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REVIEW OF GROUT SAMPLING METHODS FOR SALTSTONE FACILITY VAULTS

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Introduction

“There is significant interest in the feasibility of sampling both liquid and solid grouts that have been placed inside storage vaults at Saltstone.”[1] The goal of this review is to provide sufficient information, including budget and schedule estimates, so that sampling system development activities can be directed toward those methods that best meet the needs of the Saltstone Facility. This review describes three potential methods of sampling hardened grout, as well as a single method of retrieving a liquid grout sample.

Discussion of Assumptions

In the development of the different sampling methods that are presented it was necessary to make various assumptions about the facility and the sample requirements with regard to location, volume, and shape. These assumptions were based on discussions with Waste Solidification Engineering and SRNL personnel, along with a review of the Saltstone Vault No. 4 structural design details. In addition, a number of ASTM standards and one ANSI/ANS standard applicable to obtaining and testing concrete samples were reviewed.

Vault Structure

Access to the individual vault cells was assumed to be through the existing access ports provided in the vault roof. There are fifty, 3-inch pipe ports provided in a staggered array, 9-feet on-center.[2] It is assumed that these ports are constructed of schedule-40, 3-inch pipe; therefore, their inside diameter is nominally 3.068 inches. A 6-inch port with an assumed inside diameter of 6.065 inches is also provided near the center of each cell.[2] Two 12-inch ports with an assumed inside diameter of 12.000 inches are provided at opposite corners of each vault cell.[2] In addition to these round ports a single three-foot square opening is provided in the roof near the central wall of each cell.[2] ASTM C 42 states that core-drilled specimens should not be collected “near formed joints or obvious edges of a unit of deposit”[3]; therefore, it is assumed that hardened grout samples would need to be collected through the 3-inch or 6-inch openings. In addition it was assumed that the 3-inch openings would be preferred since they will allow for samples to be collected from a greater variety of positions within a particular vault cell.

The roof of the vault is constructed of a joist and girder system supported at the cell walls and on nine pipe columns arranged in a 25-foot on-center grid.[2] The joists are rated for a 160 lb/ft live load.[4] Therefore, each 625 ft² portion (25' x 25') of the roof can support a total distributed live load of 16,000 pounds (25.6 lb/ft²). It was assumed then that the roof would be adequate to support the planned sampling operations.

Sample Requirements

Based on conversations with SRNL personnel and sample material requirements[5] it was assumed that the following tests/measurements would be conducted with the collected grout samples: Compressive Strength, Hydraulic Conductivity, Leaching, and Porosity. In addition it was assumed that these tests would closely follow, if not adhere to, the requirements of the following standards.

- ASTM C 39, *Test Method for Compressive Strength of Cylindrical Concrete Specimens*. (Applies to compression testing of cylinders formed from liquid samples.)
- ASTM C 42, *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*. (Applies to compression testing of cylinders collected from hardened grout.)
- ASTM D 5084, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*, **or**
- ASTM D 5856, *Standard Test Method for Measurement of Hydraulic Conductivity of Porous Material Using a Rigid-Wall, Compaction-Mold Permeameter*, **or** similar. (Applies to hydraulic conductivity testing of both hardened samples and cured liquid samples.)
- ANSI/ANS 16.1, *Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short-Term Test Procedure*. (Applies to leachability testing.)
- ASTM C 642, *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete*. (Applies to porosity testing.)

The sample size desired for laboratory testing is a 3-inch diameter by 6-inch long cylinder, but other sizes would be acceptable.[5] This size sample provides the nominal 2:1 length-diameter ratio for compression testing as expected by ASTM C 42.[3] The ASTM standard recommends a core diameter of at least 3.70 inches; however, it allows for diameters less than 3.70 inches for non-structural members as is the case with the Saltstone grout slab. The core diameter size is driven mainly by the maximum size of the coarse aggregate in the concrete being tested. There is no coarse aggregate in the Saltstone grout; therefore, it is assumed that a nominal 2-inch core diameter with a 2:1 length-diameter ratio would be acceptable. However, “the compressive strengths of nominal 2-inch diameter cores are

known to be somewhat lower and more variable than those of nominal 4-inch diameter cores. In addition, smaller diameter cores appear to be more sensitive to the effect of the length-diameter ratio.”[3] For this reason, additional analyses might be required in order to understand the effects of both core diameter and length-diameter ratio on the results of compression tests in Saltstone grout.

A 3-inch cylinder is preferred for hydraulic conductivity testing.[5] However, the size requirement of ASTM D 5084 is 1-inch minimum diameter and height[6]; therefore, it is assumed that a nominal 2-inch core diameter will be adequate for this test as well.

Leach test specimens are assumed to be prepared from cast liquid samples because “using cast samples rather than samples core drilled from a cast monolith is recommended because the process of cutting a sample from a monolith alters the surface of the waste form.”[7] The size requirements for leach test specimens are not restrictive[5, 7]; therefore, no specific assumptions were made in regard to leach test specimen size.

Porosity test specimens may be “of any desired shape or size, except that the volume of each portion shall be not less than 350 cm³”[8]; therefore, it is assumed that a nominal 2-inch core diameter will be adequate for this test as long as it is at least 6.8 inches in length.

It was assumed that samples should be able to be collected at depths from 5 to 18 feet below the roof.[5]

Hardened Grout Sampling Methods

Drilled Core

Samples can be core drilled from the vault cells using commercially available concrete coring equipment. Using this equipment the core samples will be collected in much the same manner as is routinely done in the construction industry. Coring bits approximately two inches in diameter will be driven by a gas- or hydraulically-powered core drill. The drill system will be mounted on the roof of the vault, and may be anchored to the vault roof depending on the torque loads generated by the bit. The drill bit will be water-cooled. Examples of these drill systems are shown in Figure 1.



Figure 1
Commercial Concrete Core Drill Systems

The core drill will access the grout through the existing access holes in the vault roof. Two-inch diameter cores can be cut using the 3-inch penetrations. Larger cores could be cut using the 6- or 12-inch openings that are also available in the roof; however, it was assumed that adequate size samples could be collected through the 3-inch penetrations.

Cores can be cut in various lengths, although a standard core drill bit is 13 inches long. After cutting, the bottom of the core will be broken loose from the slab using a wedge-type tool inserted on one side of the core. A retrieval tool will then be used to lift the core out of the hole. Extensions, typically 18 to 24 inches in length, are added between the drive unit and the bit to attain additional depth.

Cores can be cut in approximately 12-inch long sections through the full depth of the grout or from a given depth. This will be done by first drilling to the desired depth using a drill similar to the one shown in Figure 2, and then switching to a coring bit at the required depth. One problem created by this method is the removal and disposal of the drilled "fines." A 2-inch diameter hole 20 feet deep has a volume of approximately 1/2 cubic foot, and if the bulk density of the drilled fines is assumed to be not less than 1/2 that of the set grout density, then the volume of fines will be about 1 cubic foot. These fines will be lifted out of the drilled hole by the auger portion of the bit which will be modified at the top to spread them out over the surface of the grout slab.



Figure 2
Cruciform Concrete Bit

The major advantage of this sampling method is that it is a proven technology currently in use in similar situations. Disadvantages of this system include the following: labor intensity, contamination of sample with cutting fluid, distortion of the sample surface, and the potential to crack the sample on removal.

Formed Core

Instead of drilling cores from the hardened grout slab it may be possible to form cores as the slab is poured in such a way that they could easily be removed after the grout has hardened. This system would be similar to that used by PNNL during grout characterization studies at the Hanford Site Grout Treatment Facility,[9] the main difference being that the sample tubes would be placed before the grout pour begins instead of at the end of a pour.

Conceptually this system would employ two concentric tubes that would be placed in the vault through the existing 3-inch openings before pouring begins. The outer tube would extend from its placement depth to the full height of the vault and would have a vertical opening at its lower end that would extend the length of the desired sample core. The inner tube would be positioned in the lower end of the outer tube and it would have a vertical opening corresponding to the one in the outer tube. Both tubes would be sealed at the bottom. The inner tube would be able to be rotated from the vault roof by a pipe that would extend to the roof elevation from the inner tube. A sketch of this concept is shown in Figure 3. In Figure 3 the sampler is shown installed at the bottom of the vault; however, it could be positioned at any elevation within the pour. A number of formed core samplers could be pre-placed in the vault at various elevations as might be required by the sampling plan.

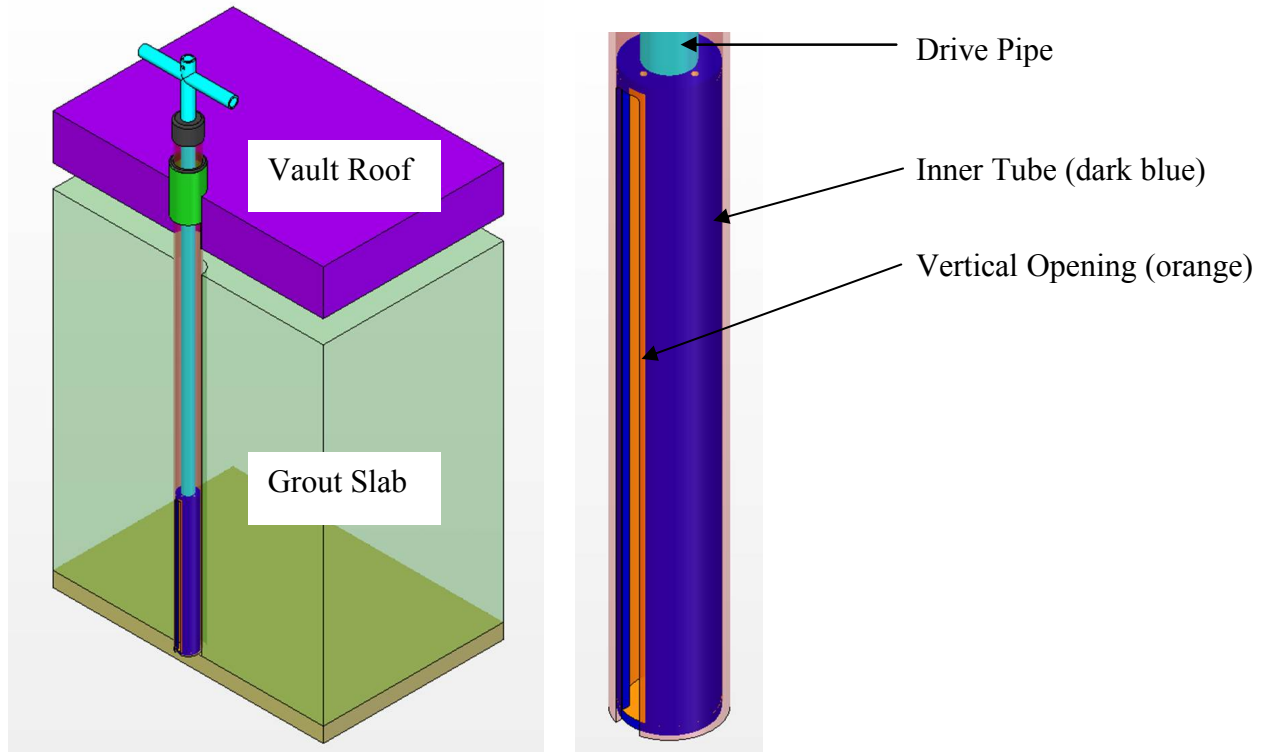


Figure 3

Schematic of Formed Core Sampler System with Sample Tube Detail

The formed core sampler would operate in the following manner. As grout begins to fill the vault cell it would also fill the sampler through the vertical openings in the inner and outer tubes. When the pour is complete or sufficient depth has been poured for the required sample, the inner tube is manually rotated to close off the vertical opening, isolating the sample from the remainder of the grout slab. After the slab has completely cured the inner tube and sample core are pulled through the outer tube to the vault roof. If necessary the outer tube could also be pulled from the slab. The hole which will remain in the grout slab will fill with clean grout as the vault is back-filled for closure. The inner and outer tubes will be constructed of thin-wall aluminum or plastic tubes coated with a form release agent on the outside, or an HDPE plastic material might be used without the release agent.

The advantages of this system include the following: less labor intensive than core drilling, the sample is not contaminated with drilling fluids, and the sample is less likely to be fractured. The main disadvantage to this system is that the development program will require a testing phase so that material behavior in the curing grout slab can be properly understood. There is also some risk that a workable system will not be able to be developed due to material or other concerns.

In Situ Analysis (No Core)

If in situ analysis could be employed, then core sampling of the grout slab would not be required. Conceptually this method would require the placement of two or more vertical forms in the vault cell prior to the start of pouring. After the grout is sufficiently cured, the forms would be removed, leaving behind void spaces that would allow an instrumentation package access to the various levels of the grout slab. A schematic representation of an in situ analysis system is shown in Figure 4.

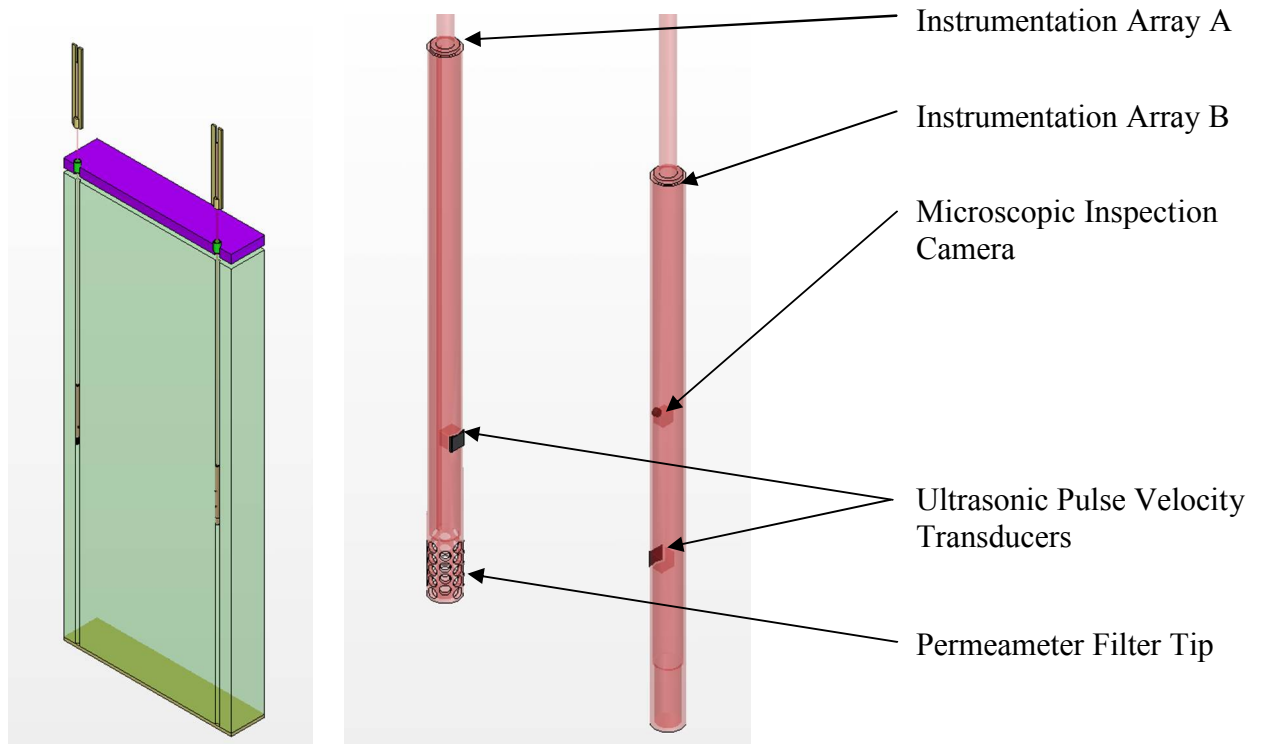


Figure 4

Schematic of In Situ Analysis System with Instrumentation Package Detail

While this method offers the potential of a large savings in operational costs since it will reduce or even eliminate the need for sample collection, handling, packaging and transport, it will require significantly more development work than the other sampling methods described in order to produce an operational capability.

A number of instruments are currently available that appear to be adaptable to in situ testing of the required Saltstone grout properties (compressive strength, hydraulic conductivity, leaching, and porosity). Ultrasonic pulse velocity tests can be used to predict the compressive strength as well as assess the condition of concrete slabs.[10] These instruments could be used in place of compression tests and they may be able to predict porosity and density as well. In situ permeability (hydraulic conductivity) instruments are available for evaluation of soil permeability and there are several ASTM standards which address field measurement of hydraulic conductivity as well. One of these tests or instruments would be adapted to test permeability within the vault grout. Several of the ASTM tests (ASTM D 6391 and D 5126) as well as commercial permeameters rely on a borehole deployment which would be formed in our case by the pre-placed form. The porosity of the grout should be able to be determined in situ using a technique similar to that described in ASTM C 457, *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete*. In situ leaching tests will prove to be the most difficult measurement to make. The ANSI/ANS standard procedure for leaching tests[7] recommends that samples be cast as opposed to core drilled; therefore, it may not be necessary to conduct this test with the hardened grout, and the samples for leach testing could be cast from the liquid samples that will be collected as part of the overall sampling program.

Liquid Grout Sampling

Wet grout samples can most easily be collected using an in-line sample valve. Several commercially available sample valves appear to be adaptable to grout sampling. A representative valve manufactured by the Fetterolf Corporation is shown in Figure 5. The plunger on this style valve remains flush with the interior wall of the pipe during normal operation. The flush installation eliminates dead space where material might collect and will allow the grout line to be “pigged” with the valve in place. Installation of a sample system utilizing this type valve will require the addition of a suitable sample collection system and a method for flushing the valve internals.



Figure 5
Ram-Seal Sample Valve

The liquid grout sampling valve can be installed in the grout delivery line located on the vault roof.

Estimates of Duration and Cost

An order of magnitude estimate for each of the sampling methods described is given in Table 1. These estimates cover the level of effort required to complete proof of concept testing for each individual sampling method. This effort will include research, prototype design, fabrication/procurement, test design, test facility construction, test execution, and analysis and reporting of the results. While it is expected that this work can be completed within the expertise and facilities of the SRNL some allowance has been made to contract some functions to other government laboratories, university research laboratories, or commercial entities such as the U. S. Army Corps of Engineers Geotechnical and Structures Laboratory, Vicksburg, Mississippi.

Table 1
Order of Magnitude Activity Estimate

Activity Description	Duration (weeks)	Cost (K\$)
Drilled Core Sampling System	28	208
Formed Core Sampling System	24	148
In Situ Analysis System	50	420
Liquid Sample Valve	20	80

References

- [1] WSRC Document Number HLW-SSF-TAR-2008-0003, Technical Assistance Request for Saltstone Vault Remote Sampler, 2008.
- [2] WSRC Drawing Number C-CC-Z-0012, Saltstone Vault No. 4 Permanent Roof Plan, Revision 4, 2006.
- [3] ASTM C42/C 42M-04, *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*, ASTM International, West Conshohocken, PA, 7/1/2004.
- [4] WSRC Drawing Number C-CC-Z-0011, Saltstone Vault No. 4 General Notes and Abbreviations, Revision 1, 1998.
- [5] Cozzi, Alex, Email to Robert Milling, Re: Saltstone Grout Sampling Proposal, 3/30/2008.
- [6] ASTM D 5084, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*, ASTM International, West Conshohocken, PA, 11/1/2003.
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- [9] Martin, P.F.C. and R.O. Lokken, "Characterization of a Low-Level Radioactive Waste Grout: Sampling and Test Results," Pacific Northwest Laboratory, December 1992.
- [10] ACI 228.1R, *In-Place Methods to Estimate Concrete Strength*, American Concrete Institute, Farmington Hills, Michigan, November 2003.

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