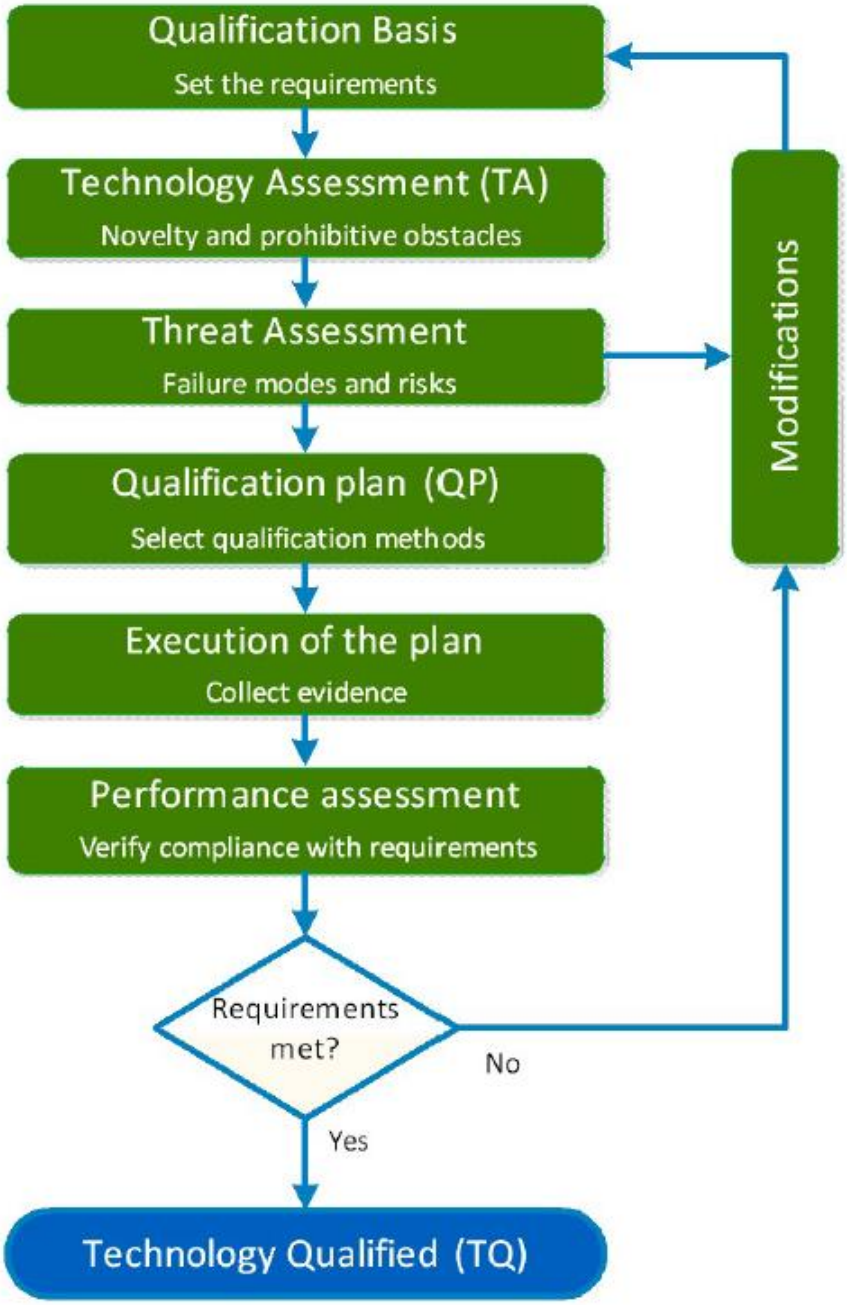

Figure 1: Qualification Process for Chemical Cement Alternative [2]

Acceptance Values

See details in Appendix II.

Protocol V: Leaching toxicity
Protocol VI: 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.

Protocols Procedure:

1) Determine the wellbore depths where the product will be placed and identify any possible exposure pathways to a receptor of the Alternative.
    a. If all proposed uses are below the base of groundwater protection or are in formations where the aquifers are saline or it's not reasonable to expect it would encounter a water body channel or well, the Chemical Cement Alternative may be approved as long as there is an understanding of:
        i. Potential wellbore integrity risks associated with the Alternative
    b. If proposed use(s) are above the base of groundwater protection or are in formations where the aquifers are non-saline or it's reasonable to expect it would encounter a water body channel or well, proceed to Step 2 below

2) Conduct a literature review of the Alternative, evaluate its composition and determine its toxicity.
    a. If the bulk material is not of concern and trace materials present are either not of concern or are present at levels that clearly won't be an issue, the Chemical Cement Alternative may be approved as long as there is an understanding of:
        i. The maximum volume of product that can be used before toxicity exceeds Acceptance Values (below) or substance-specific guidelines derived for the purpose of this test (i.e. 1.0 m^3 versus 100 m^3 pumped)
        ii. Potential wellbore integrity risks associated with the Alternative
    b. If the bulk material is of concern or there is a trace component that's of sufficiently high toxicity based on professional judgement, leachability testing on the plug is required. Proceed to Step 3 below.

3) Conduct AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives on a freshly prepared plug sample of the Chemical Cement Alternative under conditions that approximate use (i.e. performed in pHs that cover the range of groundwater expected). The test must also capture any phase transitions the Alternative is expected to undergo when deployed and set in a well.
    a. If bulk materials or a trace component were of concern but aren't leaching anything of concern into groundwater, the Chemical Cement Alternative may be approved as long as there is an understanding of:
        i. The maximum volume of product that can be used before toxicity exceeds Acceptance Values or substance-specific guidelines derived for the purpose of this test (i.e. 1.0 m^3 versus 100 m^3 pumped)
        ii. Potential wellbore integrity risks associated with the Alternative
    b. If bulk materials contain contaminants of concern in the leachate. Proceed to Step 4 below.

4) Determine if any contaminants of concern in the leachate are above Acceptance Values or substance-specific guidelines derived for the purpose of this test (as per the literature review work from step 2 and Acceptance Values below)
    a. If contaminants of concern are below guidelines for all potential receptors in any realistic scenarios, the Chemical Cement Alternative may be approved as long as there is an understanding of

i. The maximum volume of product that can be used before toxicity exceeds acceptance Values or substance-specific guidelines derived for the purpose of this test (i.e. 1.0 m3 versus 100 m3 pumped)
ii. Potential wellbore integrity risks associated with the Alternative

b. If contaminants of concern are above guidelines in any realistic scenarios for one or any number of potential receptors, evaluate the Alternative for realistic exposure scenarios. Proceed to Step 5 below.

5) Determine if the contaminant is reasonably expected to dilute below the Acceptance Values or substance-specific guidelines derived for the purpose of this test for all receptors under certain generic scenarios (distances to receptors, minimum aquifer thickness, etc.). Evaluate this for each scenario.
   a. If there are no further concerns with use under certain scenarios, the Chemical Cement Alternative may be approved as long as it is restricted to those scenarios and there is an understanding of:
      i. The maximum volume of product that can be used before toxicity exceeds Acceptance Values or substance-specific guidelines derived for the purpose of this test (i.e. 1.0 m3 versus 100 m3 pumped)
      ii. Potential wellbore integrity risks associated with the Alternative
   b. If there are further concerns with use under certain scenarios, allow use only with a site-specific assessment or restrict all shallow uses.

Acceptance Values

For Step 4 in the procedure above, refer to the lowest guideline in Tier 1 Table B-2. Groundwater Remediation Guideline Values for Agricultural Land - All Water Uses found in Appendix II. Theses are risk-based guidelines developed by the Province of Alberta for the management of contaminated sites. The above guidelines were calculated by determining the safe exposure limit (dose or concentration) to a receptor. Following this, for each exposure pathway, a conservative estimate was made of a concentration of the substance in soil or groundwater that will protect the receptor from exposure exceeding the safe amount.

If a contaminant is not found in the Tier 1 Guidelines, refer to the Tier 2 Guidelines and if not found therein, refer to the *Guidance for Selecting Toxicity Reference Values for Alberta Tier 1 and Tier 2 Soil and Groundwater Remediation Guidelines.* This document gives guidance for selecting acceptable risk-based Toxicological Reference Values (TRVs) for managing contaminated sites in Alberta. It was developed with the Scientific Working Group on Contaminated Sites in Alberta (SWGCSA), which includes Alberta Environment and Parks (AEP), the Alberta Energy Regulator (AER), Alberta Health (AH) and Alberta Health Services (AHS) [3] . To maintain alignment with the Alberta Province's toxicology assessment practices, this document is recommended as a supplementary guideline for acceptance values for the concentration of contaminants in Chemical Cement Alternatives where the Tier 1 and Tier 2 guidelines are insufficient.

Protocol VII: 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.

Protocol Procedure:
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 "Sources of Toxicological Information for Assessing Chemicals" in "An Industry Recommended Practice (IRP) for the Canadian Oil and Gas Industry, IRP 26 Wellbore Remediation" [4].
4) Ensure adequate ventilation during product preparation

Acceptance Values

No empirical values are required for this protocol.

Protocol VIII: Field Pilot

Protocol Objectives:

To ensure that the Chemical Cement Alternative meets its design specifications (Protocols I-VI) during field tests

Protocol Procedure:

1) Establish anticipated downhole conditions based on current knowledge
2) Model the effect of varying loads and external influences
3) Model placement techniques
4) Develop success/failure criteria for tests after placement
5) Confirm effectiveness of placement techniques and the extent of material contamination with yard trials. Ensure that the material has appropriate properties that allow it to displace the existing fluids and form a continuous sealing medium even when contaminated
6) Conduct function tests in the laboratory (see first topic in Appendix II-A)
7) Ensure Chemical Cement Alternative can be removed in the event that well re-entry is required
8) Deploy Alternative in pilot wellbore
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) Verify that the Chemical Cement Alternative has been successfully placed using AER approved methods
11) Retain pre-mixed and blended post-set sample for future evaluation
12) Conduct in situ pressure testing and verification of the Chemical Cement Alternative
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

Acceptance Values

The acceptance value for Procedure-6 is that the ***calculated permeability must be ≤10 microdarcy at a stabilized flow rate.*** See Appendix II-A for the justification of this criterion.

Apart from the Procedure-6 above, there are no Acceptance values for the other fourteen (14) Procedures listed above. Those fourteen procedures are based on prevailing industry best practices.

DOCUMENTATION REQUIRED FOR PROTOCOLS I 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 [2], for a detailed breakdown of each item

Protocol IX: Field Deployment Verification

Protocol Objective:

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

Protocol Procedure:

1) Determine Displacement efficiency of Chemical Cement Alternative with relevant wellbore fluids
2) Review life expectancy of Chemical Cement Alternative
3) Verify that the product blend is not altered from what was tested or accepted for use
4) Prevent slumping of Chemical Cement Alternative using AER approved methods
5) Deploy Chemical Cement Alternative in wellbore
6) 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
7) Verify that the Chemical Cement Alternative has been successfully placed using AER approved methods
8) Ensure Chemical Cement Alternative can be removed in the event that well re-entry is required
9) Document product operating envelope to prevent degradation as a result of future operations in the reservoir
10) Retain pre-mixed and blended post-set sample for future evaluation

Acceptance Values

There are no acceptance criteria listed for these ten (10) Procedures listed above. These procedures are prevailing industry best practices.

3.0 CRITERIA FOR QUALIFYING LABORATORIES IN ALBERTA

3.1 Laboratories Qualification Procedure

Objective

To provide standard criteria for approving laboratories for testing of Chemical Cement Alternative in Alberta.

Acceptance Criteria

Following a review of current industry practice, ISO 9001:2015 and ISO 17025:2005, the following criteria are the basis for qualifying a laboratory to meet the above stated objective.

1) The laboratory is not owned, promoted or is an affiliate with a specific type of Chemical Cement Alternative or Oil Well Cement manufacturer or seller.
2) A valid Provincially or Federally Certified Safety Management System
3) Permit to Practice Engineering or Geoscience from the Association of Professional Engineers and Geoscientists of Alberta (APEGA) or the Association of Science and Engineering Technology Professionals of Alberta (ASET)
4) ISO 9001:2015 Quality Management Systems -- Requirements
5) The process for conducting each Standard Test procedure from Appendix III-A to III-J within the laboratory's capability
6) List of equipment and facilities provided by the laboratories for conducting the testing procedures listed in Appendix III-A to III-J
7) Equipment Calibration Program in accordance with Equipment Manufacturer Specifications or Provincial Requirements of Alberta
8) Ability to develop non-standardised testing procedures if required
9) List of personnel capable of executing the procedures and operating the equipment
10) Certification validating personnel as being able to operate the equipment pertaining to each procedure

Inspection Team

1) The Inspection Team for visiting a laboratory in Alberta to qualify it for Chemical Cement Alternative protocol testing shall comprise of a Lead Inspector with a minimum of one other Inspector.
2) The Lead Inspector shall have a minimum of fifteen (15) years cementing experience from a combination of wellsite, office-based well engineering roles, laboratories and/or cement manufacturing plants. While the accompanying Inspector can have a lower years of experience.

Approval Certificate

1) To be issued to a laboratory.
2) Certificate to state the Test Procedures they have the capability to satisfactorily handle.
3) Details of the Test Procedures approved for the laboratory shall be outlined in a letter accompanying the Approval Certificate.
4) An Approval Certificate shall be valid for 36 months only from date of issue.

Validation of Proposed Alternative Testing Procedures

As part of the evaluation of each laboratory, alternate test procedures proposed by the laboratory to any Standard Test Procedure in Appendix III-A to III-J should be reviewed and approved according to the following criteria

1. The alternative test procedure follows the same methodology and principles as the Standard Test Procedures
2. The alternative test procedure produces similar results as the Standard Test Procedures

Note: For records purposes, when approving alternative procedures from laboratories, the laboratory applicant should document the differences between the alternative procedure and the Standard Test Procedures for the following:

a) Sample preparation,

b) Test procedures,
c) Rate of loading,
d) Percentage accuracy of specified load maintained,
e) Method used in the calculation of the property,
f) Test conditions,
g) Precision requirements and
h) The units of results
i) Any other information as will be required by the Inspection Team.

3.2 Approved Laboratories

Following the evaluation of laboratories in Alberta, in May 2019, the following laboratories:

a) Innotech Calgary,
b) Innotech Edmonton and
c) AGAT Laboratories Calgary,

are adjudged as qualified in the Province of Alberta to conduct the testing of Chemical Cement Alternatives properties subject to the conditions in the document titled “RECOMMENDED LABORATORIES IN ALBERTA FOR THE QUALIFICATION TESTING OF CHEMICAL CEMENT ALTERNATIVES AS AT MAY 2019, REVISION 01”.

3.3 Test Result Reporting Format

The format the approved laboratories will use in reporting the test results of each critical property (parameter) is as outlined in Appendix IV: Format for Test Reporting.

4.0 REFERENCES

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APPENDICES

APPENDIX I: CRITICAL PROPERTIES (PARAMETERS)

The critical properties (parameters) of the Alternatives previously identified are listed in Table 3 below.

Table 3: Critical Properties (Parameters) of Chemical Cement Alternatives and Their Relevance [1]

Critical Parameters (Applicable Protocol Number)	Definition	Units	Importance of the Property to the Chemical Cement Alternative Testing
Permeability (I)	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 (I)	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 (I, II)	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 (II, III, IV)	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 (I, II)	Change in volume	strain or % by vol.	Variable required to calculate stresses from expansion or shrinkage
Modulus of elasticity (III)	Uniaxial stress over uniaxial strain.	Pressure	Variable required to determined degree of deformation under a given pressure, and under temperature change
Poisson's ratio (III)	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 (III)	Describes a granular material's cementation strength between grains under shear stress.	Pressure	Variable required to determine shear failure
Internal friction angle (III)	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 (III)	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 (III)	Threshold at which failure occurs under a tensile load	Pressure	Describes maximum tensile stress
Unconfined compressive strength (III)	Threshold at which failure occurs under axial compressive stress	Pressure	Maximum compressive stress that a Chemical Cement Alternative can withstand
Hardness (III)	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 (I, III)	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 (I, III)	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 (III)	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 (III)	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 (V)	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

APPENDIX II: ACCEPANTANCE CRITERIA TABLES

Acceptance Values

Table 4: Alberta Tier 1 Table B-2. Groundwater Remediation Guideline Values for Agricultural Land - All Water Uses [5]

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
General and Inorganic Parameters													
pH	6.5-8.5	6.5-8.5	6.5-8.5	-	-	-	-	6.5-9	6.5-9	-	-	-	-
Ammonia	see note d	see note d	-	-	-	-	-	see note d	see note d	-	-	-	-
Bromate	0.01	0.01	0.01	-	-	-	-	-	-	-	-	-	-
Chloride	100	100	250	-	-	-	-	120	120	100	-	-	-
Cyanide (free)	0.005	0.005	0.2	-	-	-	-	0.005	0.005	-	-	-	-
Electrical Conductivity (dS/m)	1	1								1			
Fluoride	1	1	1.5	-	-	-	-	-	-	1	1	-	-
Nitrate (as nitrogen)	3	3	10	-	-	-	-	3	3	-	-	-	-
Nitrate + Nitrite (as nitrogen)	100	100	-	-	-	-	-	-	-	-	100	-	-
Nitrite (as nitrogen)	see note e	see note e	1.0	-	-	-	-	see note d	see note d	-	10	-	-
Sodium	200	200	200	-	-	-	-	-	-	-	-	-	-
Sodium Adsorption Ratio	5	5								5			
Sulphate	see note e	see note e	500	-	-	-	-	see note d	see note d	-	1000	-	-
Sulphide – Total (as S)[f]	0.0019	0.0019	0.05	-	-	-	-	0.0019	0.0019	-	-	-	-
Total Dissolved Solids (TDS)	500	500	500	-	-	-	-	-	-	-	3000	-	-
Metals													
Aluminum	see note e	see note e	-	-	-	-	-	see note d	see note d	5	5	-	-
Antimony	0.006	0.006	0.006	-	-	-	-	-	-	-	-	-	-
Arsenic	0.005	0.005	0.01	-	-	-	-	0.005	0.005	0.16	0.025	-	-
Barium	1	1	1	-	-	-	-	-	-	-	-	-	-
Boron	1.0	1.0	5	-	-	-	-	1.5	1.5	1.0	5	-	-
Cadmium	see note e	see note e	0.005	-	-	-	-	see note d	see note d	0.0082	0.08	-	-
Chromium (trivalent)	0.0049	0.0049	-	-	-	-	-	0.0089	0.0089	0.0049	0.05	-	-
Chromium (hexavalent)	0.001	0.001	-	-	-	-	-	0.001	0.001	0.008	0.05	-	-
Chromium (total)	0.05	0.05	0.05	-	-	-	-	-	-	-	-	-	-
Copper	0.007	0.007	1	-	-	-	-	0.007	0.007	0.2	0.5	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Iron	0.3	0.3	0.3	-	-	-	-	0.3	0.3	5	-	-	-
Lead	see note e	see note e	0.01	-	-	-	-	see note d	see note d	0.2	0.1	-	-
Manganese	0.05	0.05	0.05	-	-	-	-	-	-	0.2	-	-	-
Mercury (total)	0.000005	0.000005	0.001	-	-	-	-	0.000005	0.000005	-	0.003	-	-
Nickel	see note e	see note e	-	-	-	-	-	see note d	see note d	0.2	1	-	-
Selenium	0.002	0.002	0.05	-	-	-	-	0.002	0.002	0.02	0.05	-	-
Silver	0.0001	0.0001	-	-	-	-	-	0.0001	0.0001	0.02	0.05	-	-
Uranium	0.01	0.01	0.02	-	-	-	-	0.015	0.015	0.01	0.2	-	-
Zinc	0.03	0.03	5	-	-	-	-	0.03	0.03	1	50	-	-
Hydrocarbons													
Benzene	0.005	0.005	0.005	2.8	0.14	100	61	3.6	0.074	-	0.088	6.8	0.14
Toluene	0.024	0.021	0.024	NGR	74	82	59	12,000	0.021	-	4.9	NGR	180
Ethylbenzene	0.0016	0.0016	0.0016	NGR	16	42	20	NGR	41	-	3.2	NGR	NGR
Xylenes	0.02	0.02	0.02	80	3.9	21	31	NGR	2.9	-	13	NGR	NGR
Styrene	0.072	0.072	2.8	90	4.3	-	-	0.072	0.072	-	-	-	-
F1	2.2	0.81	2.2	19	0.81	6.5	7.1	NGR	9.8	-	53	NGR	NGR
F2	1.1	1.1	1.1	NGR	1.5	1.8	1.8	NGR	1.3	-	NGR	NGR	NGR
Acenaphthene	0.0060	0.0058	1.4	NGR	NGR	-	-	0.0060	0.0058	-	NGR	NGR	NGR
Anthracene	0.0034	0.000012	NGR	NGR	NGR	0.025	0.025	0.0034	0.000012	-	NGR	NGR	NGR
Fluoranthene	0.24	0.000057	NGR	NGR	NGR	0.24	0.24	NGR	0.000057	-	NGR	NGR	NGR
Fluorene	0.0042	0.003	0.94	NGR	NGR	-	-	0.0042	0.003	-	NGR	NGR	NGR
Naphthalene	0.001	0.001	0.47	14	0.6	-	-	0.001	0.001	-	NGR	NGR	NGR
Phenanthrene	0.00086	0.0004	-	-	-	-	-	0.00086	0.0004	-	NGR	NGR	NGR
Pyrene	0.71	0.000092	0.71	NGR	NGR	-	-	NGR	0.000092	-	NGR	NGR	NGR
Carcinogenic PAHs (as B(a)P TPE) [a]	0.00004	0.00004	0.00004	-	-	-	-	-	-	-	-	-	-
Benz[a]anthracene	-	-	-	-	-	-	-	NGR	NGR	-	NGR	NGR	NGR

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Benzo[b+j]fluoranthene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Benzo[k]fluoranthene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Benzo[g,h,i]perylene	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[a]pyrene [b]	0.0018	0.0018	-	-	-	0.0018	0.0018	NGR	NGR	-	NGR	NGR	NGR
Chrysene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Dibenz[a,h]anthracene	-	-	-	-	-	-	-	-	-	-	NGR	NGR	NGR
Indeno[1,2,3-c,d]pyrene	-	-	-	-	-	-	-	-	-	-	-	-	-
Halogenated Aliphatics													
Vinyl chloride	0.002	0.0011	0.002	0.018	0.0011	-	-	-	-	-	-	-	-
1,1-Dichloroethene	0.014	0.014	0.014	0.68	0.039	-	-	-	-	-	-	-	-
Trichloroethene (Trichloroethylene, TCE)	0.005	0.005	0.005	0.41	0.02	4.4	5	0.27	0.029	-	0.05	-	-
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0.010	0.010	0.010	0.25	0.012	-	-	0.11	0.11	-	-	-	-
1,2-Dichloroethane	0.005	0.005	0.005	0.17	0.01	-	-	0.1	0.1	-	0.005	-	-
Dichloromethane (Methylene chloride)	0.05	0.05	0.05	61	3.4	-	-	0.098	0.098	-	0.05	-	-
Trichloromethane (Chloroform) [i]	0.08	0.018	0.08	0.53	0.030	-	-	0.10	0.018	-	0.1	-	-
Tetrachloromethane (Carbon tetrachloride)	0.002	0.00057	0.002	0.012	0.00057	-	-	0.013	0.013	-	0.005	-	-
Dibromochloromethane	0.1	0.1	0.19	26	1.1	-	-	-	-	-	0.1	-	-
Chlorinated Aromatics													
Chlorobenzene	0.0013	0.0013	0.03	0.3	0.014	-	-	0.0013	0.0013	-	-	-	-
1,2-Dichlorobenzene	0.0007	0.0007	0.003	116	5.4	-	-	0.0007	0.0007	-	-	-	-
1,4-Dichlorobenzene	0.001	0.001	0.001	4.6	0.22	-	-	0.026	0.026	-	-	-	-
1,2,3-Trichlorobenzene	0.008	0.008	0.014	0.8	0.032	-	-	0.008	0.008	-	-	-	-
1,2,4-Trichlorobenzene	0.015	0.015	0.015	0.71	0.028	-	-	0.024	0.024	-	-	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1,3,5-Trichlorobenzene	0.014	0.014	0.014	0.38	0.015	-	-	-	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	0.0018	0.0018	0.032	NGR	0.14	-	-	0.0018	0.0018	-	-	-	-
1,2,3,5-Tetrachlorobenzene	0.0038	0.0038	0.0038	0.41	0.017	-	-	-	-	-	-	-	-
1,2,4,5-Tetrachlorobenzene	0.002	0.002	0.002	0.21	0.0088	-	-	-	-	-	-	-	-
Pentachlorobenzene	0.0094	0.0069	0.0094	NGR	0.038	-	-	NGR	0.0069	-	-	-	-
Hexachlorobenzene	0.00052	0.00052	0.00057	0.029	0.0012	-	-	-	-	-	0.00052	-	-
2,4-Dichlorophenol	0.0002	0.0002	0.0003	NGR	1500	-	-	0.0002	0.0002	-	-	-	-
2,4,6-Trichlorophenol	0.002	0.002	0.002	NGR	54	-	-	0.018	0.018	-	-	-	-
2,3,4,6-Tetrachlorophenol	0.001	0.001	0.001	NGR	NGR	-	-	0.001	0.001	-	-	-	-
Pentachlorophenol	0.00051	0.0005	0.03	NGR	NGR	0.87	0.88	0.00051	0.0005	-	-	-	-
Dioxins & Furans [c]	0.00000012	0.00000012	1.2E-07	-	-	-	-	-	-	-	-	-	-
PCBs	0.0094	0.0094	0.0094	-	-	-	-	-	-	-	-	-	-
Pesticides													
Aldicarb	0.001	0.001	0.009	-	-	-	-	0.001	0.001	0.073	0.011	-	-
Aldrin	0.0007	0.0007	0.0007	-	-	-	-	-	-	-	-	-	-
Atrazine and metabolites	0.0018	0.0018	0.005	-	-	-	-	0.0018	0.0018	0.01	0.005	-	-
Azniphos-methyl (Guthion)	0.00001	0.00001	0.02	-	-	-	-	0.00001	0.00001	-	-	-	-
Bendiocarb	0.04	0.04	0.04	-	-	-	-	-	-	-	-	-	-
Bromacil [g]	0.0002	0.0002	0.95	-	-	0.44	0.30	0.005	0.005	0.0002	1.1	-	-
Bromoxynil	0.00044	0.00044	0.005	-	-	-	-	0.005	0.005	0.00044	0.011	-	-
Carbaryl	0.0002	0.0002	0.09	-	-	-	-	0.0002	0.0002	-	1.1	-	-
Carbofuran	0.0018	0.0018	0.09	-	-	-	-	0.0018	0.0018	-	0.045	-	-
Chlorothalonil	0.00018	0.00018	0.14	-	-	-	-	0.00018	0.00018	0.0093	0.17	-	-
Chlorpyrifos	0.0000046	0.000002	0.09	-	-	-	-	0.0000046	0.000002	-	0.024	-	-
Cyanazine	0.0005	0.0005	0.01	-	-	-	-	0.002	0.002	0.0005	0.01	-	-
2,4-D	0.004	0.004	0.1	-	-	-	-	0.004	0.004	-	0.1	-	-
DDT	0.093	0.093	0.093	-	-	-	-	-	-	-	0.1	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Diazinon	0.00017	0.00017	0.02	-	-	-	-	0.00017	0.00017	-	-	-	-
Dicamba	0.000008	0.000008	0.12	-	-	-	-	0.01	0.01	0.000008	0.12	-	-
Diclofop-methyl	0.00024	0.00024	0.009	-	-	-	-	0.56	0.0061	0.00024	0.009	-	-
Dieldrin	0.0007	0.0007	0.0007	-	-	-	-	-	-	-	-	-	-
Dimethoate	0.003	0.003	0.02	-	-	-	-	0.0062	0.0062	-	0.003	-	-
Dinoseb	0.000055	0.00005	0.01	-	-	-	-	0.000055	0.00005	0.021	0.15	-	-
Diquat	0.07	0.07	0.07	-	-	-	-	-	-	-	-	-	-
Diuron	0.15	0.15	0.15	-	-	-	-	-	-	-	-	-	-
Endosulfan	0.0019	0.0000031	0.057	-	-	-	-	0.0019	0.0000031	-	-	-	-
Endrin	0.0028	0.0028	0.0028	-	-	-	-	-	-	-	-	-	-
Glyphosate	0.065	0.065	0.28	-	-	-	-	0.065	0.065	-	0.28	-	-
Heptachlor epoxide	0.000052	0.000052	0.000052	0.0043	0.00024	-	-	-	-	-	-	-	-
Lindane	0.00001	0.00001	0.0028	-	-	-	-	0.00001	0.00001	-	0.004	-	-
Linuron	0.00011	0.00011	0.019	-	-	-	-	0.007	0.007	0.00011	-	-	-
Malathion	0.0001	0.0001	0.19	-	-	-	-	0.0001	0.0001	-	-	-	-
MCPA	0.00004	0.00004	0.1	-	-	-	-	0.0026	0.0026	0.00004	0.025	-	-
Methoxychlor	0.9	0.00017	0.9	-	-	-	-	NGR	0.00017	-	-	-	-
Metolachlor	0.0078	0.0078	0.05	-	-	-	-	0.0078	0.0078	0.028	0.05	-	-
Metribuzin	0.0005	0.0005	0.08	-	-	-	-	0.001	0.001	0.0005	0.08	-	-
Paraquat (as dichloride)	0.01	0.01	0.01	-	-	-	-	-	-	-	-	-	-
Parathion	0.000013	0.000013	0.05	-	-	-	-	0.000013	0.000013	-	-	-	-
Phorate	0.002	0.002	0.002	-	-	-	-	-	-	-	-	-	-
Picloram	0.029	0.029	0.19	-	-	-	-	0.029	0.029	-	0.19	-	-
Simazine	0.0005	0.0005	0.01	-	-	-	-	0.01	0.01	0.0005	0.01	-	-
Tebuthiuron [h]	0.00043	0.00043	0.66	-	-	0.20	0.25	0.0016	0.0016	0.00043	0.13	-	-
Terbufos	0.001	0.001	0.001	-	-	-	-	-	-	-	-	-	-
Toxaphene	0.00043	0.00043	0.00043	6.4	0.31	-	-	-	-	-	-	-	-

Water Use	Lowest Guideline		Potable	Inhalation		Eco Soil Contact		Aquatic Life		Irrigation	Livestock	Wildlife Watering	
Soil Type	Fine	Coarse	All	Fine	Coarse	Fine	Coarse	Fine	Coarse	All	All	Fine	Coarse
Unit	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Triallate	0.00024	0.00024	0.12	-	-	-	-	0.00024	0.00024	-	0.23	-	-
Trifluralin	0.0012	0.0002	0.045	-	-	-	-	0.0012	0.0002	-	0.045	-	-
Other Organics													
Aniline	0.0022	0.0022	0.066	1,900	87	-	-	0.0022	0.0022	-	-	-	-
Dibutyl phthalate	0.019	0.019	0.59	NGR	NGR	-	-	0.019	0.019	-	-	-	-
Dichlorobenzidine	0.007	0.007	0.007	NGR	NGR	-	-	-	-	-	-	-	-
Diethanolamine	0.06	0.06	0.06	-	-	-	-	65,000	5.0	-	-	-	-
Diethylene glycol	6.0	6.0	6.0	-	-	-	-	4,000	200	-	-	-	-
Diisopropanolamine	1.6	1.6	3.6	-	-	160	160	1.6	1.6	3.2	-	-	-
Ethylene glycol	31	31	31	NGR	NGR	9,200	16,000	190	190	-	-	-	-
Hexachlorobutadiene	0.0013	0.0013	0.006	0.031	0.0013	-	-	0.0013	0.0013	-	-	-	-
Methanol	19	19	19	270,000	19,000	-	-	630	32	-	-	-	-
Methylmethacrylate	0.47	0.47	0.47	17	0.84	-	-	-	-	-	-	-	-
Monoethanolamine	0.6	0.6	0.6	-	-	-	-	30,000	1.0	-	-	-	-
MTBE	0.015	0.015	0.015	6.1	0.34	-	-	10	10	-	-	-	-
Nitrilotriacetic acid	0.4	0.4	0.4	-	-	-	-	-	-	-	-	-	-
Nonylphenol + ethoxylates	0.0081	0.0081	-	-	-	0.0081	0.0081	NGR	0.61	-	-	-	-
Phenol	0.002	0.002	0.57	73,000	3,700	110	150	0.004	0.004	-	0.002	-	-
Sulfolane	0.09	0.09	0.09	-	-	1,700	2,800	50	50	0.8	-	-	-
Triethylene glycol	60	60	60	-	-	-	-	25,000	550	-	-	-	-
Trihalomethanes - total (THMs)	0.1	0.1	0.1	-	-	-	-	-	-	-	-	-	-

Notes:

a. B[a]P TPE (Total Potency Equivalents) are calculated by multiplying the groundwater concentration of individual carcinogenic PAHs by a standardized Benzo[a]pyrene Potency Equivalence Factor (PEF) to produce a Benzo[a]pyrene relative potency concentration, and by subsequently summing the relative potency concentrations for the entire PAH mixture. B[a]P PEFs are order of magnitude estimates of carcinogenic potential and are based on the World Health Organization (1999) scheme, as follow:

Carcinogenic PAH Compound	PEF
Benz[a]anthracene	0.1
Benzo(b+j)fluoranthene	0.1
Benzo[k]fluoranthene	0.1
Benzo[ghi]perylene	0.01
Benzo[a]pyrene	1
Chrysene	0.01
Dibenz[a,h]anthracene	1
Indeno[1,2,3-c,d]pyrene	0.1

b. For ecological receptors only.

c. Expressed as toxic equivalents (TEQs) based on 2,3,7,8-PCDD (See CCME, 1999 and updates)

d. See Environmental Quality Guidelines for Alberta Surface Waters (ESRD, 2014) for further guidance on aquatic life pathway.

e. Tier 1 guideline = lowest of aquatic life guideline and all other guidelines.

f. As S, but can be applied to undissociated H_2S if concerns arise.

g. Eco-contact guidelines from Stantec (2012)

h. Eco-contact guidelines from Stantec (2008)

i. Guideline for protection of aquatic life (fine soil) is set at the maximum concentration of trichloromethane that will support biological degradation (MEMS, 2016).

NGR - no guideline required, calculated value > solubility or >1,000,000 mg/L

Potable GW = protection of groundwater for potable drinking water

Inhalation = protection of volatilization from groundwater and migration into indoor air

Eco Soil Contact = protection of terrestrial plants and soil invertebrates in areas with shallow groundwater

Aquatic Life = protection of groundwater discharging to a surface water body hosting aquatic life

Irrigation = protection of a potential irrigation groundwater source

Livestock Watering = protection of a potential livestock watering groundwater resource

Wildlife Watering = protection of groundwater discharging to a surface water body from which wildlife may drink

These tables below identify various testing procedures (or experimental work plans) for the qualification of the various types of Chemical Cement Alternatives based on their most likely failure modes [1]. This is not an exhaustive list for each type of Chemical Cement Alternative and more tests may be required to address other failure modes. Recommended Tests (NS, RT) do not have a standard value as they are not considered critical but informative [1]. Class G cement properties are primarily available through literature. However, after ageing, these properties will need to be determined using the standardized test procedures listed in the tables below where applicable. In some instances, like that of thermoplastics or gels, alternate test procedures will be required for Class G cement. These must be industry recognized standardized testing procedures for Class G cements and documented as part of the Test Reports for each type of Alternative.

Table 5: Acceptance Criteria for the Testing Procedures of Modified Cements/ceramics (non-setting)

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	Not Required	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	API RP 10B-5 ring test	≤ Class G cement linear expansion percentage under same conditions	Not Required
I, II	Hardened	API RP 10B-5 ring test	Not Required	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	API RP 10B-5 ring test	≤ 1.0% bulk shrinkage	Not Required
I, II	Hardened	API RP 10B-5 ring test	Not required	≤ Class G cement bulk shrinkage percentage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*	Not Required
I, II III	creep	ASTM C512-10	≤ Class G cement strain percentage under same conditions	Not required
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	API RP 10B-2	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ASTM C496	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions

III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	ASTM E384	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	ASTM C 138	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 4 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 6: Acceptance Criteria for the Testing Procedures of Grouts (non-setting)

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	Not Required	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	Not required		
I, II	Hardened	Not required		
Shrinkage				
I, II	During hardening	Not required		
I, II	Hardened	Non – identified		
I, II	Differential thermal expansion	ASTM E228	NS, RT	Not Required
I, II III	creep	Not required		
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	Not required		
III	Tensile strength	Not required		
III	Elastic modulus	Not required		
III	Hardness	Not required		
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172	NS, RT	NS, RT
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	Pressurized mud balance	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 7: Acceptance Criteria for the Testing Procedures of Thermosetting Polymers and Composites

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required		
I	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4 x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See section 8.4.1 of [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See section 8.4.2 of [1]	Not required	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	ISO 899-1	≤ Class G cement strain percentage under same conditions	-
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	API RP 10B-2	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ISO 527-1,	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ISO 527-1	NS, RT	NS, RT
III	Hardness	See section 8.4.2 of [1]	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification	≥ 1.3 MPa	≥ Class G cement under same conditions

		of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	No decomposition below operating temp.	-
V	Density	ISO 1183-1	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 6 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 8: Acceptance Criteria for the Testing Procedures of Thermoplastic Polymers and Composites

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required	-	-
I	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4 x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See section 8.4.1 of [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	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	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See section 8.4.2 of [1]	Not required	≤ Class G cement bulk percentage shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 10 K^{-1} x 10^{-6} of casing [1]*	Not required
I, II III	creep	ISO 899-1	≤ Class G cement percentage linear strain, under same conditions	Not required
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	ISO 604	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ISO 527-1	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ISO 527-1	NS, RT	NS, RT
III	Hardness	ISO 868	NS, RT	NS, RT
OTHER				

I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	No decomposition below operating temp.	-
V	Density	ISO 1183-1	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 7 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 9: Acceptance Criteria for the Testing Procedures of Elastomeric Polymers and Composites

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required	-	-
I	Diffusion coefficient	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4 x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	
I, II	Hardened	See section 8.4.1 of [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See section 8.4.2 of [1]	-	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 10 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	ISO 899-1 / ASTM D395	≤ Class G cement percentage linear strain, under same conditions	-
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	ISRM suggested method	NS, RT	-
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	BS EN ISO 604	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	BS EN ISO 527-1	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	BS EN ISO 527-1	NS, RT	NS, RT
III	Hardness	ISO 868	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification	≥ 1.3 MPa	≥ Class G cement under same conditions

		of Materials for the Abandonment of Wells" [4], substrate rugosity measurements done as per ASTM D7172		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	No decomposition below operating temp.	
V	Density	ISO 1183-1	NS, RT	NS, RT
I, II, III	Stress relaxation	ASTM D395 and NORSOK M710	≤ Class G cement percentage loss in sealing stress, under same conditions	≤ Class G cement percentage loss in sealing stress, under same conditions
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 8 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 10: Acceptance Criteria for the Testing Procedures of Formations

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required	-	-
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
Shrinkage				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
I, II	Differential thermal expansion	ASTM E228	NS, RT	-
I, II III	creep	ASTM C512-10	NS, RT	-
MECHANICAL TESTING				
III	Triaxial testing	ISRM suggested method	NS, RT	NS, RT
III	Cohesion	ISRM suggested method	NS, RT	NS, RT
III	Poisson's ratio	ISRM suggested method	NS, RT	NS, RT
III	Internal friction angle	ISRM suggested method	NS, RT	NS, RT
III	Hydrostatic compressive yield	ISRM suggested method	NS, RT	NS, RT
III	UCS	ISRM suggested method	NS, RT	NS, RT
III	Tensile strength	ASTM C496	NS, RT	NS, RT
III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	Not required		
OTHER				
I, III	Shear bond strength	Not required		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	Not required		
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 11: Acceptance Criteria for the Testing Procedures of Gels

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤2.4x10-8 m2/s with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Absorption index	NS, RT	NS, RT
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During setting	Not required		
I, II	Set	Not required		
Shrinkage				
I, II	During setting	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"	≤ 1.0% bulk shrinkage	-
I, II	Set	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"	-	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228	NS, RT	-
I, II III	creep	Not required		
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	Not required		
III	Tensile strength	Not required		
III	Elastic modulus	Not required		
III	Hardness	Not required		
OTHER				
II, III, IV	Corrosion	API Recommended Practice 13B-1.	NS, RT	NS, RT
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA / DTA / DSC	No decomposition below operating temp.	-

V	Density	Not required		
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate
Class G cement = Portland Class G cement NS = No Standard listed for this property RT = Recommended test that could provide a useful indication of performance				

Table 12: Acceptance Criteria for the Testing Procedures of Glass

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required		
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	-	≤ Class G cement percentage linear expansion under same conditions
Shrinkage				
I, II	During hardening	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	-	≤ Class G cement percentage bulk shrinkage under same conditions
I, II	Differential thermal expansion	ASTM E228, may need to investigate thermal shock	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	Not required		
MECHANICAL TESTING				
III	Triaxial testing	Not required		
III	Cohesion	Not required		
III	Poisson's ratio	Not required		
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required		
III	UCS	API RP 10B-2	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	Not required	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	ASTM E384	NS, RT	NS, RT
OTHER				
I, III	Shear bond strength	See Section 9.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≥ 1.3 MPa	≥ Class G cement under same conditions
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	ASTM C138	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		

III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 11 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 13: Acceptance Criteria for the Testing Procedures of Metals

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	Not required		
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤ Class G cement percentage linear expansion under same conditions	-
I, II	Hardened	See Section 8.4.1 of [1]	NS, RT	NS, RT
Shrinkage				
I, II	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	≤ 1.0% bulk shrinkage	-
I, II	Hardened	See Section 8.4.2 of [1]	NS, RT	NS, RT
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 10 K^{-1} x 10^{-6} of casing [1]*	-
I, II III	creep	ISO 204	≤ Class G cement percentage linear strain, under same conditions	-
MECHANICAL TESTING				
III	Triaxial testing	ISRM suggested method	NS, RT	NS, RT
III	Cohesion	Not required		
III	Poisson's ratio	ISRM suggested method (triaxial) or ASTM E1876	NS, RT	-
III	Internal friction angle	Not required		
III	Hydrostatic compressive yield	Not required	-	-
III	UCS	ASTM E9	≥ 2.1 MPa [6] **	≥ Class G cement under same conditions
III	Tensile strength	ISO 6892-1	≥ 3.65 MPa [1] ***	≥ Class G cement under same conditions
III	Elastic modulus	ISO 3312 or ASTM E9	NS, RT	NS, RT
III	Hardness	ASTM E18, ASTM E10 or ASTM E384	NS, RT	NS, RT
OTHER				
II, III, IV	Corrosion	ISO 1516/NACE MR0175		
I, III	Shear bond strength	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of	≥ 1.3 MPa	≥ Class G cement under same conditions

		Wells" [1], substrate rugosity measurements done as per ASTM D7172		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	TGA/DTA/DSC measurement	Non-melting at operating temp.	-
V	Density	ISO 3369	NS, RT	NS, RT
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
* See Table 12 in [1]
** At 8 hours thickening time for Portland Class G cement
*** Tensile strength of cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

Table 14: Acceptance Criteria for the Testing Procedures of Modified in-situ materials

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Test Value Before Ageing	Test Value After Ageing
PERMEATION TESTING				
I	Nitrogen Permeability	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.	≤ Class G cement under same conditions
I	Diffusion coefficient	Not required		
INTERACTION WITH FLUID				
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^0C	-	≤ Class G cement percentage loss in dry mass under same conditions
I, II	Absorption	Not required		
DIMENSIONAL STABILITY				
Expansion/Swelling				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
Shrinkage				
I, II	During hardening	Not required		
I, II	Hardened	ISRM suggested method	NS, RT	-
I, II	Differential thermal expansion	ASTM E228	NS, RT	-
I, II III	creep	ASTM C512-10	Creep rate determined by application	-
MECHANICAL TESTING				
III	Triaxial testing	ISRM suggested method	NS, RT	NS, RT
III	Cohesion	ISRM suggested method	NS, RT	NS, RT
III	Poisson's ratio	ISRM suggested method	NS, RT	NS, RT
III	Internal friction angle	ISRM suggested method	NS, RT	NS, RT
III	Hydrostatic compressive yield	ISRM suggested method	NS, RT	NS, RT
III	UCS	ISRM suggested method	NS, RT	NS, RT
III	Tensile strength	ASTM C496	NS, RT	NS, RT
III	Elastic modulus	ASTM C469	NS, RT	NS, RT
III	Hardness	Not required		
OTHER				
I, III	Shear bond strength	Not required		
I, III	Tensile bond strength	Not required		
III	Decomposition temperature	Not required		
V	Density	Not required		
I, II, III	Stress relaxation	Not required		
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	calculated permeability must be ≤ Class G cement at a stabilized flow rate

Class G cement = Portland Class G cement
NS = No Standard listed for this property
RT = Recommended test that could provide a useful indication of performance

APPENDIX II-A: CALCULATIONS, FORMULAS AND ASSUMPTIONS IN ACCEPTANCE CRITERIA

1) *Function test (see Appendix 8 of [1] for more details)*

A function test is a procedure used to verify the sealing ability of the Chemical Cement Alternative. The first procedure described in Appendix 8 [1] is a small scale setup and serves as a screening process prior to more expensive larger scale experiments. In general, testing in smaller diameter tubes gives better results than testing in larger diameter tubes [7]. If an Alternative fails a leak test at the smaller scale, do not test at a large scale.

The small scale apparatus consists of a test cell with a temperature probe, pressure regulators and pressure sensors, Nitrogen gas source, flow meters, bubble vessel, oven and a computer to record test data. This procedure applies differential pressure across the Alternative in a manner that prevents ballooning of the casing which causes leaks [1].

Figure 2 illustrates a standard functional test of Portland Class G cement in a small scale setup [7]. The blue line shows the output of the mass flow meter with a maximum flow of Nitrogen at 50 nml/min (normal millimetres per minute at 0^0C and 1.013 bar) reached at a differential pressure of 2 bars as reflected by the green line. The red line is from the mass flow meter with a maximum flow rate capability of 700 nml/min. The flow rate does not stabilise at higher differential pressures in a 2 hour interval. Thus when conducting a function test on Chemical Cement Alternatives, at higher leak rates, longer time steps are required to get a stable reading. Permeation of some kind will always occur through a Chemical Cement Alternative [1]. These measurements in conjunction with the Flow Equation may be used to obtain the permeability of the Chemical Cement Alternative as described in equation ([1]) below.

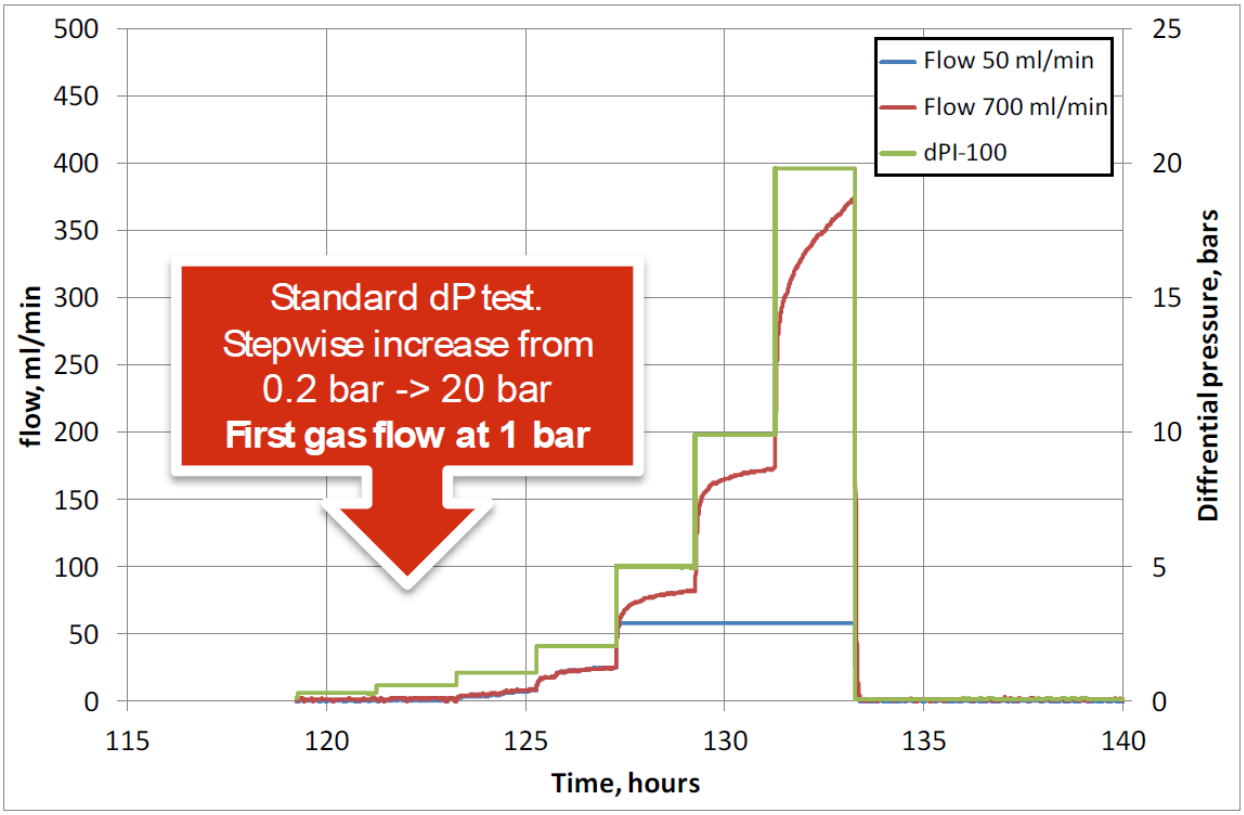

Figure 2: Small-Scale Function Test of Portland Class G Cement [7]

$$Q = -k \cdot A \cdot \left[\frac{(p_1 - p_2)}{\mu \cdot L}\right]$$ *Equation 1 [1]*

Where:

Q	=	Flow rate (m^3/s)
k	=	Permeability (m^2)
A	=	Cross sectional area of the Chemical Cement Alternative (m^2)
$p_1 - p_2$	=	Pressure difference between the top and bottom of the Alternative (Pa)
μ	=	Dynamic viscosity of the fluid (Pa.s)
L	=	Length of the Alternative (m)

The permeability of a good caprock capable of trapping hydrocarbons typically ranges from 1 to 0.001 microdarcy. Good cement has a permeability of approximately 10 microdarcy. For these reasons, a Chemical Alternative must not exceed this permeability value.

Note: The length of the cement column is increased to combat its high permeability and because its cross sectional area is significantly less than the caprock [1]. This must be done with Chemical Cement Alternatives as well.

Acceptance Value: calculated permeability must be ≤10 microdarcy at a stabilized flow rate

2) *Permeability*
Acceptance Value: ≤ 10 Microdarcy
Same justification as acceptance value for function test.

3) *Diffusion Coefficient*

$$-j = D \cdot \left[\frac{(c_1 - c_2)}{L}\right]$$ *Equation 2 [1]*

Where:

j	=	Flux per unit area ($mole/m^2$)
D	=	Diffusion coefficient
$c_1 - c_2$	=	Concentration difference between the top and bottom of the Alternative
L	=	Length of the Alternative (m)

By utilizing the ideal gas law this may be converted to

$$-j = D \cdot \left[\frac{(P_1 - P_2)}{R \cdot T \cdot L}\right]$$ *Equation 3 [1]*

Where:

j	=	Flux per unit area (mole/m^2)
D	=	Diffusion coefficient
$P_1 - P_2$	=	Partial pressure difference between the top and bottom of the Alternative
R	=	Gas constant (J/mol.K)
T	=	Temperature (K)
L	=	Length of the Alternative (m)

Since the rate of gas diffusion is linearly related to the casing internal diameter (ID) and diffusion coefficient, diffusion coefficient acceptance values must include a some assumptions. As previously mentioned, all Chemical Cement Alternatives must be held to the same standard as Portland Class G cement. In Alberta, Portland Class G cement is expected to successfully pass a 7.0 MPa differential pressure test post-setting according to the AER Directive 20, Guidelines on Well Abandonment. In that directive, zonal abandonments require 15 m of good Portland Class G cement above the top of perforations and 15 m below the bottom of the perforations. As previously recognized, Portland Class G cement has a permeability of 10 microdarcy. Using the permeability equation ([1]) and applying the mentioned differential pressure standard (7.0 MPa) from the reservoir to the described cement plug (15m length above perforations), a methane gas flow rate of 0.07 m^3 per year would be obtained in 177.8 mm casing (15.75 cm ID) assuming methane has a dynamic viscosity of 4.00 x 10^{-05} Pa.S [1].

Converting flux per unit area in equation (3) to this methane gas release rate at standard conditions will result in a diffusion coefficient of 2.4x10^{-8} m^2/s. Under these assumptions the standard values are

a. a diffusion coefficient of 2.4x10^{-8} m^2/s
b. With a maximum gas flow rate of 0.07 m^3/year.

Note: For a 15 m plug of Chemical Cement Alternative, a smaller casing ID will result in a smaller rate of gas diffusion. Subsequently, a larger casing size would result in a larger rate of gas diffusion. Therefore, to maintain the maximum gas flow rate of 0.07 m^3/year, the length of the Chemical Cement Alternative plug must be increased accordingly.

Acceptance Value: Diffusion Coefficient ≤ 2.4 x10^{-8} m^2/s, gas flow rate <0.07 m^3/year

4) *Shrinkage and Expansion*

Standard Portland Class G cement will normally undergo total shrinkage (internal or chemical shrinkage) during hardening and up to 4-5% total shrinkage post hardening, whether the expanding additives such as Calcium Oxide or Magnesium Oxide are added or not [7]. Without adding an expanding additive, the standard Portland Class G cement undergoes a bulk (external) shrinkage of 1% after hardening while the inclusion of an expanding additive will result in a bulk expansion after hardening (120 hours) [7]. Any shrinkage during or post hardening is detrimental to the performance of a Chemical Cement Alternatives [1]. It is preferred that a Chemical Cement Alternative demonstrates a bulk volume increase greater than or equal to a Portland G blend mixed with an expanding additive. Given that standard Portland Class G cement with no expanding additive is the Alberta Provincial standard for plug and abandonments, a bulk shrinkage performance equal to or better than Portland Class G cement's performance is set as the standard.

Acceptance Value: Bulk Shrinkage ≤ 1.0%

5) Shear Bond Strength

The value for the minimum shear bond strength is based on the equation below that describes the shear stress required to move the Chemical Cement Alternative from it's set position.

$$\tau = \frac{\Delta p \cdot A}{A_c} \qquad \textit{Equation 4 [1]}$$

Where:

τ = Stress required to break the bond between the casing and the Alternative (Pa)

Δp = Pressure difference across the Alternative (Pa)

A = Cross-sectional area of the Alternative (m^2)

A_c = Contact surface between the Alternative and casing (m^2)

Portland G cement has a shear bond strength in steel of approximately 1.31 MPa [8]. A Chemical Cement Alternative must perform equal to or better than this value. Using equation (4) above, a 1.0 m length Portland G cement plug in 177.8 mm, 34.23 kg/m casing would require a differential pressure of over 26 MPa to break the bond between the cement and the casing.

Acceptance Value: Shear Bond Strength ≥ 1.3 MPa

6) Outstanding Properties

Justification for remaining mechanical and chemical properties as captured in Table 5 through to Table 14 are on the basis that Portland Class G cement is the Alberta Provincial standard product for well remediation thus Portland Class G's properties will serve as the acceptance values for the Chemical Cement Alternatives' properties.

Acceptance Value: Portland Class G cement properties

7) *Ageing Testing*

This involves exposing Chemical Cement Alternatives to likely worst case downhole conditions and measuring changes to certain properties over time. Extrapolation techniques are used to determine longevity of the product in the selected well environment [1]. Therefore, the performance of the Chemical Cement Alternatives' mechanical and chemical properties should be the same as or better than Portland Class G cement's properties post ageing.

Acceptance Value ≥ Performance Mechanical and Chemical Properties Post Ageing of Portland G Cement

7.1 Ageing Environments In the Absence of Relevant Well Data

Ageing testing performed on Portland Class G cement in crude oil, brine and H_2S in brine showed minimal effects in crude oil, moderate effects in brine and significant degradation in brine with 0.5% H_2S dissolved gas [9]. It is critical that ageing testing be conducted in one or more of these environments based on the functional specifications of the Chemical Cement Alternative. Since fluid compositions vary from well to well, in the absence of relevant well data, the environments captured in ASTM D1141-98 for brine solution (i.e artificial

seawater) [9] and the *Guidelines on the Qualification of Abandonment Materials* for oil and gas environments will serve as conservative choices.

Table 15: Chemical Composition of a Formation Water Brine [9]

Species	Concentration (g/L)
NaCl	24.53
$MgCl_2$	5.2
Na_2SO_4	4.09
$CaCl_2$	1.16
KCl	0.695
$NaHCO_3$	0.201
KBr	0.101
H_3BO_3	0.027
$SrCl_2$	0.025
NaF	0.003

Table 16: Chemical Constituents of Crude Oil [1]

Species	Approximate Proportion (% by volume)
Asphaltenes	5
Resins	10
Aromatics	15
Naphthenes	35
Iso-Alkanes	15
n-Alkanes	20

Table 17:Typical Composition of Natural Gas [1]

Species	Range (mole %)
Methane	87.0 – 96.0
Ethane	1.5 – 5.1
Propane	0.1 – 1.5
Iso – Butane	0.01 -0.3
Normal – Butane	0.01 -0.3
Iso – Pentane	Trace – 0.14
Normal – Pentane	Trace – 0.04
Hexane plus	Trace – 0.06
Nitrogen	0.7 – 5.6
Carbon Dioxide	0.1 – 1.0
Hydrogen	Trace -0.02

Actual well conditions may vary significantly from these tables. Use numerical or analytical models when extrapolating because the chemical degradation reactions occur several orders of magnitude faster in laboratory ageing tests than in a well [10].

Note: Depending on the area of application, the medium and high risk failure modes associated with the Chemical Cement Alternative, the properties of Portland class G cement may be an inadequate qualification standard. It is recommended that a remedial cement blend is used as a standard for Chemical Cement Alternatives when superior sealing of micro channels is desired. When high temperature performance is desired, a thermal blend should be used as a baseline alternative. Portland Class G cement blend with silica designed to withstand H_2S may be used when attempting to validate performance of the Alternative in a highly sour environment [9]. Table 18 shows generic recipes for each of the three types of cement products.

Table 18: Generic Types of Remedial Cement Blends

Cement Blends	Base Formulation	Common Expanding Additives	Range of Expanding Additives (%)	Common Dispersants	Range of Dispersants (%)	Common Fluid Loss Additives	Range of Fluid Loss Additives (%)
Class G	OWG Cement (OWG = Oil Well G)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0
Microfine	Blast furnace slag based cement	CaO, MgO	Not commonly used	Sodium Lignosulfonate, PolyCarbonxylates	1.0	Not Commonly used	N/A
Thermal 40 F	OWG Cement + 40% Silica Flour (By Weight of Cement)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0

APPENDIX III: LABORATORY INSPECTION REPORT FORMAT

INSPECTION REPORT FORMAT

Approval Form for Chemical Cement Alternative Protocol Testing Laboratories in Alberta

1	Inspection Date	
2	Inspectors	Lead Inspector:
		Inspector:
		Inspector:

The Laboratory

1	Laboratory Name	
2	Laboratory Address	
3	Contact Phone Number	
4	Contact Email	
5	Contact Person	

The Laboratory Inspection

	Inspection	Items	Remarks
1	Laboratory Certificate of Incorporation	Registration #:	
		Date:	
2	Valid Laboratory APEGA or ASET Permit to Practice	Permit #:	
		Expiry Date:	
3	Laboratory relationship with any Chemical Cement Alternative manufacturer		
4	Certificate of Recognition (COR) – Alberta Occupational Health and Safety	Certificate #:	
		Certificate Issuer:	
		Date Issued:	
		Expiration Date:	
5	ISO 9001:2015 Certified	Certificate #:	
		Certificate Issuer:	
		Date Issued:	
		Expiration Date:	
6	List of Procedures per Chemical Cement Alternative this Laboratory can handle	See Appendix III-A - III-J	
7	List of Equipment Per Procedure	See Appendix III-A – III-J	
8	List of Equipment Calibration Certificates	See Appendix III-A – III-J	
9	List of Personnel and Relevant Certification	See Appendix III-K	

The Inspection Result (delete one)

All criteria for approving this Laboratory for conducting Chemical Cement Alternative Protocol Testing in Alberta has been met. **Or** The following gaps have been identified and will have to be addressed for a follow-up inspection. See attached summary sheet of the gaps supported by Appendix III-A to III-J and Appendix III-K.

Report Signed by Lead Inspector:

Name: _____ Signature: _____

Date: _____

APPENDIX III-A: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR MODIFIED CEMENTS/CERAMICS (NON-SETTING)

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedures		Does the Alternative Procedure meet Recommended Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-A-001	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-A-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-A-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-A-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-A-005	API RP 10B-5 ring test				
I, II	Hardened	CCA-A-006	API RP 10B-5 ring test				
Shrinkage							
I, II	During hardening	CCA-A-007	API RP 10B-5 ring test				
I, II	Hardened	CCA-A-008	API RP 10B-5 ring test				
I, II	Differential thermal expansion	CCA-A-009	ASTM E228				
I, II III	creep	CCA-A-010	ASTM C512-10				
MECHANICAL TESTING							
III	Triaxial testing	CCA-A-0011	Not required				
III	Cohesion	CCA-A-0012	Not required				
III	Poisson's ratio	CCA-A-0013	Not required				
III	Internal friction angle	CCA-A-0014	Not required				
III	Hydrostatic compressive yield	CCA-A-0015	Not required				
III	UCS	CCA-A-0016	API RP 10B-2				
III	Tensile strength	CCA-A-0017	ASTM C496				
III	Elastic modulus	CCA-A-0018	ASTM C469				
III	Hardness	CCA-A-0019	ASTM E384				
OTHER							
I, III	Shear bond strength	CCA-A-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of				

			Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-A-0021	Not required				
III	Decomposition temperature	CCA-A-0022	Not required				
V	Density	CCA-A-0023	ASTM C 138				
I, II, III	Stress relaxation	CCA-A-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-A-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-A-0026	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.				
V, VI	Leaching Toxicity	CCA-A-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-B: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR GROUTS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-B-001	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-B-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-B-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-B-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-B-005	Not required				
I, II	Hardened	CCA-B-006	Not required				
Shrinkage							
I, II	During hardening	CCA-B-007	Not required				
I, II	Hardened	CCA-B-008	Non – identified				
I, II	Differential thermal expansion	CCA-B-009	ASTM E228				
I, II III	creep	CCA-B-010	Not required				
MECHANICAL TESTING							
III	Triaxial testing	CCA-B-0011	Not required				
III	Cohesion	CCA-B-0012	Not required				
III	Poisson's ratio	CCA-B-0013	Not required				
III	Internal friction angle	CCA-B-0014	Not required				
III	Hydrostatic compressive yield	CCA-B-0015	Not required				
III	UCS	CCA-B-0016	Not required				
III	Tensile strength	CCA-B-0017	Not required				
III	Elastic modulus	CCA-B-0018	Not required				
III	Hardness	CCA-B-0019	Not required				
OTHER							
I, III	Shear bond strength	CCA-B-0020	See Section 8.6 of "Guidelines on Qualification				

			of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-B-0021	Not required				
III	Decomposition temperature	CCA-B-0022	Not required				
V	Density	CCA-B-0023	Pressurized mud balance				
I, II, III	Stress relaxation	CCA-B-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-B-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-B-0026	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.				
V, VI	Leaching Toxicity	CCA-B-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-C: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR THERMOSETTING POLYMERS AND COMPOSITES

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-C-001	Not required				
I	Diffusion coefficient	CCA-C-002	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-C-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-C-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-C-005	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-C-006	See section 8.4.1 of [1]				
Shrinkage							
I, II	During hardening	CCA-C-007	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-C-008	See section 8.4.2 of [1]				
I, II	Differential thermal expansion	CCA-C-009	ASTM E228				
I, II III	creep	CCA-C-010	ISO 899-1				
MECHANICAL TESTING							
III	Triaxial testing	CCA-C-0011	Not required				
III	Cohesion	CCA-C-0012	Not required				
III	Poisson's ratio	CCA-C-0013	Not required				
III	Internal friction angle	CCA-C-0014	Not required				
III	Hydrostatic compressive yield	CCA-C-0015	Not required				
III	UCS	CCA-C-0016	API RP 10B-2				

III	Tensile strength	CCA-C-0017	ISO 527-1				
III	Elastic modulus	CCA-C-0018	ISO 527-1				
III	Hardness	CCA-C-0019	See section 8.4.2 of [1]				
OTHER							
I, III	Shear bond strength	CCA-C-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-C-0021	Not required				
III	Decomposition temperature	CCA-C-0022	TGA/DTA/DSC measurement				
V	Density	CCA-C-0023	ISO 1183-1				
I, II, III	Stress relaxation	CCA-C-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-C-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-C-0026	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.				
V, VI	Leaching Toxicity	CCA-C-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-D: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR THERMOPLASTIC POLYMERS AND COMPOSITES

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Current Equipment Calibration Certificate
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-D-001	Not required				
I	Diffusion coefficient	CCA-D-002	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-D-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-D-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-D-005	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-D-006	See section 8.4.1 of [1]				
Shrinkage							
I, II	During hardening	CCA-D-007	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-D-008	See section 8.4.2 of [1]				
I, II	Differential thermal expansion	CCA-D-009	ASTM E228				
I, II III	creep	CCA-D-010	ISO 899-1				
MECHANICAL TESTING							
III	Triaxial testing	CCA-D-0011	Not required				
III	Cohesion	CCA-D-0012	Not required				
III	Poisson's ratio	CCA-D-0013	Not required				
III	Internal friction angle	CCA-D-0014	Not required				
III	Hydrostatic compressive yield	CCA-D-0015	Not required				
III	UCS	CCA-D-0016	ISO 604				
III	Tensile strength	CCA-D-0017	ISO 527-1				
III	Elastic modulus	CCA-D-0018	ISO 527-1				

III	Hardness	CCA-D-0019	ISO 868				
OTHER							
I, III	Shear bond strength	CCA-D-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-D-0021	Not required				
III	Decomposition temperature	CCA-D-0022	TGA/DTA/DSC measurement				
V	Density	CCA-D-0023	ISO 1183-1				
I, II, III	Stress relaxation	CCA-D-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-D-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-D-0026	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.				
V, VI	Leaching Toxicity	CCA-D-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-E: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR ELASTOMERIC POLYMERS AND COMPOSITES

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-E-001	Not required				
I	Diffusion coefficient	CCA-E-002	See section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-E-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-E-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-E-005	See section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-E-006	See section 8.4.1 of [1]				
Shrinkage							
I, II	During hardening	CCA-E-007	See section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-E-008	See section 8.4.2 of [1]				
I, II	Differential thermal expansion	CCA-E-009	ASTM E228				
I, II III	creep	CCA-E-010	ISO 899-1 / ASTM D395				
MECHANICAL TESTING							
III	Triaxial testing	CCA-E-0011	Not required				
III	Cohesion	CCA-E-0012	Not required				
III	Poisson's ratio	CCA-E-0013	ISRM suggested method				
III	Internal friction angle	CCA-E-0014	Not required				
III	Hydrostatic compressive yield	CCA-E-0015	Not required				
III	UCS	CCA-E-0016	BS EN ISO 604				
III	Tensile strength	CCA-E-0017	BS EN ISO 527-1				
III	Elastic modulus	CCA-E-0018	BS EN ISO 527-1				

III	Hardness	CCA-E-0019	ISO 868				
OTHER							
I, III	Shear bond strength	CCA-E-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-E-0021	Not required				
III	Decomposition temperature	CCA-E-0022	TGA/DTA/DSC measurement				
V	Density	CCA-E-0023	ISO 1183-1				
I, II, III	Stress relaxation	CCA-E-0024	ASTM D395 and NORSOK M710				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-E-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-E-0026	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.				
V, VI	Leaching Toxicity	CCA-E-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-F: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR FORMATION

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-F-001	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-F-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-F-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-F-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-F-005	Not required				
I, II	Hardened	CCA-F-006	ISRM suggested method				
Shrinkage							
I, II	During hardening	CCA-F-007	Not required				
I, II	Hardened	CCA-F-008	ISRM suggested method				
I, II	Differential thermal expansion	CCA-F-009	ASTM E228				
I, II III	creep	CCA-F-010	ASTM C512-10				
MECHANICAL TESTING							
III	Triaxial testing	CCA-F-0011	ISRM suggested method				
III	Cohesion	CCA-F-0012	ISRM suggested method				
III	Poisson's ratio	CCA-F-0013	ISRM suggested method				
III	Internal friction angle	CCA-F-0014	ISRM suggested method				
III	Hydrostatic compressive yield	CCA-F-0015	ISRM suggested method				
III	UCS	CCA-F-0016	ISRM suggested method				
III	Tensile strength	CCA-F-0017	ASTM C496				
III	Elastic modulus	CCA-F-0018	ASTM C469				
III	Hardness	CCA-F-0019	Not required				
OTHER							
I, III	Shear bond strength	CCA-F-0020	Not required				
I, III	Tensile bond strength	CCA-F-0021	Not required				
III	Decomposition temperature	CCA-F-0022	Not required				

V	Density	CCA-F-0023	Not required				
I, II, III	Stress relaxation	CCA-F-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-F-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-F-0026	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.				
V, VI	Leaching Toxicity	CCA-F-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-G: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR GELS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-G-001	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-G-002	See Section 8.2.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-G-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-G-004	Absorption index				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-G-005	Not required				
I, II	Hardened	CCA-G-006	Not required				
Shrinkage							
I, II	During hardening	CCA-G-007	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"				
I, II	Hardened	CCA-G-008	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells"				
I, II	Differential thermal expansion	CCA-G-009	ASTM E228				
I, II III	creep	CCA-G-010	Not required				
MECHANICAL TESTING							
III	Triaxial testing	CCA-G-0011	Not required				
III	Cohesion	CCA-G-0012	Not required				

III	Poisson's ratio	CCA-G-0013	Not required				
III	Internal friction angle	CCA-G-0014	Not required				
III	Hydrostatic compressive yield	CCA-G-0015	Not required				
III	UCS	CCA-G-0016	Not required				
III	Tensile strength	CCA-G-0017	Not required				
III	Elastic modulus	CCA-G-0018	Not required				
III	Hardness	CCA-G-0019	Not required				
OTHER							
II, III, IV	Corrosion	CCA-G-0020	API Recommended Practice 13B-1.				
I, III	Shear bond strength	CCA-G-0021	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-G-0022	Not required				
III	Decomposition temperature	CCA-G-0023	TGA / DTA / DSC				
V	Density	CCA-G-0024	Not required				
I, II, III	Stress relaxation	CCA-G-0025	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-G-0026	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-G-0027	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.				
V, VI	Leaching Toxicity	CCA-G-0028	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-H: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR GLASS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-H-001	Not required				
I	Diffusion coefficient	CCA-H-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-H-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-H-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-H-005	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-H-006	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
Shrinkage							
I, II	During hardening	CCA-H-007	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-H-008	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Differential thermal expansion	CCA-H-009	ASTM E228, may need to investigate thermal shock				
I, II III	creep	CCA-H-010	Not required				
MECHANICAL TESTING							
III	Triaxial testing	CCA-H-0011	Not required				
III	Cohesion	CCA-H-0012	Not required				
III	Poisson's ratio	CCA-H-0013	Not required				
III	Internal friction angle	CCA-H-0014	Not required				
III	Hydrostatic compressive yield	CCA-H-0015	Not required				

III	UCS	CCA-H-0016	API RP 10B-2				
III	Tensile strength	CCA-H-0017	Not required				
III	Elastic modulus	CCA-H-0018	ASTM C469				
III	Hardness	CCA-H-0019	ASTM E384				
OTHER							
I, III	Shear bond strength	CCA-H-0020	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-H-0021	Not required				
III	Decomposition temperature	CCA-H-0022	Not required				
V	Density	CCA-H-0023	ASTM C138				
I, II, III	Stress relaxation	CCA-H-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-H-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-H-0026	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.				
V, VI	Leaching Toxicity	CCA-H-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-I: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR METALS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-I-001	Not required				
I	Diffusion coefficient	CCA-I-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-I-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-I-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-I-005	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Hardened	CCA-I-006	See Section 8.4.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
Shrinkage							
I, II	During hardening	CCA-I-007	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], may need to investigate thermal shock				
I, II	Hardened	CCA-I-008	See Section 8.4.2 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I, II	Differential thermal expansion	CCA-I-009	ASTM E228				
I, II III	creep	CCA-I-010	ISO 204				
MECHANICAL TESTING							
III	Triaxial testing	CCA-I-0011	ISRM suggested method				
III	Cohesion	CCA-I-0012	Not required				
III	Poisson's ratio	CCA-I-0013	ISRM suggested method (triaxial) or ASTM E1876				

III	Internal friction angle	CCA-I-0014	Not required				
III	Hydrostatic compressive yield	CCA-I-0015	ISRM suggested method				
III	UCS	CCA-I-0016	ASTM E9				
III	Tensile strength	CCA-I-0017	ISO 6892-1				
III	Elastic modulus	CCA-I-0018	ISO 3312 or ASTM E9				
III	Hardness	CCA-I-0019	ASTM E18, ASTM E10 or ASTM E384				
OTHER							
II, III, IV	Corrosion	CCA-I-0020	ISO 1516/NACE MR0175				
I, III	Shear bond strength	CCA-I-0021	See Section 8.6 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1], substrate rugosity measurements done as per ASTM D7172				
I, III	Tensile bond strength	CCA-I-0022	Not required				
III	Decomposition temperature	CCA-I-0023	TGA/DTA/DSC measurement				
V	Density	CCA-I-0024	ISO 3369				
I, II, III	Stress relaxation	CCA-I-0025	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-I-0026	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-I-0027	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.				
V, VI	Leaching Toxicity	CCA-I-0028	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-J: LIST OF PROCEDURES, EQUIPMENT, CURRENT CALIBRATION CERTIFICATE FOR MODIFIED IN-SITU MATERIALS

Subject (Applicable Protocol #)	Property	Procedure Code #	Test Procedure		Does the Alternative Procedure meet Standard Test Requirements	Applicable Equipment	Equipment Calibration Certificate # & Expiry Date
			Standard Test Procedures	Alternative Procedures Used by the Laboratory			
PERMEATION TESTING							
I	Nitrogen Permeability	CCA-J-001	See Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
I	Diffusion coefficient	CCA-J-002	Not required				
INTERACTION WITH FLUID							
V, IV	Dry Mass	CCA-J-003	Measurement of mass after drying to constant mass at 105^0C				
I, II	Absorption	CCA-J-004	Not required				
DIMENSIONAL STABILITY							
Expansion/Swelling							
I, II	During hardening	CCA-J-005	Not required				
I, II	Hardened	CCA-J-006	ISRM suggested method				
Shrinkage							
I, II	During hardening	CCA-J-007	Not required				
I, II	Hardened	CCA-J-008	ISRM suggested method				
I, II	Differential thermal expansion	CCA-J-009	ASTM E228				
I, II III	creep	CCA-J-010	ASTM C512-10				
MECHANICAL TESTING							
III	Triaxial testing	CCA-J-0011	ISRM suggested method				
III	Cohesion	CCA-J-0012	ISRM suggested method				
III	Poisson's ratio	CCA-J-0013	ISRM suggested method				
III	Internal friction angle	CCA-J-0014	ISRM suggested method				
III	Hydrostatic compressive yield	CCA-J-0015	ISRM suggested method				
III	UCS	CCA-J-0016	ISRM suggested method				
III	Tensile strength	CCA-J-0017	ASTM C496				
III	Elastic modulus	CCA-J-0018	ASTM C469				
III	Hardness	CCA-J-0019	Not required				
OTHER							
I, III	Shear bond strength	CCA-J-0020	Not required				
I, III	Tensile bond strength	CCA-J-0021	Not required				
III	Decomposition temperature	CCA-J-0022	Not required				

V	Density	CCA-J-0023	Not required				
I, II, III	Stress relaxation	CCA-J-0024	Not required				
II, III, IV	Ageing Testing (i.e. Product integrity under anticipated adverse conditions such as H2S or diesel products)	CCA-J-0025	'See Section 8.10 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]				
III, IV, VIII	Function Test	CCA-J-0026	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.				
V, VI	Leaching Toxicity	CCA-J-0027	AER accepted modified US EPA 1311 procedure for leachate testing of Chemical Cement Alternatives				

APPENDIX III-K: LIST OF PERSONNEL AND RELEVANT QUALIFICATION

	Equipment as Per Appendix III-A-III-J	Operator's Name	Relevant Certification
1		1)	1)
		2)	2)
		3)	3)
2		1)	1)
		2)	2)
		3)	3)
3		1)	1)
		2)	2)
		3)	3)
4		1)	1)
		2)	2)
		3)	3).
5		1)	1)
		2)	2)
		3)	3)
6		1)	1)
		2)	2)
		3)	3)
7		1)	1)
		2)	2)
		3)	3)
8		1)	1)
		2)	2)
		3)	3)
9		1)	1)
		2)	2)
		3)	3)
10		1)	1)
		2)	2)
		3)	3)

APPENDIX IV: FORMAT FOR TEST REPORTING

Report Format for Chemical Cement Alternative Testing in Alberta

1	Laboratory Name	
2	Laboratory Address	
3	Contact Phone Number	
4	Contact Email	
5	Contact Person	

Toxicity Testing

Leachates from Chemical Cement Alternative

General and Inorganic parameters	Alberta Tier 1 Soil and Groundwater Remediation Guideline Values for Agricultural Land – Table B.2	Test Values	Acceptable Performance (Y/N)
pH	6.5 – 8.5		
An "N" under "Acceptable Performance means that the Alternative has failed and needs to be modified and requalified following a review of the remaining test results			

Composition of Ageing Environment

Chemical Composition of a Formation Water Brine

Pressure _____ kPa, Temperature _____ ^{0}C
Test Duration _____ days _____hours _____minutes

Species	Recommended Concentration (g/L)	Actual Concentration (g/L)
NaCl	24.53	
$MgCl_2$	5.2	
Na_2SO_4	4.09	
$CaCl_2$	1.16	
KCl	0.695	
$NaHCO_3$	0.201	
KBr	0.101	
H_3BO_3	0.027	
$SrCl_2$	0.025	
NaF	0.003	

Chemical Constituents of Crude Oil

Pressure _____ kPa, Temperature _____ ^{0}C
Test Duration _____ days _____hours _____minutes

Species	Recommended Proportion (% by volume)	Actual Proportion (% by volume)
Asphaltenes	5	
Resins	10	
Aromatics	15	
Naphthenes	35	
Iso-Alkanes	15	
n-Alkanes	20	

Pressure _____ kPa, Temperature _____ ^{0}C
Test Duration _____ days _____hours _____minutes

Species	Recommended Range (mole %)	Actual Range (mole %)
Methane	87.0 – 96.0	
Ethane	1.5 – 5.1	
Propane	0.1 – 1.5	
Iso – Butane	0.01 -0.3	
Normal – Butane	0.01 -0.3	
Iso – Pentane	Trace – 0.14	
Normal – Pentane	Trace – 0.04	
Hexane plus	Trace – 0.06	
Nitrogen	0.7 – 5.6	
Carbon Dioxide	0.1 – 1.0	
Hydrogen	Trace -0.02	

Testing of Critical Parameters

Generic Types of Remedial Cement Blends

Cement Blends	Base Formulation	Common Expanding Additives	Range of Expanding Additives (%)	Common Dispersants	Range of Dispersants (%)	Common Fluid Loss Additives	Range of Fluid Loss Additives (%)
Class G	OWG Cement (OWG = Oil Well G)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0
Microfine	Blast furnace slag based cement	CaO, MgO	Not commonly used	Sodium Lignosulfonate, PolyCarbonxylates	1.0	Not Commonly used	N/A
Thermal 40 F	OWG Cement + 40% Silica Flour (By Weight of Cement)	CaO, MgO	1.0 to 3.0%	Sodium Lignosulfonate, PolyCarbonxylates	0.5 - 1.0	PVA, AMPS, Polyacrylamide	0.4 - 1.0

Actual Cement Blend Used Before and After Ageing

Cement Blend	Base Formulation	Expanding Additives	Percentage Expanding Additives (%)	Dispersants	Percentage of Dispersants (%)	Fluid Loss Additives	Percentage of Fluid Loss Additives (%)

Acceptance Criteria for the Testing Procedures of Modified Cements/ceramics (non-setting)

Subject (Applicable Protocol Number)	Property	Standard Test Procedure	Accepted Test Value Before Ageing	Test Value of Alternative Before Ageing	Test Value of Class G Cement Before Ageing	Acceptable Performance Before Ageing (Y/N)	Accepted Test Value After Ageing	Test Value of Alternative After Ageing	Test Value of Class G Cement After Ageing	Acceptable Performance After Ageing (Y/N)
PERMEATION TESTING										
I	Nitrogen Permeability	Section 8.2.1 of "Guidelines on Qualification of Materials for the Abandonment of Wells" [1]	≤10 microdarcy with a calculated release rate <0.07 m^3/year, see justification under diffusion.				≤ Class G cement under same conditions			
I	Diffusion coefficient	Not required								
INTERACTION WITH FLUID										
V, IV	Dry Mass	Measurement of mass after drying to constant mass at 105^{0}C	Not Required				≤ Class G cement percentage loss in dry mass under same conditions			
I, II	Absorption	Not required								
DIMENSIONAL STABILITY										
Expansion/Swelling										
I, II	During hardening	API RP 10B-5 ring test	≤ Class G cement linear expansion percentage under same conditions				Not Required			
I, II	Hardened	API RP 10B-5 ring test	Not Required				≤ Class G cement percentage linear expansion under same conditions			

Shrinkage										
I, II	During hardening	API RP 10B-5 ring test	≤ 1.0% bulk shrinkage				Not Required			
I, II	Hardened	API RP 10B-5 ring test	Not required				≤ Class G cement bulk shrinkage percentage under same conditions			
I, II	Differential thermal expansion	ASTM E228	Coefficient of thermal expansion ± 5 K^{-1} x 10^{-6} of casing [1]*				Not Required			
I, II III	creep	ASTM C512-10	≤ Class G cement strain percentage under same conditions				Not required			
MECHANICAL TESTING										
III	Triaxial testing	Not required								
III	Cohesion	Not required								
III	Poisson's ratio	Not required								
III	Internal friction angle	Not required								
III	Hydrostatic compressive yield	Not required								
III	UCS	API RP 10B-2	≥ 2.1 MPa [7] **				≥ Class G cement under same conditions			
III	Tensile strength	ASTM C496	≥ 3.65 MPa [1] ***				≥ Class G cement under same conditions			
III	Elastic modulus	ASTM C469	NS, RT				NS, RT			
III	Hardness	ASTM E384	NS, RT				NS, RT			
OTHER										
I, III	Shear bond strength	See Section 8.6 of "Guidelines	> 1.3 MPa				≥ Class G cement			

		on Qualification of Materials for the Abandonment of Wells" [1]					under same conditions			
I, III	Tensile bond strength	Not required								
III	Decomposition temperature	Not required								
V	Density	ASTM C 138	NS, RT				NS, RT			
I, II, III	Stress relaxation	Not required								
III, IV, VIII	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.	calculated permeability must be ≤10 microdarcy at a stabilized flow rate	Permeability _____ microdarcy Flow Rate _____ ml/min	Permeability _____ microdarcy Flow Rate _____ ml/min		calculated permeability must be ≤ Class G cement at a stabilized flow rate	Permeability _____ microdarcy Flow Rate _____ ml/min	Permeability _____ microdarcy Flow Rate _____ ml/min	

Class G cement = Portland Class G cement

* See Table 4 in [1]

** At 8 hours thickening time for Portland Class G cement

*** Tensile strength of cement

NS = No Standard listed for this property

RT = Recommended test that could provide a useful indication of performance

An "N" under "Acceptable Performance Before" or "Acceptable Performance After Ageing" means that the Alternative has failed and needs to be modified and requalified following a review of the remaining test results.

This Table is only for Modified Cements/ceramics (non-setting). Standard Test Procedures and Acceptance Values will need to correspond to those of Table 5-Table 14 in Appendix II for the remaining types of Chemical Cement Alternatives.

Note: Class G cement properties are primarily available through literature. However, after ageing these properties will need to be determined using the standardized test procedures listed in this table where applicable. In some instances, alternate test procedures will be required for Class G cement. These must be industry recognized standardized testing procedures for Class G cements and documented as part of the Test Reports for each type of Alternative.

Testing Result (delete one)

All criteria for approving this Chemical Cement Alternative for use in in Alberta has been met.

Or

Some gaps have been identified as captured in the tables above and the Chemical Cement Alternative needs to be modified and requalified at a later date.

Report Signed by Laboratory Technical Authority:

Name: _____ Signature: _____

Date: _____