This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

WSRC-TR-2005-00558, Rev. 0

Keywords: basin, leak rate, CLSM

Estimation of Leak Rate from the Emergency Pump Well in L-Area Complex Basin

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Publication Date: December, 2005

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DOCUMENT: **WSRC-TR-2005-00558, Rev. 0**

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1.0 EXECUTIVE SUMMARY

This report provides an estimate of the leak rate from the emergency pump well in L-basin that is to be expected during an off-normal event. This estimate is based on expected shrinkage of the engineered grout (i.e., controlled low strength material) used to fill the emergency pump well and the header pipes that provide the dominant leak path from the basin to the lower levels of the L-Area Complex. The estimate will be used to provide input into the operating safety basis to ensure that the water level in the basin will remain above a certain minimum level. The minimum basin water level is specified to ensure adequate shielding for personnel and maintain the "as low as reasonably achievable" concept of radiological exposure.

The need for the leak rate estimation is the existence of a gap between the fill material and the header pipes, which penetrate the basin wall and would be the primary leak path in the event of a breach in those pipes. The gap between the pipe and fill material was estimated based on a full scale demonstration pour that was performed and examined. Leak tests were performed on full scale pipes as a part of this examination. Leak rates were measured to be on the order of 0.01 gallons/minute for completely filled pipe (vertically positioned) and 0.25 gallons/minute for partially filled pipe (horizontally positioned). This measurement was for water at 16 feet head pressure and with minimal corrosion or biofilm present. The effect of the grout fill on the inside surface biofilm of the pipes is the subject of a previous memorandum (see Appendix A).

2.0 BACKGROUND

During visual inspection activities in L-basin, the condition of the sluice gates in the emergency coolant pump well (ECPW), a safety significant (SS) system, could not be determined. The ECPW has several pipe penetrations that go through the basin wall, but is isolated from the rest of L-basin by two sluice gates that prevent a drop in basin level in the event of a pipe rupture or a leak through one of the wall penetrations. The sluice gates are positioned such that UT (ultrasonic testing) inspection would be difficult, but preliminary visual inspection of the gates showed signs of advanced corrosion. Several options were considered to mitigate this condition as subject matter experts from Spent Fuel Projects (SFP) Operations, Engineering and SRNL provided input as to the best course of action. The options were summarized in a technical memorandum[1]. The option chosen entails complete filling of the well with engineered grout to support the sluice gate and prevent loss of basin water (see Figure 1). The engineered grout would need to fill all void spaces including pipes open to the well, encase all components inside the well and be suitable for underwater placement. A specification was drafted for the procurement of the grout used and method of placement to support the implementation of this option[2]. The grout material selected is a controlled low strength material (CLSM) suitable for underwater placement (shown in Table I). The grout composition and other technical considerations were discussed in a technical report[3]. The recommended path forward was verified in a full-scale demonstration pour[4].

In order to develop an accurate leak rate estimate through the emergency pump suction well, shrinkage rate test were performed on the CLSM mix design to determine the expected gap at the grout/pipe interface. The tests were performed per specification ASTM C490[5] and yielded higher than expected results (0.14% shrinkage)[6]. The applicability of the shrinkage test was in question due to the low strength of the material. Specifically, the measurement of the length change of specimen requires some amount of rigidity and it was proposed that measuring the length of the specimen may induce some amount of shrinkage. Hence, it became necessary to perform a full scale leak rate test in parallel with the full-scale prototype placement. A prototypic form was built of plywood and supported by scaffolding (3 ft. wide X

20 ft long X 6 ft high). The 24 inch diameter pipe section was horizontally mounted on the side of a rectangular form. A blank flange was connected to the end of the pipe section and the form was filled with water. CLSM was pumped from a mixing truck, through a grout pump and into the form, underwater. The CLSM was allowed to fill the form from the bottom, flow horizontally and fill the pipe by gravity. The mix design specified a certain level of fluidity (flow diameter = 12 inches)[7] but the mix did not achieve this (flow diameter = 11 inches). A separate vertical pipe was also filled with the same CLSM underwater and allowed to cure. The demonstration form and the vertical pipe were allowed to cure underwater for 28 days. Leak testing was performed on both pipe sections to determine an estimate for leak rate through the ECPW pipes. The results and discussion of their impact to leak rate calculations are presented herein.

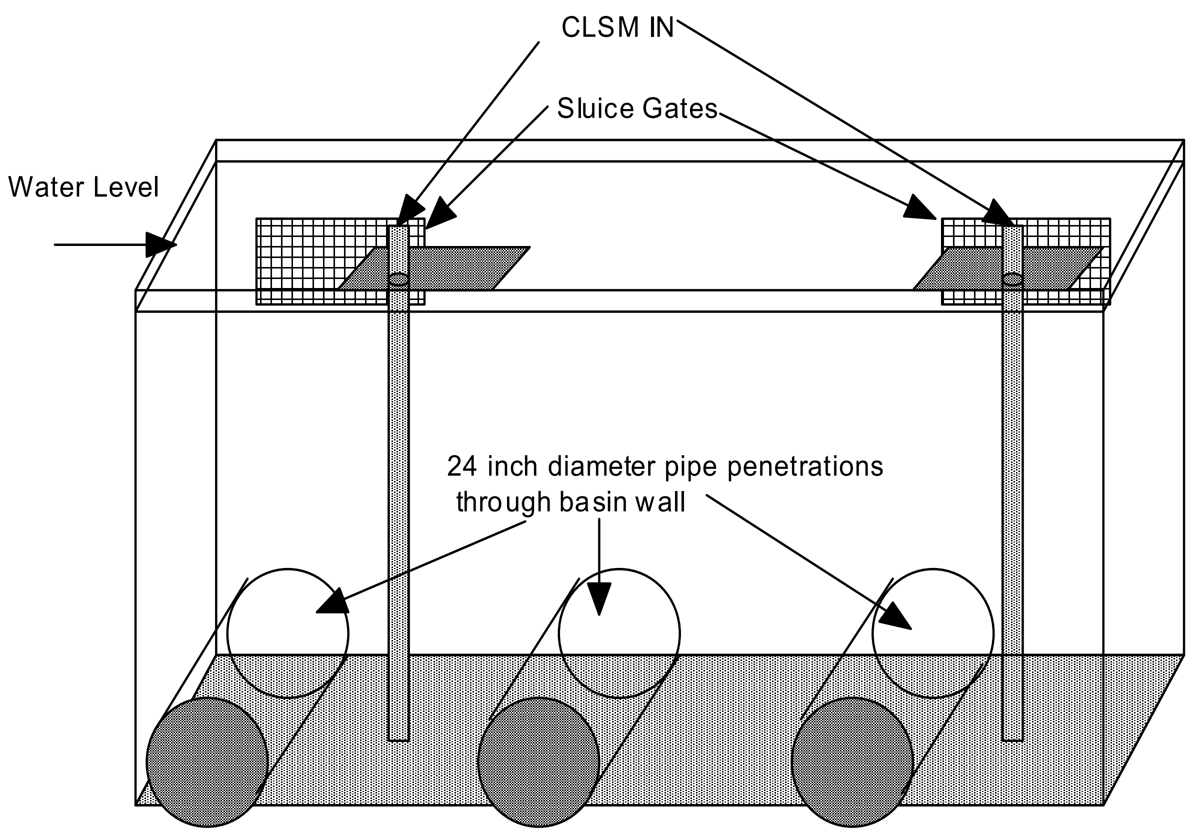

Figure 1: Schematic of the Emergency Cooling Water Pump Intake Well and Pipe Penetrations through the Basin Wall.

Table I: Proportions for CLSM used in the Demonstration Pour

Components	Type or Trade Name	SRS MSDS #	Quantity (lbs/cubic yard)
Cement (lb/cy)	Type I or II ASTM C 150	10326-1	200 lbs.
Fly Ash (lb/cy)	Class F ASTM C 618	24989-1	450 lbs.
Sand/ Fine Aggregate (lb/cy)	ASTM C 33	n/a	2260 lbs
Aggregate (lb/cy)	n/a	n/a	n/a
Water (lb/cy)	Potable	n/a	525 lbs (63 gallons) Hold back > 83 lbs (10 gallons)
Suggested Retarding Agent	W. R. Grace Recover	26834-1	0.93 lbs. (13 fl. oz.)
Suggested Water Red. Admixture (lb/cy)	ASTM C 494 Type F SikaViscocrete 2100	36359-1	Sufficient for 11.0" flow properties 7.2 lbs. (100 fl. oz.)
Visc. Mod. Admix (lb/cy)	KelcoCrete	26007-1	0.46 lbs (210 g)
Suggested AntiWashout Admixture (lb/cy)	Sikament 100 SC	36434-1	Sufficient for desired washout resistance 6 lbs. (77 fl. oz.)

3.0 EXPERIMENTAL

The leak tests were performed in the vicinity of the demonstration pour. After the CLSM was completely cured, the horizontal pipe was removed from the form; special care was taken not to crack the grout inside the pipe. The vertical pipe was turned 90 degrees. Both pipe sections were inspected for irregularities and gaps at the pipe/grout interface. The horizontal pipe connected to the form did not fill completely (see Figure 2) except for the initial 10 inches of its length. This was thought to be a result of the grout trapping water (or air) in the top portion of the pipe during the final stages of filling. The high rate of placement and low fluidity of the CLSM during the demonstration is thought to have contributed to this condition. A schematic drawing of the grout filling profile in this pipe is represented in Figure 3. No filling problems were observed in the vertical pipe section. The length of grout in this pipe was measured to be 39 inches. Additionally, no significant gap between the grout and pipe wall was observed.

Both pipe sections were outfitted with a flange, pressure regulator, transducer and bleed valve on one side of the pipe (see Figure 4). The pressure regulator was hooked up to building water supply and this side of the grout flooded with water. The opposite side was left open. The pressure regulator was adjusted to simulate 15 and 21 feet of water. This is the range of pressures that the ECPW pipes are under in the basin. The water that leaked through the pipe section was collected in a pan and measured using a digital balance. The mass of water (lbs.) collected as a function of time (min) was used to calculate the leak rate (gallons/min).

During the leak rate measurements it was noted that the water did not leak out of the grout/pipe interface uniformly. In the case of the vertical pipe, the leakage was confined to a 10-12 inch section of chord length along the bottom of pipe wall. This presumably resulted from incomplete filling, pressure gradient effects or irregularities on the inside of the pipe. In the case of the horizontal pipe, the water leakage was concentrated in the channel visible in Figures 2 and 3.

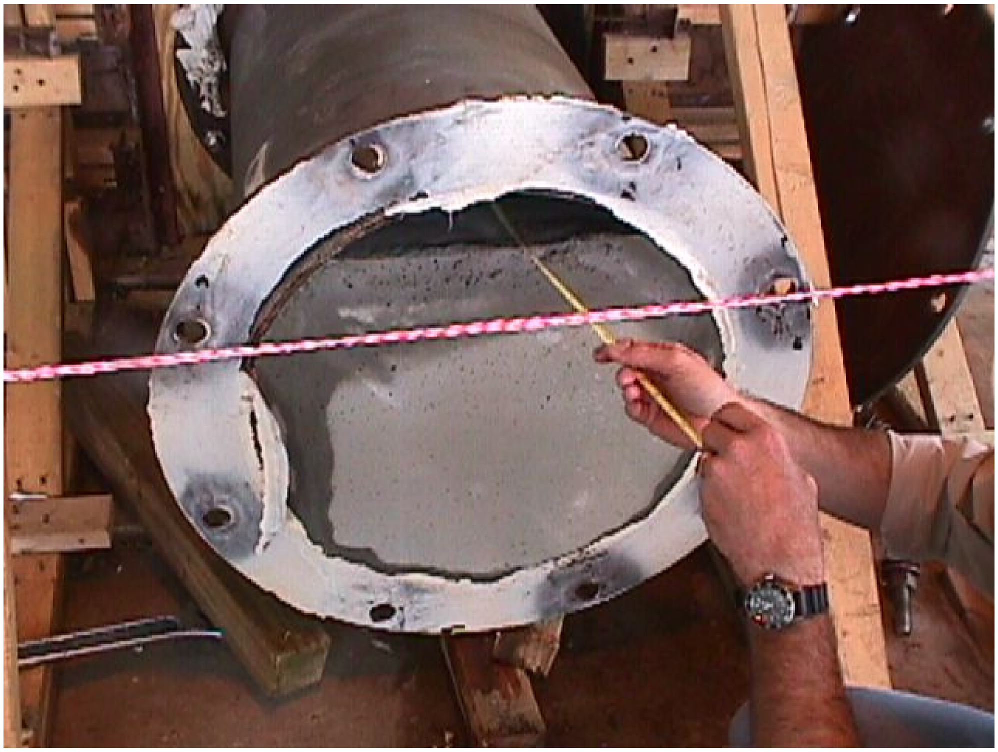

Figure 2: Picture of Horizontal Pipe with the End Flange Removed

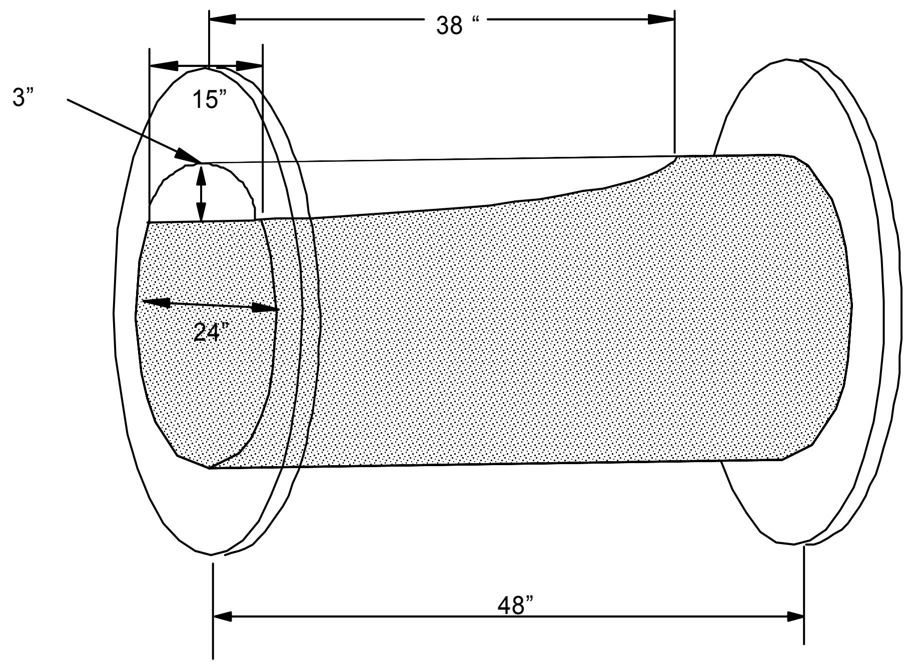

Figure 3: Schematic of the Horizontal Pipe Section Filled with CLSM during Demonstration.

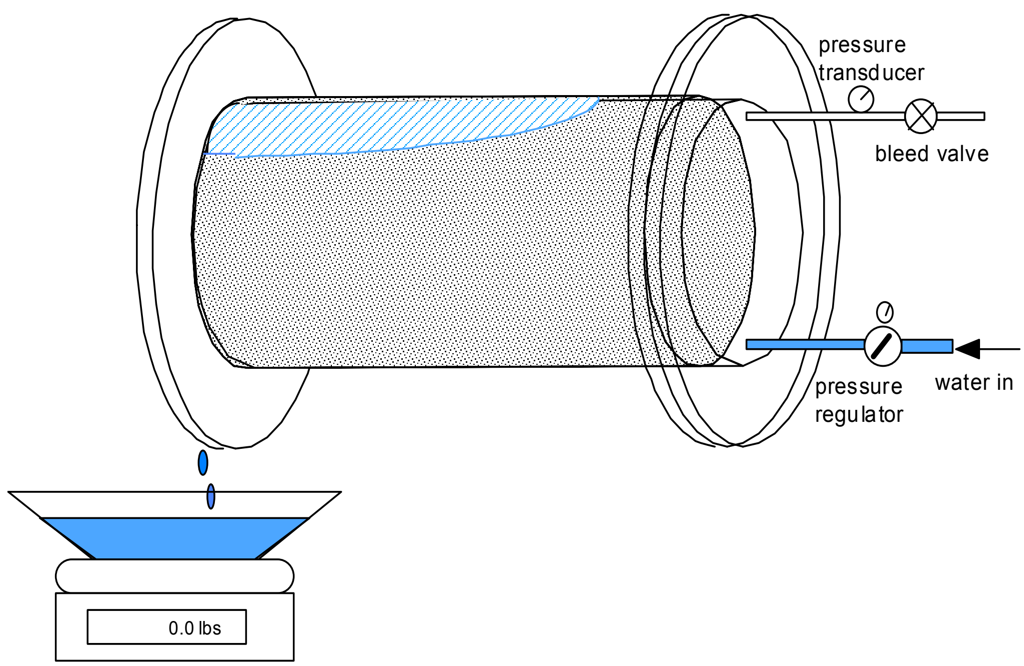

Figure 4: Schematic of Leak Rate Test for Pipe Sections Filled with CLSM
(note: vertical pipe section was completely filled for 39" and did not have the large void shown here)

4.0 RESULTS AND DISCUSSION

Leak rates were measured in both pipe sections at two different pressures. The leak rate measurements were tabulated in Table II. The individual measurements are graphed in Figure 5. Fewer measurements were performed on the vertical pipe section because the measurements were recorded over a longer time frame (1 hr for the vertical pipe versus a few minutes for the horizontal pipe). This was done to provide an adequate water volume for a precise measurement. The results indicate that the leak rates in the vertical pipe section are an order of magnitude lower than the horizontal pipe section. This can be understood as resulting from the incomplete filling that was observed in the horizontal pipe. From the schematic drawing in Figure 3, it should be noted that the pipe was only completely full through 10 inches of length. The vertical pipe exhibited 39 inches of complete filling. This increased the pressure drop across the section and consequently reduced the flow.

Table II: Data of Measured Leak Rate for Vertical and Horizontal Pipe Sections

Vertical Pipe Section (complete fill)			Horizontal Pipe Section (incomplete fill)		
Measurement	**Pressure**	**Leak Rate**	**Measurement**	**Pressure**	**Leak Rate**
Date	**ft of H_2O**	**gallons/min**	**Date**	**ft of H_2O**	**gallons/min**
9/26 1	21.5	0.0090	10/17 A1	20.1	0.270
9/26 2	21.5	0.0086	10/17 A2	20.1	0.266
9/27 1	21.2	0.0124	10/17 A3	20.1	0.263
9/27 2	21.2	0.0136	10/17 A4	20.1	0.264
9/27 3	21.5	0.0139	10/17 A5	20.1	0.270
9/27 4	21.5	0.0144	10/17 A6	20.1	0.267
			10/17 A7	20.1	0.266
			10/17 A8	20.1	0.267
			10/17 A9	20.1	0.288
			10/17 A10	20.1	0.264
			10/17 A11	20.1	0.264
			10/17 A12	20.1	0.264
Average	**21.4**	**0.0120**	**Average**	**20.1**	**0.268**
9/27 5	16.4	0.0112	10/17 1	16.3	0.239
9/27 6	16.9	0.0115	10/17 2	16.3	0.234
9/27 7	15.7	0.0098	10/17 3	16.3	0.235
9/27 8	16.2	0.0106	10/17 4	16.3	0.234
			10/17 5	16.3	0.240
			10/17 6	16.3	0.233
			10/17 7	16.3	0.235
			10/17 8	16.3	0.234
			10/17 9	16.3	0.252
			10/17 10	16.3	0.240
			10/17 11	16.3	0.238
			10/17 12	16.3	0.236
Average	**16.3**	**0.0108**	**Average**	**16.3**	**0.238**

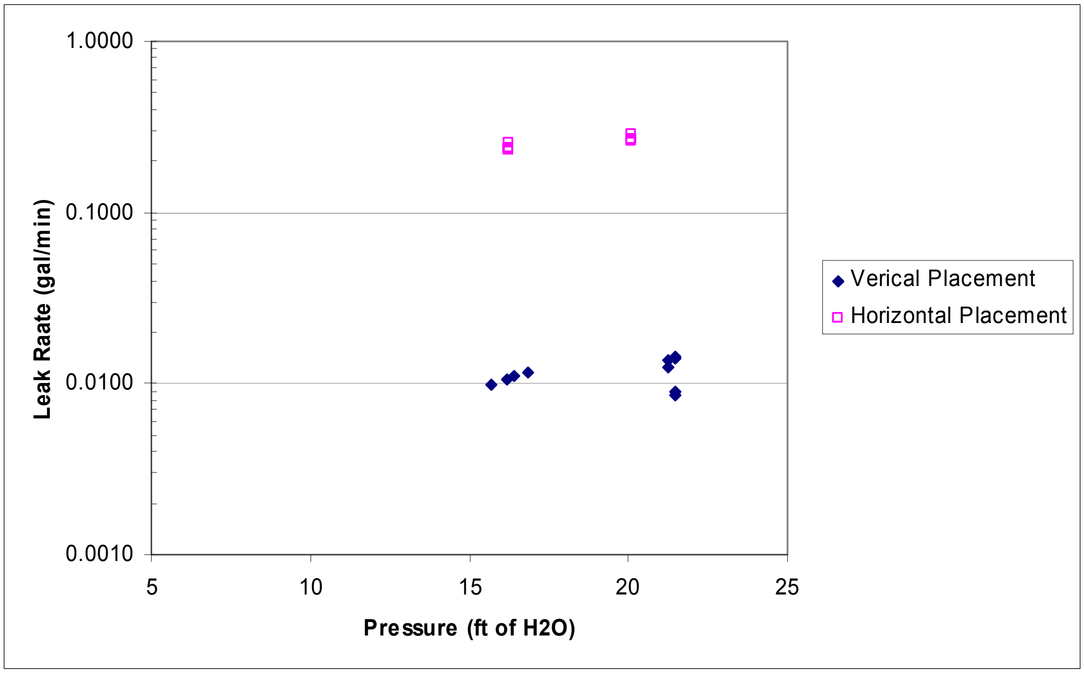

Figure 5: Measured Leak Rate for CLSM filled Pipes.

As mentioned above, the gap between the grout and the pipe section is too narrow to measure. The gap size can be estimated, however, based on empirically developed fluid flow relationships.[8] To empirically correlate the flow through the annulus of the grout/pipe interface, the problem can be simulated using a model for flow between parallel plates. Geiger and Poirier state the relationship of flow and pressure for fluid flow between plates as:

$$Q = \frac{2\,W\,\delta^3}{3\,\eta}\,\frac{(P_0 - P_L)}{L}$$

where Q is volume flow rate
W is width if the plates
δ is the ½ the distance between the plates
P_0 is the initial pressure
P_L is the pressure at length L
L is the length of the plates in the direction of flow
η is the viscosity of the fluid

Knowing the $P_0 - P_L$ (16.5 ft H_2O), L (3.25 ft or 0.83 ft), η (1.1 centipoise) and W (πD or 1 ft) it becomes possible to determine the relationship between leak rate (Q) and annular gap size (2δ). Figure 6 illustrates this relationship for leak rate versus gap size for three cases. The first case (blue diamonds) is for water leaking though the annular space completely around the circumference (W= πD) at a grout length of 3.25 ft. This case would exhibit the highest leak rate for a given gap size. The second case (pink squares) is the solution for water leaking through only a portion of the annular space (W= 1ft) at a grout length of 3.25 ft. This case would accurately represent the leak test on the vertical pipe section (see Table II) and yields the lowest leak rate. The third case (gold triangles) represents a solution for water leaking through only a portion of the annular space (W= 1ft, L= 0.83 ft) where the pipe has not been completely filled.

This case yields an intermediate leak rate and would accurately represent the leak rate test of the horizontal pipe section (see Table II).

Using these cases, the annular gap size in the pipes can be estimated. For the vertical pipe, that exhibited the lowest leak rate, a gap size of approximately 0.003 to 0.004 inch is predicted. In the case of the horizontal pipe, that exhibited the large leak rate, a gap size of 0.006 to 0.007 inch is predicted in the filled portion. The larger gap section (shown in Figures 2 and 3) is neglected and assumed to have no pressure drop across it. The difference between these two gap sizes is most likely due to estimates used for constants in the equation (see above). Specifically, estimates for L and W that may not be geometrically accurate were utilized in the calculations.

Based on these estimates, the gap size in the basin pipes may be predicted, but other factors must also be considered. First, the estimated gap size at present appears to be < ½ the gap size that would result if the CLSM shrinks the full 0.14% that was measured in the shrinkage test (0.017 inch). This should cast doubt on the validity of the ASTM C 490[5] shrinkage measurement method for low strength grouts. Additionally, the memorandum included in Appendix A recommends that an additional 0.002 of an inch be added to the gap estimates for the thickness of the biofilm observed in the basin (not simulated in the present tests). This additional gap would increase the leak rate, only if the biofilm dissolved after the CLSM sets. Although this is unlikely, its occurrence would not raise the leak rate to an alarming level based on the calculations in Figure 6. Finally, it should be noted that water leaking around the full circumference of the annulus (as represented in case 1) was not observed during the test, and may not accurately represent the preferred leak path through the annular space. Perhaps a leak throughout the top portion of the annular space of the ECPW pipes (resulting from incomplete filling or directional shrinkage) may be a more realistic geometry for the leak path.

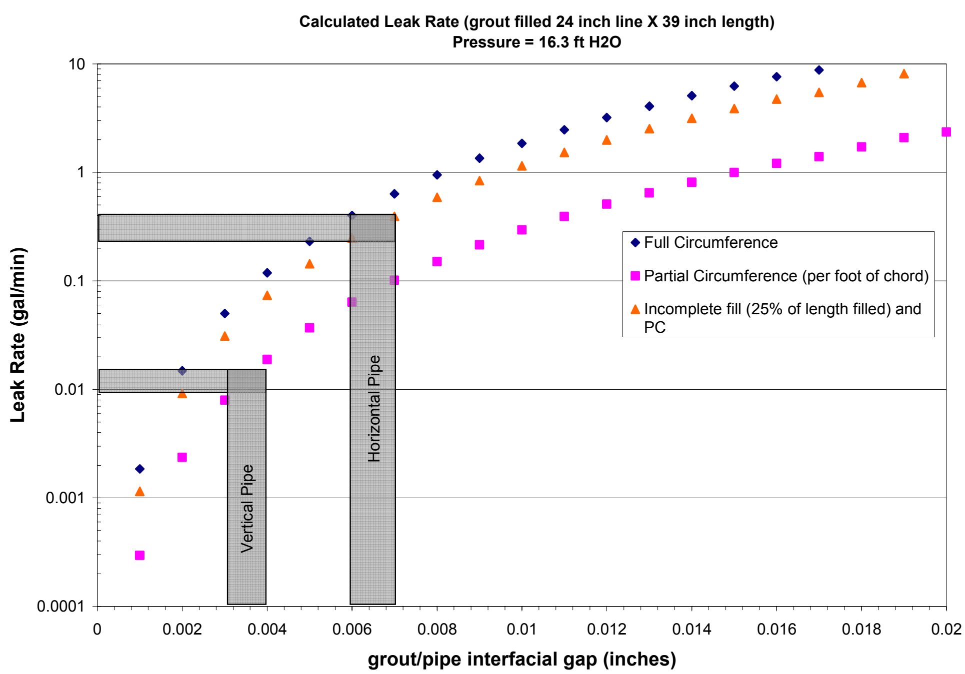

Figure 6: Estimated Leak Rate from the Pipe as a Function of the Grout/Pipe Interfacial Gap
(shaded regions denote a gap size prediction for the experimental filled pipes based on measured leak rates)

5.0 SUMMARY AND CONCLUSIONS

Leak rate tests were performed on 2 ft diameter pipes that were grouted with CLSM while underwater. These tests were performed to form the basis for an estimate of leak rates through the grout/pipe interface of these pipes in the event of a pipe rupture. Leak rates of two cases were measured: 1) complete filling of the pipe (achieved by filling the pipe with grout in a vertical position) and 2) incomplete filling of the pipe (achieved by filling the pipe with grout in a horizontal position). These leak rates were measured to be 0.011 and 0.24 gallons/min, respectively. Based on these leak rates, the average gap size between the grout and the inside surface of the pipe were estimated using the correlation for laminar flow through parallel plates. A gap size of 0.003 (case 1) and 0.007 (case 2) of an inch was estimated for the two cases. Leak rates (and correlated gap sizes) determined from these prototypic tests are significantly lower than the leak rate estimated from ASTM shrinkage test results and illustrates the ability of CLSM to fill confined spaces and stop leaks

The presence of biofilm should not appreciably increase the leak rate based on flow through parallel plates. In addition, the leak path in the annular space was only a portion of circumference. This means the permeability of the annular space is not uniform in the test and will most likely not be uniform in the actual case. The primary leak path appears to be the portion of the annular space with the largest gap. Modeling this behavior in leak rate calculations will enhance their accuracy if it is applied to the leak rate calculations in a methodologically sound way.

6.0 ACKNOWLEDGEMENTS

The technical input of C. E. Olson, W. H. Mhyre and S. A. Carey toward the development of the experimental approach is gratefully acknowledged. Assembly and disassembly of the placement form and assembly of the test apparatus was overseen by M. L. Brott. Technical review of this manuscript was performed by B. J. Wiersma.

7.0 REFERENCES

[1] C.E. Olson, "Options for the Disposition of the Sluice Gate NCR," Technical Memorandum #OBU-SFP-2004-00204, November 15, 2004.
[2] Statement of Work # C-SOW-L-00008, "CLSM for 105-L Pump Well," SRS, Aiken, SC, 29808 (2005)
[3] A. J. Duncan, Technical Report # WSRC-TR-2005-00051 Rev. 2 "Recommended Fill Specification for Emergency Pump Well Mitigation Strategy" SRS, Aiken, SC, 29808 (2005)
[4] Work Package # 618712, SRS, Aiken, SC, 29808 (2005)
[5] ASTM D490-04, "Standard Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete" American Society for Testing Materials, West Conshohocken, PA
[6] Length of Change of Hardened Hydraulic-Cement Mortar and Concrete, Concrete CLSM Test Report # 2005-ERL618712-0003.
[7] ASTM D6103-97, "Standard Test Method for Flow Consistency of Controlled Low Strength Material (CLSM)" American Society for Testing Materials, West Conshohocken, PA
[8] G. H. Geiger and D. R. Poirier, **Transport Phenomena in Metallurgy**, Addison Wesley Publishing Company (1980) p 42.

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WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

SRNL-MTS-2005-30007

March 2, 2005

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Date: 4/5/2005

To: C. E. Olson, 704-26L

From: A. J. Duncan, 773-A AJD
C. J. Berry, 999-W CJB

Technical Review: J. I. Mickalonis
J. I. Mickalonis

Management Approval: R. L. Sindelar
R. L. Sindelar

Subject: Effects of Recommended Fill Existing on Microbial Biofilm in 105-L Basin Emergency Pump Well.

Summary:

An initial assessment was conducted to determine the effect of specified grout fill on the biofilm present in the 105L emergency pump well. Although the grout did not eliminate the biofilm, its presence only occupied a marginal amount of space at the grout/substrate interface (0.002 inch). The effects of the microbial biofilm on the longevity of the grout or its leaktightness are expected to be minimal and no immediate mitigation or pretreatment to the well area is required.

Background:

During visual inspection activities in L-basin, the condition of one safety significant (SS) system was found to be indeterminate. The emergency pump suction well is isolated from the rest of L-basin by two sluice gates that prevent a drop in basin level in the event of a pipe rupture of one of the intake pipes to the emergency cooling water system or a leak through the basin wall adjacent to the well. The sluice gates are positioned such that ultrasonic (UT) inspection would be difficult, but preliminary visual inspection showed them to be badly corroded. Several options were considered to mitigate this condition. Subject matter experts from operations, engineering and SRNL provided input as to the best course of action. The options were summarized in an Engineering memorandum[1]. The safest option chosen entails filling the well with engineered grout to support the structure and prevent loss of fluid. However, several details of the grout placement have not been determined. For example, a biofilm is known to exist on the surface of basin walls. This biofilm consists of several species of bacteria in mature colonies attached to underwater surfaces (see Fig. 1). The grout fill will be placed in the well without any surface treatment of the walls, so the presence of a biofilm may impact the planned mitigation strategy. Specifically, the ability of the grout to completely fill the well with a biofilm present on the concrete is unknown. The grout may compress the biofilm or dissolve it, neutralizing any impact it may have on the mitigation strategy. Alternatively, the biofilm may create pockets at the grout/concrete interface which enhance the leak rate through the well or provide an environment unsuitable for long term service of grout/concrete. Hence, the effect of grout fill on the biofilm was examined and its impact on a potential leak rate is discussed.

Assessment of Grout Effects on Biofilm

An initial experiment was conducted to determine the effect of the grout on the biofilm present in the well. Initially, an atomic wipe was pressed against the wall and swiped to remove some of the microbial colonies. The wipe was sealed in a plastic bottle and was brought to SRNL where the microbes were transferred to the inside of a clay pot (porous substrate) with additional water and complex growth media. After 10 days of incubation, the microorganisms had developed a complex biofilm with streamers (hair-like material) protruding 3-6 mm (1/8 – 1/4 inch) into the bulk solution, inside of the pot. The biofilm consisted of bacteria, yeast, and fungal species that formed a thick and complex three dimensional structure. Predominantly, the biofilm consisted of several species of bacteria with yeast. The water and growth solution were removed (Fig. 2) and grout was cast in the pot (Fig. 3). The composition of the grout is referenced in Table 1. The pH of water present in this mix was not measured but pH of water in similar grout is usually as high as ~ 12. After 3 days the grout was removed as a solid piece (Fig. 4) and the biofilm was examined. The grout appeared to adhere to the inside surface of the clay pot. Samples of the biofilm and adhered grout, remaining on the pot, were stained with fluorescent dye, 4'-6-Diamidino-2-phenylindole (DAPI) a DNA specific stain, and imaged using an epifluorescent microscope with the appropriate filter set. A photomicrograph image of pre sample biofilm is shown in Figure 5. Organisms identified from post grout sampling included, *Bacillus cereus,* a spore forming aerobic bacteria, and *Pseudomonads*, aerobic

[1] Options for the Disposition of the Sluice Gate NCR, OBU-SFP-2004-00204, C. E. Olson, November 15, 2004

organisms associated with complex biofilm formation. Samples of the residue remaining on the surface were taken and placed on sterile Petri plates. After three days of incubation, the plates showed active growth from the swipe taken off the surface of the removed grout and from the inside of the pot. Biofilm thickness after the pot was grouted was estimated to be about 50 μm (0.002 inch). This was determined by examination of the inside of the pot using the DAPI stain after the grout had been removed.

Impact of Demonstration on Emergency Pump Well Mitigation

The primary observation from this assessment is that the bacterial cultures in the biofilm do not appear to be killed after the grout was cast in the pot. Although the biofilm was compressed from ~ 3mm to 50 μm, the solution of cementatous minerals, silica and water did not dissolve or penetrate the film and destroy the bacteria living in it. Since viable bacteria were present after the grout had been added to the pot there is potential for future microbial impact to the wall if enough nutrients, water, and sulfur are available to the organisms. Concrete degradation has been observed in areas with large concentration of sulfides or elemental sulfur. Sulfur oxidizing bacteria, predominantly *Thiobacillus*, are able to oxidize the sulfides or elemental sulfur to sulfuric acid, which lowers the pH at the concrete/biofilm interface and attacks the concrete. However, Thiobacillus bacteria, acid producing bacteria, have not been found in large concentrations in the L-Area basin[2], or in the biofilm formed during this test.

Historically, concrete degradation has not been observed in the L-Area basin or inside the pump well. Sulfur concentrations in the concrete should be low (less than 1 percent by weight with most non-mobile). Although water intrusion could continue to be a problem in the pump well, controlling the available sulfur and other nutrients, required for growth, over time will reduce microbial activity and should not pose a risk to the grout to support the structure and prevent loss of fluid.

Shrinkage of the grout was measured to be less than 0.03 % after three days. Although the above demonstration was not a standardized test the results are consistent with previously published values for CLSM grout[3]. The added gap of 50 μm for microbial biofilm could slightly increase the leak rate for water if the biofilm decayed. This is not likely to occur. The biofilm, which is water permeable should restrict flow and fill any gap left by shrinkage or bleed water, provided enough nutrients are available for continued growth.

[2] FY 2003 Summary of the Microbial Condition in Spent Fuel Storage Facilities at SRS, C. J. Berry, SRT-EST-2004-0028
[3] Grout Formulations for Closing Hanford High-Level Waste Tanks – Bench-Scale Study, T. H. Lorier, D. H. Miller, W. L. Mhyre, J. R. Harbour and C. A. Langton, WSRC-TR-2003-00447, Rev. 0, Sept., 2003

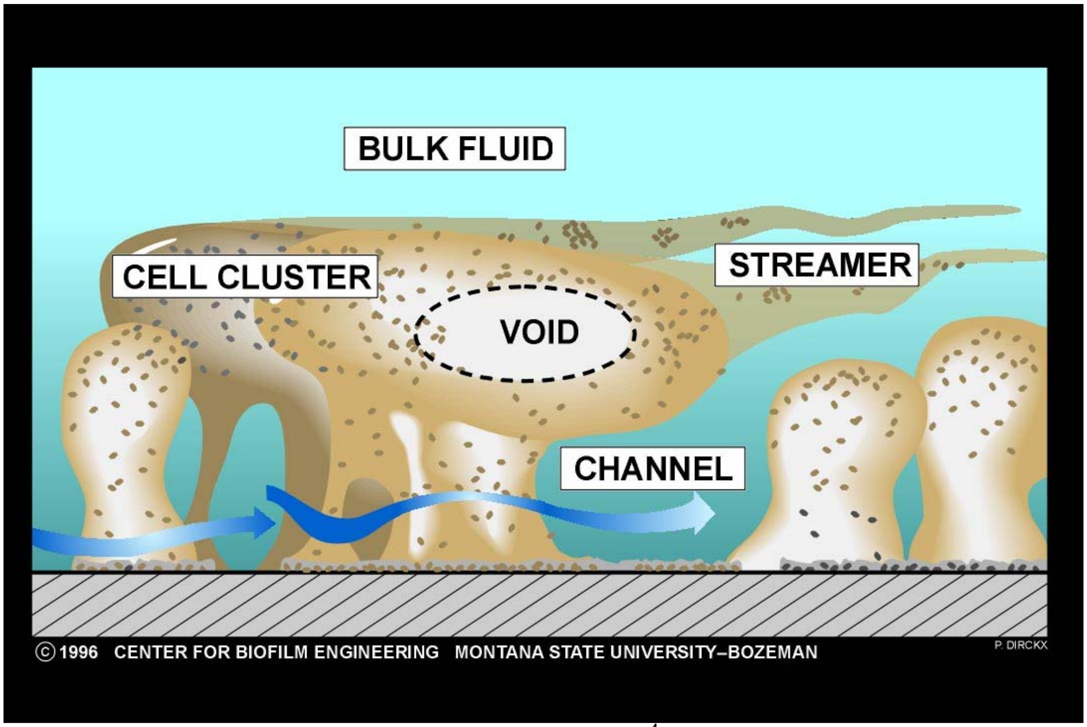

Figure 1: Schematic representation of mature biofilm[4]

Figure 2: Clay pot after 10 days of Bacteria Incubation

[4] Private Communication, Peg Dirckx and Zbigniew Lewandowski, The Center for Biofilm Research at Montana State University-Bozeman, MT

Table 1: Proportions for grout used during initial assessment

Components	Type or Trade Name	Quantity (grams)	Equivalent Quantity (lb/cy)
Cement	Type I ASTM C 150	212.4	150
Fly Ash	Class F ASTM C 618	712.8	500
Sand “fine aggregate”	ASTM C 33	3125	2300
Aggregate	n/a	n/a	
Water	Process	800	500
Admixtures	n/a	n/a	n/a

Figure 3: Clay pot after filling with CLSM type grout

Figure 4: CLSM grout and Clay pot after separation

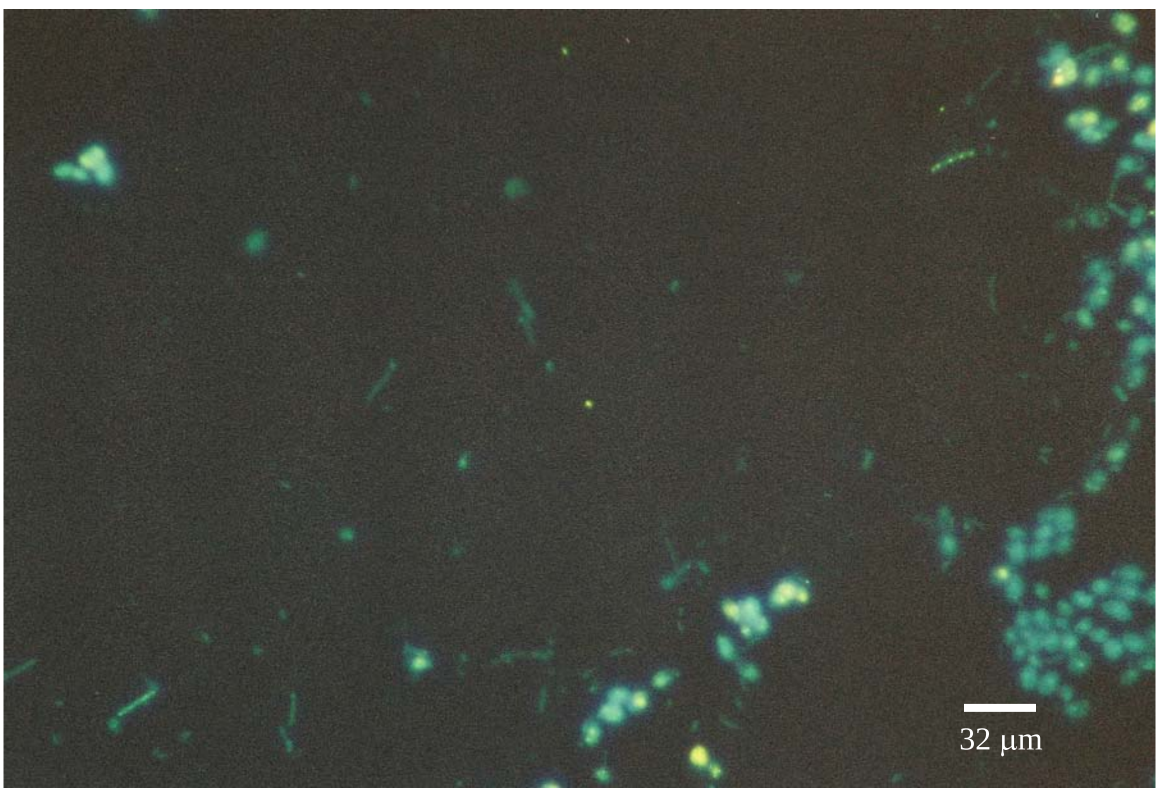

Figure 5: Photomicrograph of stained bacteria taken from the pot prior to adding the grout.