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Standard Guide for Interpretation of Standard Humidity Cell Test Results[1]

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1. Scope

1.1 This kinetic test guide covers interpretation and cooperative management of a standard laboratory weathering procedure, Test Method D5744. The guide suggests strategies for analysis and interpretation of data produced by Test Method D5744 on mining waste rock, metallurgical processing wastes, and ores.

1.1.1 Cooperative management of the testing involves agreement of stakeholders in defining the objectives of the testing, analytical requirements, planning the initial estimate of duration of the testing, and discussion of the results at decision points to determine if the testing period needs to be extended and the disposition of the residues.

1.2 The humidity cell test (HCT) enhances reaction product transport in the aqueous leach of a solid material sample of specified mass. Standard conditions allow comparison of the relative reactivity of materials during interpretation of results.

1.3 The HCT measures rates of weathering product mass release. Soluble weathering products are mobilized by a fixed-volume aqueous leach that is performed and collected weekly. Leachate samples are analyzed for pH, alkalinity/acidity, specific conductance, sulfates, and other selected analytes which may be regulated in the environmental drainage at a particular mining or metallurgical processing site.

1.4 This guide covers the interpretation of standard humidity cell tests conducted to obtain results for the following objectives:

Guide and Objective	Sections
A – Confirmation of Static Testing Results	5 – 6
B – Evaluation of Reactivity and Leachate Quality for Segregating Mine, Processing Waste, or Ore	7 – 8
C – Evaluation of Quality of Neutralization Potential Available to React with Produced Acid	9 – 10

1.5 This guide is intended to facilitate use of Test Method D5744 to meet kinetic testing regulatory requirements for metallurgical processing products, mining waste rock, and ores sized to pass a 6.3-mm (0.25-in.) Tyler screen.

1.5.1 Interpretation of standard humidity cell test results has been found to be useful for segregation of ore and waste and design of proper stockpiling and disposal facilities.

1.6 Interlaboratory testing of the standard D5744 humidity cell has been confined to mine waste rock. Application of this guide to metallurgical processing waste (for example, mill process tailings) is not supported by interlaboratory test data. Method B of Test Method D5744, however, has been found useful for testing of metallurgical products, and this guide is also useful for interpretation of those results (**1**).[2]

1.7 This guide is intended to describe various procedures for interpreting the results from standard laboratory weathering of solid materials in accordance with Test Method D5744. It does not describe all types of sampling and analytical requirements that may be associated with its application, nor all procedures for interpretation of results.

1.8 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this guide.

1.8.1 *Exception*—The values given in parentheses are for information only.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[1] This guide is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.01.04 on Waste Leaching Techniques.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D5681 Terminology for Waste and Waste Management

D5744 Test Method for Laboratory Weathering of Solid Materials Using a Humidity Cell

D6234 Test Method for Shake Extraction of Mining Waste by the Synthetic Precipitation Leaching Procedure

E1915 Test Methods for Analysis of Metal Bearing Ores and Related Materials for Carbon, Sulfur, and Acid-Base Characteristics

E2242 Test Method for Column Percolation Extraction of Mine Rock by the Meteoric Water Mobility Procedure

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, see Terminology D5681.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acid concentration present (ACP), n—in static acid-base classification,* an estimate of mineral acidity determined by titration of a sample slurry with water.

3.2.2 *acid generation potential (AGP), n—in static acid-base classification,* an estimate of sulfidic mineral content determined from mineralogy or the sulfide sulfur content.

3.2.3 *acid neutralization potential (ANP), n—in acid-base classification,* an estimate of basic mineral content determined from mineralogy, the carbonate carbon content, or acid neutralization potential acidity titration result. The preferred estimate for use is based on the capacity of the mineral to maintain circumneutral pH as it dissolves.

3.2.4 *adaptive management plan (AMP), n—in environmental kinetic testing,* a structured, iterative process of robust decision making in the face of uncertainty, with an aim to reduce uncertainty over time via system monitoring.

3.2.5 *decision point, n—in management of a humidity cell test operation,* a point in time during the operation of a humidity cell that is selected, during the planning stage, for the stakeholders to meet and make decisions on whether to continue or modify the operation of the test.

3.2.6 *humidity cell performance database, n*—a compilation of: (*1*) tested rock sample, mining waste, ore, or metallurgical tailings characterization; (*2*) completed sample collection representing the geological classifications and acid-base characteristics; and (*3*) humidity cell field weathering test reports, for use in planning and interpretation of HCTs.

3.2.7 *mining waste, n*—overburden or waste rock excavated and disposed of during mining operations.

3.3 *Symbols*—Variables listed in this guide are defined in the individual sections in which they are discussed.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

4. Significance and Use

4.1 *Use of HCT Data and Testing Objectives*—The laboratory weathering test method (D5744) generates data that can be used to:

4.1.1 Determine whether a solid material will produce an acidic, alkaline, or neutral effluent;

4.1.2 Identify solutes in the effluent that represent dissolved weathering products formed during a specified period of time, and inform the user of their potential to produce environmental impacts at a mining or metallurgical processing site under proposed operating conditions;

4.1.3 Determine the mass of solute release; and

4.1.4 Determine the rate at which solutes are released (from the solids into the effluent) under the closely controlled conditions of the test for comparison to other materials.

4.1.5 These approaches are based on the existence of detailed mineralogical work and static tests that provide a basis for interpreting HCT results.

4.1.6 Detailed mineralogical work might lead a reviewer to suspect either acid neutralization potential (ANP) or acid generation potential (AGP) minerals have questionable availability, which would be a significant factor in interpreting HCT results and decisions concerning test duration.

4.2 Interpretation of data generated by the laboratory weathering procedure can be used to address the following objectives:

4.2.1 Determine the variation of drainage quality as a function of compositional variations (for example, iron sulfide and calcium plus magnesium carbonate contents) within individual mine rock lithologies;

4.2.2 Determine the amount of acid that can be neutralized by the sample while maintaining a drainage pH of ≥6.0 under the conditions of the test;

4.2.3 Estimate mine rock weathering rates to aid in predicting the environmental behavior of mine rock; and

4.2.4 Determine mine rock weathering rates to aid in experimental design of site-specific kinetic tests.

4.3 *Interpretation Approaches*—Guides A, B, and C are intended as examples of what to consider in developing an approach for determining how reasonable objectives for humidity cells might be structured, and some possible criteria for cooperative management of HCTs involving stakeholders.

4.3.1 It is also possible to use an approach to establish a decision point, rather than an end point, to the humidity cell test during the planning stage. Guides A, B, and C are examples of techniques and associated criteria comprising some approaches to help interpret data generated by humidity cell tests. Decision points can be established during the planning stage to allow stakeholders an opportunity to review the results and decide if additional weathering cycles are needed to meet the objectives of the testing.

4.3.2 Continuation of the HCT beyond the decision point may or may not provide important information regarding the acceleration or deceleration of oxidation and metal leaching in the material being tested.

4.3.3 More detailed leachate information from a longer HCT may be critical information for designing waste management or water treatment facilities as accounted for in an AMP, but an agreed-upon endpoint of test objectives would allow for a decision that advances mine planning and permitting.

4.3.4 The laboratory weathering procedure provides conditions conducive to oxidation of solid material constituents and enhances the transport of weathering reaction products contained in the resulting weekly effluent. This is accomplished by controlling the exposure of the solid material sample to such environmental parameters as reaction environment temperature and application rate of water and oxygen.

4.3.5 Because efficient removal of reaction products is vital to track mineral dissolution rates during the procedure, laboratory leach volumes are large per unit mass of rock to promote the rinsing of weathering reaction products from the mine rock sample. Interpretation of laboratory kinetic tests by comparison with field tests has shown that more reaction products from mineral dissolution are consistently released per unit weight and unit time in laboratory weathering tests (**2**). For example, sulfate release rates observed in laboratory tests of metal mine rock have been reported to be three to eight times those for small-scale field test piles of Duluth complex rock (**3**), and from two to 20 times those for small-scale field test piles of Archean greenstone rock (**4**). A greater increase is anticipated when laboratory rates are compared with field rates measured from operational waste rock piles.

4.4 In some cases, it may be useful to establish criteria for a decision to end the weathering cycles for a particular cell based on HCT results but still continue to maintain the HCT test weathering cycles for a longer duration.

4.4.1 In other cases, it might be useful to have duplicate HCTs and use one as a basis for a decision point and subsequent destructive evaluation of reaction products.

4.4.1.1 The duplicate cell could be maintained to confirm the basis for the decision and be used to update the AMP and financial guarantee, if necessary.

4.4.2 This approach supports a decision concerning mine waste management and planning, including an AMP.

4.4.3 This approach does not necessarily resolve the need for accurate prediction of long-term metal leaching and drainage quality, but is recommended as a tool for making decisions on how to conduct testing with the objective of determining how ore and waste will be handled and monitored, and the potential level of risk involved in related decisions for specific sites and materials.

4.5 Continuing HCT weathering cycles for an extended period of time may also provide a higher level of certainty.

4.6 Depending on the site-specific resources at risk and behavior of waste materials, an extended HCT weathering cycle duration may be an important consideration for stakeholder groups to use in evaluating HCTs.

4.7 As a mine typically involves very large quantities of waste rock, which will be leached by at least some amount of incident precipitation for extended times, ongoing monitoring of waste facility performance, including any produced effluent or leachate, is almost always required as a condition of permit approval.

4.8 Performance monitoring of permitted facilities can be a critical element in the development of a humidity cell performance database, as well as support for the evolving HCT weathering cycle duration criteria and approach proposed here.

4.9 A humidity cell performance database could be developed in a standard format to allow comparison of laboratory weathering results with drainage from field waste facility performance, based on publicly available information.

4.9.1 A model approach with possible objectives and criteria are presented below as examples to help interpret HCT results.

4.10 Variations in specific approach requirements and criteria (% sulfur, sulfide sulfur, carbonate, pH, sulfate release, etc.) will depend on the site-specific objectives, deposit mineralogy, and characterization, including various static test results and management plans agreed upon by stakeholders.

4.10.1 Regardless of the site-specific stakeholder objectives, instability in metal release rates should strongly suggest continuation of weathering cycle testing.

4.10.2 Regardless of the decision process followed, the ultimate responsibility for the permitting decision lies with the permitting agency(s), and the ultimate environmental liability and operating responsibility lies with the mining company.

4.11 These approaches are suggested as a model to be used by the involved stakeholders for their determination of when it is appropriate to schedule and extend HCT weathering cycles and how to treat the residues.

4.12 The specific parameters (sulfur, $CaCO_3$, SO_4^{-2} release rates, metal release rates, etc.) involved will likely vary depending on site-specific factors, which could include the lithology, petrology and mineralogy, climate, regulatory approach, environmental risk for the units, and ore deposit type being evaluated.

4.13 The criteria selected for management of the duration of HCTs should rely on a combination of parameters, as any criteria based on a single parameter value like % sulfur will not be reliable (**5**).

4.14 The values in the approaches presented are chosen only as examples, and actual cell management criteria are intended to be reviewed and agreed upon by the stakeholders, on a site-specific basis.

4.15 The specific parameters and values selected might vary considerably depending on site-specific factors, which might include environmental risk. It is up to the stakeholders to modify and use this approach to develop objectives which meet the specific requirements at their site and to use their modifications to reach a consensus on test duration.

4.16 The following decision criteria (sulfide sulfur quantitative limit, sulfate release rates, pH, and steady state duration) must be developed on a site/project-specific basis based on considerations including site-specific lithology, mineralogy, trace metal characteristics, and potential environmental risks. The values given in the following guides are merely example criteria; it is up to the stakeholders to manage their own criteria.

GUIDE A

CONFIRMATION OF STATIC TESTING RESULTS

5. Summary of Guide

5.1 Stakeholders agree on preliminary scope and duration of HCT tests based on lithology, mineralogy, static testing results, ore, mine, and processing requirements. Materials are classified and tested by Test Method D5744 and results interpreted to compare with Test Methods E1915 static testing classifications.

6. Procedure

6.1 Classify the HCT test materials according to their acid-base classification in accordance with Test Methods E1915, as shown in Table 1.

6.1.1 Results from materials tested by Test Method D5744 and interpreted may be used to assess the suitability of static testing classifications and the relative ranges of drainage quality parameters to be associated with the static testing classifications for the materials tested on a site-specific basis.

6.1.2 An example of the classification of materials and humidity cell final pH results for the Genesis Project (**6**) is shown in Table 2.

TABLE 1 Summary of Acid-Base Characteristics

Classification	Specifications, % $CaCO_3$[A]
Highly Acidic[B]	NCC ≤ –10
Acidic	–10 < NCC ≤ –2
Slightly Acidic	–2 < NCC ≤ –0.2
Neutral	–0.2 < NCC < 0.2 and AGP < –0.2 or ANP > 0.2
Inert	–0.2 < NCC < 0.2 and AGP > –0.2 and ANP < 0.2
Slightly Basic	0.2 ≥ NCC < 2.0
Basic	2.0 ≥ NCC < 10
Highly Basic	NCC ≥ 10

[A] Common acid-base account units of parts per thousand $CaCO_3$ may be calculated by multiplying % $CaCO_3$ by a factor of ten.

[B] Negative units are used for acid characteristics so that they can be balanced by positive base characteristics through addition.

TABLE 2 Summary of NCC Classifications and Final HCT pH Ranges for the Genesis Project

NCC Classification	Lowest HCT Final pH	Highest HCT Final pH	Number of Composites
Acidic	2.24	2.33	2
Slightly Acidic	2.62	2.81	2
Inert-Neutral	4.45	7.94	7
Slightly Basic	3.79	7.46	3
Basic	6.66	7.61	4
Highly Basic	7.11	7.98	2

6.2 Confirmation of static test results using humidity cells should be initiated early in the mine and process development cycle to identify whether certain waste materials will require further study when the plan of operations for the facilities is better defined.

6.3 The tests should include weathered solid material analyses according to Test Method D5744, or mass balance calculations, as appropriate.

6.4 *End Member Classifications*—Highly acidic (ABA values of ≤ –10 net calcium carbonate [NCC]), or highly basic lithologies (NCC values ≥ +10), as determined by Test Methods E1915.

6.4.1 If the objective of the humidity cell test is to confirm static test results for samples that show high potential for acid generation (slightly acidic to highly acidic) or high net potential available for neutralization of acid (basic to highly basic), a 20-week duration test period (or even shorter durations, in particular in the case of highly reactive samples with significant acid generation potential) should be adequate to confirm the classification for ore and waste control during mining and metallurgical operations.

6.4.2 A decision point should be planned at 20 weeks to determine whether or not the static test results have been confirmed.

6.4.3 It is important to note that even for highly acidic (high potential for acid generation) or highly basic (high net neutralizing potential) samples, a longer test duration may provide important information regarding the acceleration or deceleration of oxidation and metal release behavior that may be critical information for designing waste management or water treatment facilities.

6.5 Screening effluents for water treatment requirements should include comparisons of effluents between HCTs (weathering of sample) and Test Method E2242 or D6234, representing the best case (water leach of sample mobile salts), and the residual solutions from the University of British Columbia Research Confirmation Test (**7**) to represent the worst case (extended reaction of sample with bacteria and acid at low pH).

6.5.1 Effluent concentrations should be compared to site-specific discharge requirements and U.S. EPA primary and secondary drinking water maximum contaminant limits (MCLs) to identify, rate, and rank analytes that should be monitored during operations and leaching tests.

6.5.2 If this screening information raises concerns, then it may be appropriate to identify a different objective and testing protocol for use in water treatment process development, such as large columns or weathering pads at the site.

6.6 *Mid-Range Classifications – Inert-Neutral or Slightly Basic Lithologies (NCC –0.2 to 2.0):*

6.6.1 If the overall objective is to evaluate a material that is classified as having an uncertain or lower potential (inert-neutral to slightly basic) to produce acid leachate by static testing, then the criteria developed will be more site specific (mineralogy, lithology, environmental risk) and more complex.

6.6.2 If the objective is to identify material that may produce acid leachate (inert-neutral, slightly basic) and will be