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THIS REPORT:

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

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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

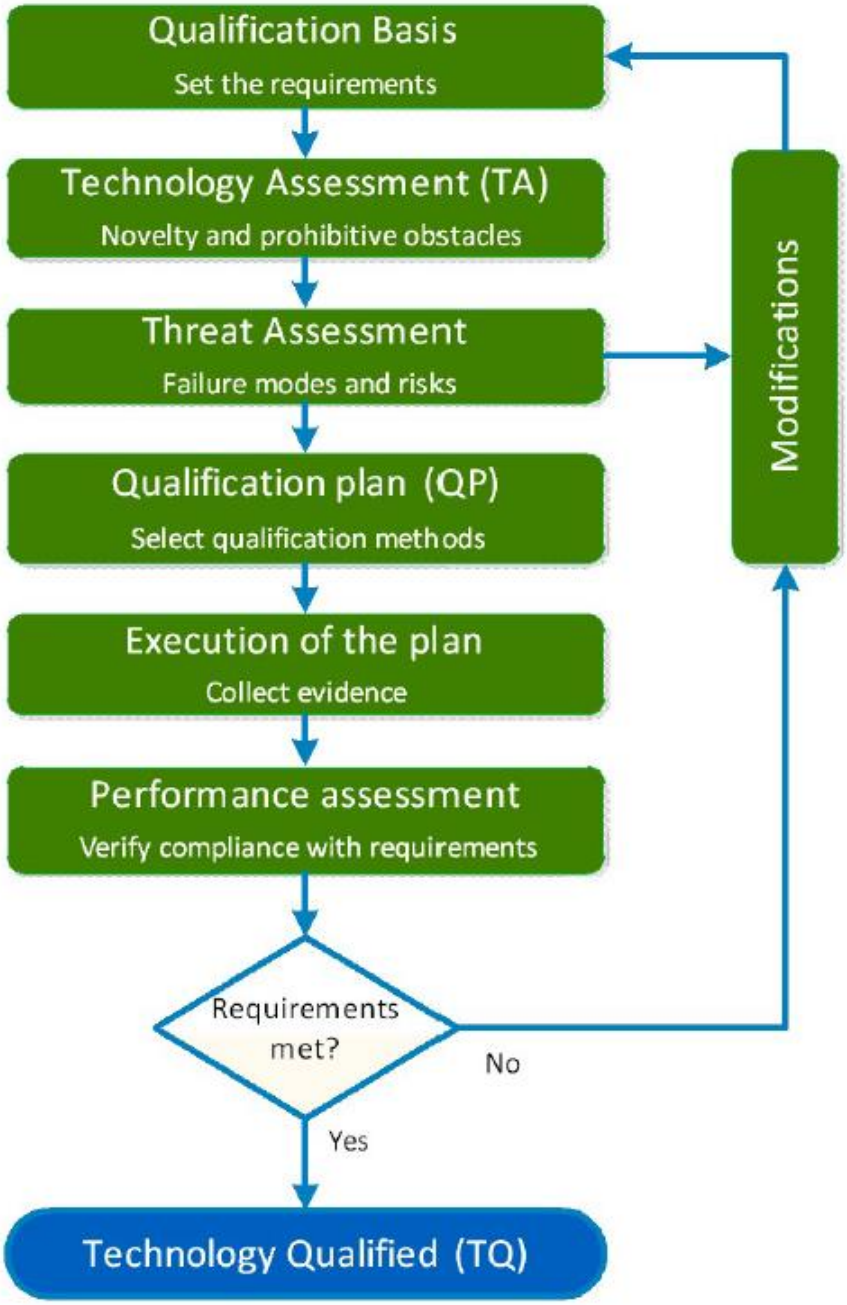


Figure 1: Qualification Process for Chemical Cement Alternative [2]

**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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