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Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

C-200 Series Tanks Vacuum Retrieval System Aerosol Test Results

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September 2003

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Richland, Washington

Executive Summary

The radioactive wastes stored in tanks 241-C-201, 241-C-202, 241-C-203, and 241-C-204 (C-200 series tanks) are to be retrieved with the C-200 vacuum retrieval system (VRS). The VRS will use high-volume, liquid-ring vacuum pumps (LRVPs) to suck the wastes up through an articulated mast system, separate it from the suspending air, collect and transfer it to a receiver batch tank, and return the air as exhaust to the waste tank being retrieved. Analysis of potential accidents has indicated that a break in the line used to return the VRS exhaust to the waste tank might release unacceptable quantities of suspended radioactive material to the environment.

To estimate the quantity of suspended material in the VRS exhaust line and allow a more definitive determination of accident risks, the contractor responsible for the C-200 series tanks waste retrieval, CH2M HILL Hanford Group, Inc. (CH2M HILL), and staff from Pacific Northwest National Laboratory (PNNL) conducted a series of tests with the VRS using non-radioactive waste simulants at the Hanford Cold Test Facility. The test plan and procedures are given by Baide and Huckaby (2003). This report describes the tests conducted and presents and discusses the results.

The goal of the C-200 VRS aerosol tests was to collect sufficient information to make a conservative estimate of particulate and aerosol mass concentrations in the VRS exhaust line under actual operating conditions. Because the potential exists to accumulate waste in the VRS between the batch tank (where the bulk of the waste is collected) and the exhaust line, and the accumulation of waste in this section of the VRS directly affects the exhaust aerosol concentration, it is important to be able to estimate the rate of waste accumulation and relate it to the exhaust aerosol concentration. Consequently, the tests were designed to evaluate the collection efficiency of the batch tank, the rate at which waste accumulated in the LRVP seal water, and the rate at which the LRVP seal water separator released materials to the exhaust line.

Tests were conducted with the VRS retrieving two different waste simulants; one was intended to represent aqueous wastes conservatively and the other to examine system performance on a dry material. Aqueous wastes were simulated by water and dry wastes by graded dry sand in the tests, which used the same process equipment as, under conditions similar to, the actual retrievals from the C-200 series tanks. The aqueous waste simulant was tagged with trace levels of nonradioactive Cs, and the LRVP seal water was tagged with trace levels of Rb.

Testing consisted of collecting air samples from the VRS exhaust line while the VRS was applied to collect full-scale batches of waste simulant. The exhaust air sample was heated to evaporate the liquid water portion of the aerosol and then filtered to collect essentially all the solid particles in the sample air. Samples of the LRVP seal water were collected at the beginning and end of each test run to establish initial and final conditions of this key process fluid. Also, the liquid that tended to collect and run along the inside of the exhaust line was sampled during

the test runs. All samples were subsequently analyzed for chemical tracers (when tests involved the aqueous waste simulant) or mass and particle size distribution (when tests involved the dry waste simulant).

Not all tests planned by Baide and Huckaby (2003) were conducted; all the planned aqueous waste simulant tests were completed, but, after the first dry waste simulant test run, testing was interrupted and two planned test runs were not conducted. The lack of data from these final two test runs was determined to be acceptable by the CH2M HILL test coordinator.

Table ES.1 lists the aqueous waste simulant aerosol concentrations measured in the VRS exhaust line. As indicated in the table, the first test run was performed with a single LRVP operating, and subsequent test runs were performed with both LRVPs. The aerosol concentration was expected to increase with each successive test run (because waste simulant concentrations in the LRVP seal water increase), but the approximately geometric increases observed were larger than expected. The anomalously high aerosol concentration observed during the CsCl4 test run may be due to the re-entrainment of droplets from the thin streams of liquid running along the inside wall of the exhaust line.

Table ES.1. Aqueous Waste Simulant Test Aerosol Mass Concentrations

Test Run	Description	VRS Exhaust Aqueous Waste Simulant Aerosol Mass Concentration (mg/m^3)
CsCl1	Test run with one LRVP	2.5
CsCl2	Test run with two LRVPs	6.6
CsCl3	Test run with two LRVPs	25
CsCl4	Test run with two LRVPs	102

The VRS exhaust was estimated to contain from 0.07 to 0.7 mL/m^3 of LRVP seal water as an aerosol, based on measured tracer concentrations in the LRVP seal water and quantities of the tracers on the aerosol filters. Higher concentrations of seal water aerosol in the exhaust were associated with increased LRVP operating temperatures and the use of two LRVPs instead of one. Informal testing performed subsequent to the aerosol tests indicates entrainment of LRVP seal water is strongly affected by the amount of seal water introduced to the LRVPs. The amount of condensate and entrained seal water was reduced by approximately a factor of five by reducing the seal water flowrate.

The VRS batch tank collection efficiency was calculated from the accumulation of aqueous waste simulant tracer (Cs) in the LRVP seal water. Collection efficiency was markedly higher for the test conducted with one LRVP than for the three tests conducted with two LRVPs. The calculated batch tank efficiency with one LRVP was 99.98%; with two LRVPs the average was about 98.3%. The reason for this difference was not established but could be explained by a nonrepresentative sample of LRVP seal water or an error in its chemical analysis. Because it is inconsistent with subsequent test runs, we recommend that the batch efficiency calculated for the first test run not be used for safety-related analyses and that the batch tank collection efficiency be assumed to be 98.3% regardless of whether one or two LRVPs are used.

The single test run using dry waste simulant was determined to produce an exhaust aerosol with approximately 9.8 mg/m^3 of simulant. Particle size analysis indicated the aerosol was composed predominantly of particles smaller than about 50 μm and about 80% of the aerosol mass was due to particles greater than about 10 μm.

Reference

Baide DG and JL Huckaby. 2003. *C-200 Series Retrieval Project – Test Implementation Plan for Measurement of Particulate and Aerosol Discharge for the Vacuum Retrieval System*. RPP-17356 Rev. 1, CH2M HILL Hanford Group, Inc., Richland, WA.

Acknowledgments

The authors would especially like to thank John Schofield for his contributions to the understanding of the retrieval system, the test conditions and results, and for various other help with the report itself.

Acronyms and Abbreviations

AMS	articulated mast system
CH2M HILL	CH2M HILL Hanford Group, Inc.
CTF	Cold Test Facility
g	grams
ICP-MS	inductively coupled plasma mass spectrometry
L	liters
LRVP	liquid ring vacuum pump
mg	milligrams
mL	milliliters
PNNL	Pacific Northwest National Laboratory
psi	pounds per square inch
VRS	vacuum retrieval system
wt%	weight percent
μg	micrograms
μm	micrometers

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1.0 Introduction

The radioactive wastes stored in tanks 241-C-201, 241-C-202, 241-C-203, and 241-C-204 (the C-200 series) are to be retrieved with the C-200 vacuum retrieval system (VRS). The VRS will use high-volume vacuum pumps to draw the wastes up through an articulated mast system (AMS), separate it from the suspending air, collect and transfer it to a receiver tank, and return the air as exhaust to the waste tank being retrieved. Analysis of potential accidents has indicated that a break in the line used to return the VRS exhaust to the waste tank could release unacceptable quantities of suspended radioactive material to the environment.

To estimate the quantity of suspended material in the VRS exhaust line and allow a more definitive determination of accident risks, the contractor responsible for the C-200 series tank waste retrieval, CH2M HILL Hanford Group, Inc. (CH2M HILL), and staff from Pacific Northwest National Laboratory (PNNL) conducted a series of tests with the VRS using non-radioactive waste simulants at the Hanford Cold Test Facility (CTF). The test plan and procedures are given by Baide and Huckaby (2003). This report describes the tests conducted and presents and discusses the results.

1.1 C-200 VRS Aerosol Test Objective

The goal of the C-200 VRS aerosol tests was to collect sufficient information to conservatively bound the particulate and aerosol mass loading in the VRS exhaust line under actual operating conditions. Based on criteria developed by CH2M HILL safety analysts, the tests were to provide an aerosol detection limit of about 1 mg/m^3.

1.2 C-200 VRS Description

This section provides background information on the C-200 VRS and its operational conditions during the tests.

1.2.1 Overview of Equipment and Operations

The C-200 VRS consists of the AMS, a batch tank and two waste transfer pumps, two liquid ring vacuum pumps (LRVPs), the LRVP liquid/air separator vessel, a monitoring and control system, a portable exhauster, and hose-in-hose transfer lines. The AMS is installed through a riser on the tank to be retrieved and extended so that its inlet reaches within several inches of the waste surface. Compressed air is injected at the inlet of the AMS to lower the density of the waste inside the AMS, and assist the vacuum retrieval of waste vertically into the batch tank. Water can also be added at the inlet of the AMS as a lubricant for collecting dry wastes. The

AMS is also equipped with high-pressure “scarifier” jets (1,500 psi) that can be used to break up and mobilize the waste.

The bulk of the waste drawn up through the AMS is separated from the entraining air in the batch tank. Waste is collected at the bottom of the batch tank while air exits the top of the tank. The batch tank has a maximum capacity of approximately 1,200 L, with a working volume of approximately 950 L. Progressive cavity pumps are used to transfer wastes from the batch tank to the designated waste receipt tank.

The vacuum system consists of two liquid ring vacuum pumps (LRVPs), a seal water/air separator vessel, and a seal water cooler. The two pumps may be operated one at a time or simultaneously. The LRVPs use water as the sealing and heat removal medium. The seal water/air separator vessel performs two functions. It acts as a cyclone to collect particulate and aerosols entrained in the LRVP discharge stream, and it serves as the reservoir of seal water. Seal water collected in the LRVP separator vessel flows through a heat exchanger (to remove the heat generated by the LRVPs) and back into the LRVPs. High- and low-level switches in the seal water/air separator vessel maintain proper level for pump operation. The air leaving the LRVP separator vessel is routed back to the waste tank being retrieved to complete a closed-loop air recirculation system. More detailed descriptions of the C-200 VRS are given by Baide and Huckaby (2003).

1.2.2 Aerosol Separation Processes Within the VRS

The VRS uses a sequence of three separation processes to separate retrieved waste from the exhaust air. These are 1) the bulk separation of waste from air in the batch tank, 2) the mixing and centrifugal separation of air and waste aerosol with water in the LRVPs, and 3) the cyclonic separation of LRVP seal water from air in the LRVP separator vessel.

The air and entrained waste enter the batch tank via a side inlet into the top of the tank that directs the waste and air downward. Gravity and inertia cause the bulk of the waste to accumulate at the bottom of the batch tank while the air is removed via a vertical pipe in the top of the tank.

Air and any entrained waste leaving the batch tank enter the LRVPs. The LRVPs use violent mixing of the incoming air with water and centrifugal forces inside the LRVPs to effect the removal of particulates from the air. This results in the collection of virtually the entire waste aerosol that enters the LRVPs by the seal water. However, some of the seal water is itself entrained as droplets in the air leaving the LRVPs, and to the extent that these droplets contain dissolved or suspended waste and pass through the LRVP separator vessel, waste can be re-entrained in the VRS exhaust. Thus, the waste aerosol mass concentration in the VRS exhaust line is expected to be a strong function of the concentration of waste in the LRVP seal water.

The mixture of air and LRVP seal water pumped out of the LRVPs enters the LRVP separator vessel. It is a cyclone separator, and the LRVP separator vessel tends to be very efficient at removing all particles above a cut size and allows most particles below the cut size to pass through. The cut size will vary with the velocity of incoming air, the extent to which the vessel is filled with material (seal water), and the density and aerodynamic properties of the particles.

Because the concentration of waste in the LRVP water increases steadily as waste aerosol enters from the batch tank, the waste aerosol mass concentration in the VRS exhaust will also continue to rise (other things being equal) until the LRVP water is drained and replaced with fresh water.

1.2.3 Operating Conditions that Maximize Exhaust Aerosols

According to Baide and Huckaby (2003), the bounding conditions that result in the maximum aerosol concentration in the VRS exhaust line are the following:

- No scarifier or lube water running. Any water addition at the AMS inlet nozzle will enhance removal in the batch vessel.
- Batch vessel full. A full vessel reduces the available space for inertial or settling effects and supports resuspension of material.
- Both vacuum pumps operating. Maximum airflow and volume enhances turbulence in the batch vessel and seal water/air separator vessel, which supports resuspension of material and short-circuits inertial or settling effects.
- Normal liquid level in the seal water/air separator vessel. Maximum vacuum pump efficiency creates highest pass-through.

Informal testing performed subsequent to the aerosol tests indicates entrainment of LRVP seal water is strongly affected by the amount of seal water introduced to the LRVPs. The amount of condensate and entrained seal water observed during the aerosol tests was reduced by approximately a factor of five by reducing the seal water flowrate. Based on operating experience with the VRS, the manufacturer has confirmed that the listed conditions represent worst-case pass-through into the exhaust stream (Baide and Huckaby 2003).

1.3 Quality Assurance

The quality assurance requirements applied to the testing are described by Baide and Huckaby (2003). Chemical analyses of the liquid and filter samples were conducted by the 222-S Laboratory in compliance with the DOE's Hanford Analytical Services Quality Assurance Document. Sample chain of custody records, calibration certificates, and test exceptions are documented in the field copy of the test plan and procedures (Baide 2003).

1.4 Organization of the Report

Descriptions of the tests, waste simulants, the test apparatus and instrumentation, the sequence of events, and deviations from the test plan are given in Section 2 of this report. Sections 3 and 4 provide the test data, sample analyses, and detailed results for the aqueous and dry waste simulant tests, respectively. Conclusions from the test results are given in Section 5 and cited references in Section 6.

2.0 Test Description

Testing of the C-200 VRS for exhaust aerosols was governed by *C-200 Series Retrieval Project – Test Implementation Plan for Measurement of Particulate and Aerosol Discharge from the Vacuum Retrieval System* (Baide and Huckaby 2003), which provides both the test plan and test procedure. The field copy of that test plan, with instrument calibration records, completed data sheets, and a record of test exceptions, has been released as Baide (2003).

This section summarizes the testing, test apparatus and instrumentation, the sequence of events, and deviations from the test plan.

2.1 Overview of Tests

Tests were conducted using the same process equipment that will be used to retrieve wastes from the C-200 series tanks under conditions similar to those of the actual retrievals. Test conditions, waste simulants, and sample locations were also chosen to provide the information needed to develop reasonably conservative estimates of waste aerosol concentrations in the VRS exhaust line.

Tests were conducted using the C-200 VRS as it was installed at the Hanford CTF in July 2003. Two waste simulants were tested. Aqueous wastes were simulated by water containing a chemical tracer, and dry wastes were simulated by #70 sand (see Section 2.2). Testing consisted of collecting air samples from the VRS exhaust line while the VRS was applied to collect full-scale batches of waste simulant. The exhaust air sample was heated to evaporate the liquid water portion of the aerosol, then filtered to collect essentially all the solid particles in the sample air. The collected filter samples were subsequently analyzed for chemical tracers (when tests involved the aqueous waste simulant) or mass and particle size distribution (when tests involved the dry waste simulant).

To establish the rate at which the aqueous wastes accumulate in the LRVP seal water, samples were collected after each aqueous waste simulant test run and analyzed for the waste simulant tracer. A second chemical tracer was added to the LRVP seal water to independently track the LRVP seal water in the exhaust aerosol.

2.2 Waste Simulants

Tests were conducted with the VRS retrieving two different waste simulants, one intended to conservatively represent aqueous wastes and the other to examine system performance on a dry material. Aqueous wastes were simulated in the tests by water, and dry wastes were simulated in the tests by graded dry sand.

2.2.1 Aqueous Waste Simulant

Water is a conservative simulant of aqueous wastes because it has a lower density and the efficiencies of the VRS separation processes tend to increase as the density of the aerosol particles increases. The cyclonic separation of LRVP separator vessel and the centrifugal action of the LRVPs both rely on the inertia of the aerosol particles to effect their separation from air, and higher density particles (other things being equal) are preferentially separated. A small amount of cesium chloride (CsCl) was added to the water (i.e., the waste simulant) to allow the simulant to be tracked through the VRS process and quantitatively measured in the VRS exhaust line. Cs was selected as a tracer because it is not normally present at significant concentrations in water and can be accurately measured by standard laboratory techniques at very low concentrations.[a] The CsCl was added strictly as a chemical tracer. At the concentration that was used it was not expected to modify the physical properties of the water.

2.2.2 Dry Waste Simulant

In an attempt to simulate worst-case performance of the VRS on C-200 series waste, preliminary testing was conducted in late July using a silicon dioxide powder having a mean particle size of about 3.5 μm. By comparison, Creze and Jewett (2002) estimated the C-200 series wastes had a median particle size of 7.5 μm (i.e., 50% of all waste particles have an equivalent diameter of 7.5 μm or less), and a 95th percentile particle size of 140 μm (i.e., 95% of all particles are smaller than 140 μm). The preliminary testing conducted in late July with 3.5 μm simulant was performed without the benefit of lubrication water at the entrance of the AMS and with both LRVPs operating. Under these operating conditions, a significant fraction of the extremely fine powder was passed through the batch tank and collected in the LRVP seal water. The wetted powder accumulated and eventually fouled portions of the LRVP heat exchanger, causing the temperature of the LRVP system to rise.

While much of the waste to be retrieved with the VRS contains fine particles, it is expected to be agglomerated and have much larger effective particle sizes than the extremely fine, loose, dry SiO_2 powder used in the preliminary tests. Consequently, the dry waste simulant chosen for the tests discussed in this report was not intended to be a direct simulant of the C-200 series tank wastes. These tests were conducted with commercially available #70 sand. The vendor-supplied particle size distribution determined using screen filtration[b] is given in Table 2.1, with comparable results from light scattering particle size analysis[c] performed by PNNL. More detailed particle size analyses by both screen analysis and light scattering are given in Appendix A.

(a) An informal analysis by PNNL of a CTF process water sample indicated Cs to be present at about 0.014 ng/mL.
(b) Lane Mountain Company, Valley, WA.
(c) Analyses conducted on two grab samples of the simulant using a Horiba LA-920 particle size analyzer.

Table 2.1. Dry Waste Simulant Particle Size Distribution

Particle Size[(a)] *d* (μm)	Vendor Analysis[(b)] (wt%)	Particle Size *d* (μm)	Light-Scattering Analysis (average)[(c)] (wt%)
$d \leq 74$	5.0	$d \leq 77$	0.00
$74 < d \leq 105$	10.5	$77 < d \leq 101$	0.02
$105 < d \leq 147$	18.0	$101 < d \leq 152$	0.35
$147 < d \leq 208$	31.0	$152 < d \leq 229$	2.0
$208 < d \leq 297$	32.0	$229 < d \leq 301$	3.3
$297 < d$	3.5	$301 < d$	94

(a) Particle size is the effective particle diameter.
(b) Vendor analysis was conducted by screening a sample, and particle sizes correspond to screen mesh sizes.
(c) Two samples of the sand in the waste simulant trough were analyzed by light-scattering. Results from the two samples were averaged by first converting the size distribution (see Appendix A) to a mass distribution, and then averaging the fractions of mass in each size bin from the two samples.

The large difference between the particle size distributions from the vendor (based on shaking the sand through screens of different mesh size) and from light-scattering analysis is not understood. Some settling of the finer particles in the waste simulant trough (prior to sample collection) and in the sample vials (prior to sub-sampling for the light-scattering analyses) may have occurred, but this does not completely explain the large differences in reported size distributions. The sand itself was supplied in 80-pound bags, and it is possible that the two analyses were based on samples from different portions of a much larger supply of sand.

2.2.3 VRS Exhaust Line Modifications

The VRS exhaust aerosol sampling apparatus is illustrated in the lower half of Figure 2.1. It consisted of a 48-in. long section of clear 4-in. inside-diameter Plexiglas pipe with a 45° wye, blind flange, and long-radius pipe elbow; a sampling probe inserted into the Plexiglas pipe, an aerosol filter holder with two filters, valves for controlling airflows, and associated instruments for measuring airflows and temperatures. As indicated in the figure, this apparatus was connected to the exhaust of the LRVP separator vessel. Because the LRVP separator vessel is housed in a steel Connex box and room within the Connex box is limited, the sampling apparatus was installed outside the Connex box, connected to the VRS in place of the VRS exhaust line (a 4-in. inside diameter hose). The exhaust air passed through the sampling apparatus and was directed downward into a bucket to collect the bulk of condensate and entrained liquid from the LRVP separator vessel.

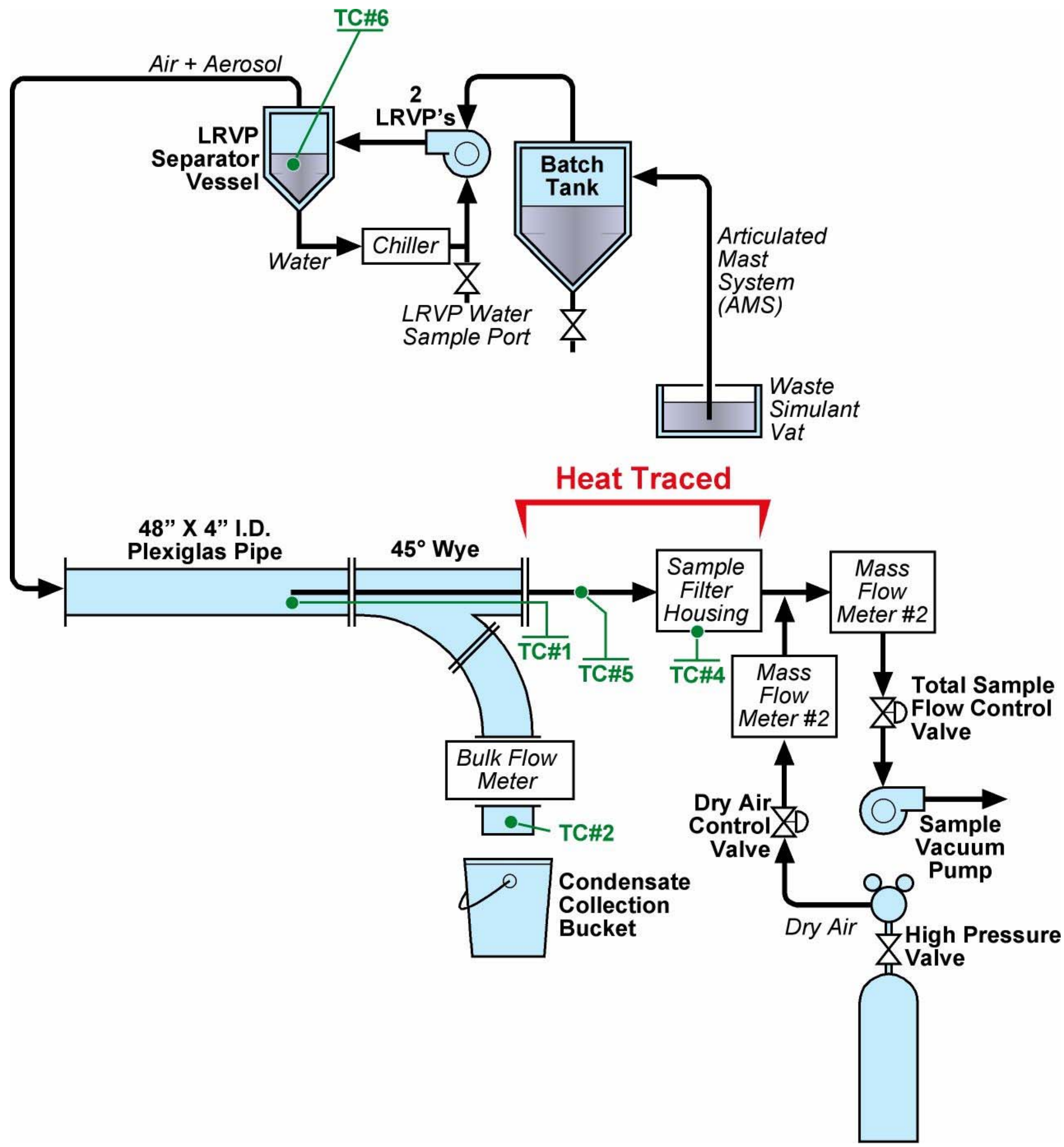


Figure 2.1. Diagram of Test System

2.2.4 Aerosol Sample Filters

The aerosol sample filter assemblies were composed of commercially available 47 mm filter holders[(a)] modified to include a 34.25-in.-long, 0.245-in.-inside diameter straight stainless steel tubes with a beveled (knife-edge) inlet. As depicted in Figure 2.1, the aerosol filter holder was located outside the plastic sampling manifold and accessed the exhaust air via a straight sampling probe. Each filter sample was collected with a dedicated sampling probe and filter holder, so that aerosol particles collected on the inner wall of the sampling probe could be rinsed from the

(a) Model 2220, Paul Gelman, East Hill, New York.

probe and included in the sample. The sampling probe was inserted at a marked location approximately 40 in. (10 pipe diameters) away from the entrance of the Plexiglas pipe and 8 in. (2 pipe diameters) upstream of the 45° wye. The probe location was chosen to provide fully developed flow profile.

The filter holder and the sampling probe between the blind flange and the filter holder were wrapped with heat tape and heated when samples were collected to evaporate any water droplets in the air stream and protect the filters from becoming wet.[a] Because the VRS exhaust air was hot (105° to 140°F) and essentially saturated with water vapor from the LRVPs, precautions were necessary to prevent the condensation of water in the sample air mass flow meter. For this purpose, the sample air was mixed with a measured stream of dry air that effectively reduced its dewpoint to below the ambient temperature.

Two filters were used for each sample to demonstrate that the first (upstream) filter had indeed collected essentially all the aerosols and had not been wetted. In the event that either filter exhibited water spots (nonuniform coloration of deposits) or breakage, the second (downstream) filter would also be analyzed. Two glass fiber filters[b] were installed in the filter holder when the aqueous waste simulant was tested, and two mixed cellulose membrane filters[c] were installed in the filter holder when the dry particulate waste simulant was used. The glass fiber filters were considered less likely to break during sample collection and were easily analyzed for the chemical tracers. The mixed cellulose membrane filters were used for tests of the dry waste simulant (sand) because, unlike the glass fiber filters, they could be incinerated to recover the simulant.

2.2.5 Sample and Total Airflow Control and Measurement

The total VRS exhaust flow rate was measured using an Annubar meter installed about 8 in. (two pipe diameters) from the exhaust outlet. Total exhaust flow rate was not a critical measurement of the tests, but was needed to adjust sample airflow rates to an isokinetic velocity. Because the Annubar meter proved unreliable in the wet exhaust conditions and insensitive to low flow rates, two hand-held flow rate instruments were also used. These were a thermal anemometer[d] and a vane anemometer.[e]

(a) Collection efficiency of the filters would be significantly reduced if the filters were allowed to become wetted.
(b) Type A/E 47 mm diameter, Pall Corporation, Ann Arbor, MI.
(c) Type SMWP04700, Millipore Corporation, Bedford, MA.
(d) Model TA4, AIRFLOW Technical Products, Netcong, NJ.
(e) Model AV6, AIRFLOW Technical Products, Netcong, NJ.

The Annubar meter was calibrated by Dick Munns Company[a] for a range from 235 to 1,130 scfm. A copy of the calibration certificate is included in the field copy of the test plan (Baide 2003). Both the thermal anemometer and the vane anemometer were outside their allowed calibration periods. These instruments were used for indication purposes only during the tests.

Sample airflow rates were measured with two mass flow meters.[b] Each of these had its own digital readout, calibrated for 0 to 3 scfm. Both sample air mass flow meters were also connected to a datalogger for electronic recording of data on a laptop computer. Dry air was supplied from a standard high-pressure air cylinder equipped with a pressure regulator. Metering and shut-off (quarter-turn ball) valves were used to control dry air and sample airflow rates. A rotary vane vacuum pump was used to draw sample air through the sampling probe, filters, and sample flow meter.

The sample air and dry air mass flow meters, datalogger, and dedicated laptop computer were calibrated as a unit by the PNNL Instrument Calibration Facility. A copy of the calibration certificate is included in the field copy of the test plan (Baide 2003).

Condensate and entrained liquid in the VRS exhaust was collected in a plastic bucket and measured using either a 500- or 2,000-mL plastic graduated cylinder.

2.2.6 System Temperatures

Key VRS and sampling apparatus temperatures were measured using Type J thermocouples[c] connected to a thermocouple reader.[d] The LRVP separator vessel temperature was monitored to establish an approximate water vapor concentration in the exhaust, which was in turn used to establish the ratio of dry air to sample air needed to prevent condensation in the sample air mass flow meter. The VRS exhaust air temperature was measured in two locations: in the air stream itself via a port in the sampling apparatus blind flange and at the outlet of the sampling apparatus. Two other thermocouples were inserted under the heat tape of the filter sample probe and filter holder to ensure their temperatures were adequate to prevent water droplets from wetting the filters.

The Omega thermocouples and thermocouple reader were calibrated as a unit by the PNNL Instrument Calibration Facility. Readings were established as ± 2°C. A copy of the calibration certificate is included in the field copy of the test plan (Baide 2003).

(a) Dick Munns Company, Los Alamitos, CA.
(b) Model 826-NX-OV1-PV1-VT, Sierra Instruments, Monterey, CA.
(c) Model SA 1-J, Omega Engineering Inc., Stamford, CT.
(d) Model CN1507-TC, Omega Engineering Inc., Stamford, CT.

2.3 Test Sequence and Deviations from the Test Plan

Tests were conducted on August 6 and 7, 2003. The sequence of events is given in Table 2.2. Of the seven planned test runs using waste simulant, only five were actually performed. All four tests runs using the aqueous waste simulant were successfully performed, and all planned samples associated with these runs were collected. Only one of the three planned dry waste simulant runs was performed because of operability problems with the sample air mass flow meters. Issues encountered during the tests include the following:

1. Aerosol droplets in the VRS exhaust were apparently causing the Annubar airflow meter to give questionable readings. In addition, airflow rates in the VRS during waste retrieval were expected to be in the 75 to 250 cfm range, and the Annubar was neither calibrated for (nor did it respond to) flow rates less than 200 cfm. For indication of the exhaust flow rate, an Airflow TA4 thermal anemometer (serial number 087556, last calibrated in 1998) was used.

   The exhaust airflow rate data were originally specified as necessary for the tests because they were to be used to establish isokinetic sample airflow rates.[a] To compensate for the lack of accurate exhaust airflow rate data, the sample airflow rates were set to ensure sub-isokinetic sampling. When an air stream is sampled for aerosol particles using sub-isokinetic sampling rates, the sampling tends to collect more aerosol particles per unit volume of sampled air than are actually in the air stream being sampled. This ensures a conservatively high estimate of the aerosol concentration in the exhaust stream. The size distribution of particles collected on the filter is also biased by the disproportionate collection of larger particles.

2. A gradual rise in the temperature of the LRVP separator vessel from 35º to 59ºC was observed during the tests conducted on August 6, 2003. This coincided with an increase in the amount of liquid (condensate and entrained seal water) in the VRS exhaust line.

3. After completion of test runs on August 6, the LRVP separator vessel was drained, and the LRVP seal water from the aqueous waste simulant tests was replaced with fresh water. This maintenance related event was not a planned test event. It effectively eliminated the CsCl and RbCl chemical tracers from the system and negated the value of collecting further LRVP seal water samples. Only ancillary data were lost.

4. Field observations of the initial dry waste simulant test run on August 7 caused the run to be stopped before a complete batch of simulant had been collected. The appearance of fine suspended particulates in the exhaust line liquid, the increasing temperature of the LRVP separator vessel, and the relatively large quantities of exhaust line liquid collected all contributed to the decision by the test coordinator to abort the test run. Approximately 1,900 lb of dry waste simulant were collected; a complete batch would be 2,000 lb.

(a) Sampling of an air stream is isokinetic when the velocity of air entering the sampling probe matches the velocity of air flowing past the probe.

Table 2.2. Test Chronology

Date	Time	Event
6-Aug-03	14:25	One LRVP started for system warmup
		15-min warmup run performed
	14:43	LRVP stopped
	15:16	Filter sample air started
	15:17	One LRVP started
		Collected system blank "Filter1"
	15:36	LRVP stopped
	15:36	Filter sample air stopped
		Collected LRVP seal water sample "LRVP1"
		Added RbCl solution to LRVP seal water
		Added CsCl solution to simulant trough and mixed
		Collected aqueous waste simulant sample "CsCl1"
	16:17	Started filter sample airflow
	16:19	Started one LRVP
		Collected aerosol filter assembly sample "FilterCs1"
	16:27	Stopped LRVP
	16:27	Stopped filter sample airflow
		Collected LRVP seal water sample "LRVP2"
		Collected aqueous waste simulant sample "CsCl2"
	16:59	Started filter sample airflow
	17:01	Started two LRVPs
		Collected aerosol filter assembly sample "FilterCs2"
	17:08	Stopped LRVPs
	17:08	Stopped filter sample airflow
		Collected exhaust line liquid sample "Cond1"
		Collected LRVP seal water sample "LRVP3"
		Collected aqueous waste simulant sample "CsCl3"
	17:32	Started filter sample airflow
	17:36	Started two LRVPs
		Collected aerosol filter assembly sample "FilterCs3"
	17:42	Stopped LRVPs
	17:42	Stopped filter sample airflow
		Collected exhaust line liquid sample "Cond2"
		Collected LRVP seal water sample "LRVP4"
		Collected aqueous waste simulant sample "CsCl4"
	18:09	Started filter sample airflow
	18:10	Started two LRVPs
		Collected aerosol filter assembly sample "FilterCs4"
	18:18	Stopped LRVPs
	18:18	Stopped filter sample airflow
		Collected exhaust line liquid sample "Cond3"
		Collected LRVP seal water sample "LRVP5"
7-Aug-03	11:08	Started filter sample airflow
	11:09	Started one LRVP
		Collected aerosol filter assembly sample "Filter2"
	11:33	Collected exhaust line liquid sample "Cond4"
	11:38	Stopped LRVPs
	11:39	Stopped filter sample airflow
		Collected exhaust line liquid sample "Cond5"

The decision was also made at that time to drain the LRVP seal water, flush the LRVP separator vessel, and change the test sequence to include a test run using lubricating water in the AMS inlet nozzle. However, during the transfer of waste simulant from the VRS batch tank to the CTF spent simulant pond, a vent line overflowed with water, and the Sierra sample air and dry air mass flow meters were sprayed with water. The mass flow meters were briefly tested with dry air, and found to be inconsistent with each other. Based on their key role in the tests, the tests were stopped.

3.0 Aqueous Waste Simulant Tests

Four tests were run using water as an aqueous waste simulant. This section discusses the test conditions and presents the results of these test runs.

3.1 Aqueous Waste Simulant and LRVP Water Tracers

Four tests were run using water as an aqueous waste simulant. In each of these runs the VRS was used to "retrieve" about 240 gal of water from an open trough. About 500 mL of an aqueous solution of cesium chloride (CsCl) containing 117.2 g of CsCl (about 1.4 M CsCl) was added to the trough of water, and the trough of water was stirred to mix in the CsCl. The CsCl was added strictly as a tracer that could be identified and quantitatively measured in samples collected and did not alter the physical properties of the water significantly. CsCl was selected as a convenient source of ionic Cs, which could be measured at very low concentrations by standard analytical methods and was otherwise present at very low levels in the CTF process water.

Samples of the CsCl waste simulant were collected before each test run (see Table 2.2) and analyzed for Cs by inductively coupled plasma mass spectrometry (ICP-MS). Each sample consisted of four 25-mL vials of the waste simulant; two of these were combined and analyzed, and the remaining two were set aside for possible duplicate analysis. Table 3.1 lists the results of these analyses. The initial sample analyses are higher than subsequent analyses because the batch tank and waste transfer pumps contained a heel of water that was not mixed with the initial batch of waste simulant water.

Table 3.1. Aqueous Waste Simulant ICP-MS Analyses

Sample Name	Sample Collection Time	Cs Concentration (µg/mL)
CsCl1	Prior to CsCl1 aerosol sample test run	103
CsCl2	Prior to CsCl2 aerosol sample test run	73.8
CsCl3	Prior to CsCl3 aerosol sample test run	71.8
CsCl4	Prior to CsCl4 aerosol sample test run	72.0

As discussed in Section 2, a chemical tracer was added to the LRVP seal water. About 50 mL of an aqueous solution of rubidium chloride (RbCl) containing 14.08 g of RbCl (about 2.3 M) was added to the LRVP seal water tank before the first aqueous waste simulant test started. As with Cs, Rb was selected because it could be measured at very low concentrations and was present at very low concentrations in the CTF process water.[a] Samples of the LRVP seal water were collected from the LRVP separator vessel drain prior to the addition of the RbCl solution, and after each of the aqueous simulant batch test runs (see Table 2.2). Samples were collected by first flushing the piping upstream of the sampling port with several line volumes (a minimum of about 2 L) of seal water and then collecting the sample from the running stream. Each sample consisted of four 25-mL vials of the LRVP seal water; two of these were combined and analyzed, and the remaining two were set aside for possible duplicate analysis. The samples were analyzed for Rb and Cs. Analytical results are presented in Table 3.2.

Table 3.2. LRVP Seal Water Sample ICP-MS Analyses

Sample Name	Sample Collection Time	Rb Concentration (μg/mL)	Cs Concentration (μg/mL)
LRVP1	Prior to CsCl1 aerosol sample test run and prior to addition of RbCl	9.62×10^{-4}	$< 2.06 \times 10^{-6}$
LRVP2	After CsCl1 aerosol sample test run	75.8	0.135
LRVP3	After CsCl2 aerosol sample test run	49.0	14.9
LRVP4	After CsCl3 aerosol sample test run	40.4	17.0
LRVP5	After CsCl4 aerosol sample test run	33.1	22.7

In addition to the aerosol present, the exhaust line generally had droplets and thin streams of liquid running along the inside of the pipe. This was due both to condensation of water vapor downstream of the LRVP separator vessel, and the collection of entrained LRVP seal water droplets by the exhaust line wall. During the CsCl2, CsCl3, and CsCl4 test runs, this liquid was collected in a plastic bucket, its volume was estimated, and samples were collected and analyzed. (No exhaust line liquid sample was collected during the CsCl1 test run because there was very little of the liquid present.) Table 3.3 summarizes the available data.

Table 3.3. VRS Exhaust Line Liquid Volumes and Sample Analyses

Sample Name	Description	Estimated Volume (mL)	Rb Concentration (μg/mL)	Cs Concentration (μg/mL)
Cond1	Liquid collected during CsCl2 test run	450	1.98	0.00529
Cond2	Liquid collected during CsCl3 test run	550	10.6	3.16
Cond3	Liquid collected during CsCl4 test run	950	12.3	5.33

(a) An informal analysis conducted by PNNL prior to the aerosol tests indicated the background concentration of Rb in the CTF process water to be about 0.85 ng/mL.

Comparison of the exhaust line liquid Rb and Cs concentrations with the LRVP seal water concentrations suggests that the exhaust line liquid was composed predominantly of condensed water vapor and that entrained LRVP seal water accounted for less than 40% of the liquid in the exhaust line. Specific values are given in Table 3.4, where the concentration of each tracer in the liquid samples has been divided by the corresponding concentration in the LRVP seal water samples collected before and after each test run. Assuming that the Rb seal water concentration decreased linearly with time during each test run and that the Cs seal water concentration increased linearly, the average concentrations of each tracer in the seal water during a test run can be approximated by averaging their concentrations before and after the test run. This ratio corresponds to the fraction of entrained seal water in the exhaust line liquid sample.

Table 3.4. Comparison of Exhaust Line Liquid and LRVP Seal Water

Test Run	Concentration Ratio	Rb Ratio	Cs Ratio	Test Run Average
CsCl2	$\frac{\text{Concentration in Cond1}}{\text{Concentration in LRVP2}}$	0.026	0.039	0.027
	$\frac{\text{Concentration in Cond1}}{\text{Concentration in LRVP3}}$	0.040	0.0004	
	$\frac{\text{Concentration in Cond1}}{\text{Average Concentration in LRVP2 and LRVP3}}$	0.033	0.020	
CsCl3	$\frac{\text{Concentration in Cond2}}{\text{Concentration in LRVP3}}$	0.22	0.21	0.22
	$\frac{\text{Concentration in Cond2}}{\text{Concentration in LRVP4}}$	0.26	0.19	
	$\frac{\text{Concentration in Cond2}}{\text{Average Concentration in LRVP3 and LRVP4}}$	0.24	0.20	
CsCl4	$\frac{\text{Concentration in Cond3}}{\text{Concentration in LRVP4}}$	0.30	0.31	0.31
	$\frac{\text{Concentration in Cond3}}{\text{Concentration in LRVP5}}$	0.37	0.23	
	$\frac{\text{Concentration in Cond3}}{\text{Average Concentration in LRVP4 and LRVP5}}$	0.34	0.27	

Note that the estimated fraction of seal water in the exhaust line liquid samples is consistently smaller when calculated using the Cs data. The reason for this is not clear. If some if the Cs in the waste simulant was passed through the LRVPs without being collected in the seal water, the exhaust line liquid samples would have been enriched in Cs, but the opposite was observed.

3.2 Aerosol Sample Results

Aerosol samples from the VRS exhaust air stream were collected during the entire time that the VRS was used to collect the aqueous waste simulant. Sample airflow through the aerosol filters began before the LRVPs started and not turned off until after the LRVPs had been stopped. Sample airflow volumes were calculated for the period that the LRVPs were running and did not include the short times before and after LRVP operation that sample air was being drawn through the filters. This is justified because before the LRVPs were started the exhaust was relatively free of aerosols, and the time span between the LRVPs stopping and sampling itself stopping was relatively short. The errors associated with this treatment of the data tend to increase the calculated aerosol mass concentration, giving a conservatively large value. Table 3.5 lists the calculated sample air volumes for the system blank run (Filter1) and four aqueous waste simulant runs (FilterCs1, FilterCs2, FilterCs3, and FilterCs4).

Table 3.5. Aqueous Waste Simulant Test Aerosol Sample Volumes and Flow Rates

Sample Name	Sample Volume (m^3)	Estimated Total Exhaust Flow Rate (cfm)	Isokinetic Sample Airflow Rate (cfm)	Average Sample Airflow Rate (cfm)
Filter1	0.31	370	1.37	0.58
FilterCs1	0.088	Not Measured	--	0.34
FilterCs2	0.067	156	0.58	0.34
FilterCs3	0.050	245	0.91	0.29
FilterCs4	0.079	225	0.83	0.35

Because total exhaust airflow rates were not accurately measured and appeared to fluctuate with time, no attempt was made to collect the aerosol samples at isokinetic flow rates. Sample airflow rates were further constrained by the ranges of the sample air and dry air mass flow meters and the need to mix relatively large amounts of dry air with the sample air to prevent condensation of water in the meters. To address these issues, the aerosol sampling was conducted at sub-isokinetic airflow rates. Sub-isokinetic sampling tends to cause the collection of additional particles with a bias favoring larger particles. The effect is negligible (on the order of 3%) for 1 μm water droplets, and becomes potentially significant (on the order of a factor of three) for droplets larger than about 35 μm.[a] This has the effect of 1) collecting a greater than representative aerosol mass on the filter and 2) skewing the particle size distribution towards larger particles.

As discussed in Section 2.2.4, the filter samples were collected with dedicated sampling probe, filter holder, and two filters (in series) for each sample. The entire filter assembly was sealed after sampling and sent to 222-S Laboratory for analysis. Each filter assembly was then dismantled to remove the filters, leach the filters to remove the Cs and Rb, and rinse any

(a) Based on the correlation of Belyaey and Levin (1974) as presented by Brockman (1993).

particulate material attached to the inner wall of the sampling probe. The procedures for sample preparation and analysis are described by Callaway (2003a). Probe rinsate and filter leachate from each sample were combined and analyzed by ICP-MS. Table 3.6 lists the results in µg of each analyte per filter assembly; Callaway (2003b) provide further details and the results of laboratory quality assurance samples.

Table 3.6. Tracer Masses Measured in Filter Assemblies

Sample Name	Description	Rb Mass on Filter (µg)	Cs Mass on Filter (µg)
Filter1	System blank	0.0130	0.00197
FilterCs1	Run with one LRVP	0.931	0.0232
FilterCs2	Run with two LRVPs	1.09	0.0330
FilterCs3	Run with two LRVPs	0.613	0.0918
FilterCs4a	Run with two LRVPs, primary (upstream) filter	1.88	0.582
FilterCs4b	Breakthrough (downstream) filter	0.00980	0.00765

Inspection of the primary (upstream) and breakthrough (downstream) filters indicated no water spots or other evidence that any of the filters had been damaged or failed in any way (Callaway 2003b). To further verify that the upstream filters had indeed collected essentially all the aerosol material in the air stream, the downstream filter of FilterCs4 was analyzed for Rb and Cs. Results of this analysis are given in the last row of Table 3.6. Comparison of masses of Rb and Cs measured on the downstream filter with the masses measured on the upstream filters confirms that the upstream filter caught essentially the entire aerosol. The mass of Rb on the downstream filter is about 0.5% of the Rb mass on the upstream filter, and the mass of Cs on the downstream filter is about 1.3% of the Cs mass on the upstream filter. Note that the masses of Cs and Rb measured on the downstream filter (FilterCs4b) are also approximately the same as on the system blank (Filter1).

The mass of Cs measured in each filter assembly is directly related to the concentration of aqueous waste simulant aerosol present in the exhaust. The formula used to calculate aqueous aerosol concentration, $C_{Waste\ Aerosol}$, in units of mg/m^3 is

$$C_{Waste\ Aerosol} = \frac{1000\,\rho_{Waste}}{C_{Cs}\,V_{Sample}}\left(m_{Cs} - \frac{V_{Sample}}{V_{blank}}m_{Cs\,blank}\right) \qquad (3.1)$$

where ρ_{Waste} is the density of the waste simulant (g/mL); m_{Cs} and $m_{Cs\,blank}$ are the masses of Cs measured in the filter assembly and system blank, respectively (µg); C_{Cs} is the mass concentration of Cs in the waste simulant (µg/mL); and V_{Sample} and V_{blank} are the volumes of the aerosol sample and system blank, respectively (m^3). Assuming ρ_{Waste} = 1.0, Eq. (3.1) has been applied to the sample air volumes (Table 3.5), filter assembly Cs masses (Table 3.6), and the Cs concentrations in the waste simulant (Table 3.1) to calculate the waste aerosol concentrations for each sample. Results are listed in Table 3.7. As expected, the aerosol concentration of waste simulant in the exhaust increased with each successive test run, presumably for reasons described in Section 1.2.2.

Table 3.7. Aqueous Waste Simulant Test Aerosol Mass Concentrations

Test Run	Description	VRS Exhaust Aqueous Waste Simulant Aerosol Mass Concentration (mg/m^3)
CsCl1	Test run with one LRVP	2.5
CsCl2	Test run with two LRVPs	6.6
CsCl3	Test run with two LRVPs	25
CsCl4	Test run with two LRVPs	102

Note that the results in Table 3.7 are specific to an aqueous waste (simulant) having a density of 1.0 g/mL. Ignoring the small increases (decreases) in batch tank and LRVP separator vessel aerosol removal efficiencies associated with denser (less dense) materials, the aerosol concentrations given in Table 3.7 can be adjusted to any specific liquid waste density by multiplying the value in Table 3.7 by the specific gravity of the waste.

The aerosol mass concentration measured for test run CsCl4 is anomalously high, based on the expectation that increases in aerosol masses between test runs CsCl1, CsCl2, CsCl3, and CsCl4 should approximately follow the successive increases in LRVP seal water Cs concentrations given in Table 3.2. The reason for the high CsCl4 result was not clearly established, but it appears to be related to the increased temperature of the LRVP system. The volume of condensate and entrained seal water (Table 3.3) collected from the exhaust line during the CsCl4 test had increased, and it is possible the re-entrainment of relatively large droplets from the exhaust line wall resulted in the high aerosol mass concentration measured for this test run.[a]

(a) Informal testing conducted since these tests were performed included several test runs with the blind flange at the end of the aerosol sampling wye removed (see Figure 2.1). It was noticed that, as the amount of liquid in the exhaust line increased, there was a disproportionate increase in the number of large droplets in the exhaust. These droplets were large enough to feel as individual drops on one's hand, and too large to have passed directly from the LRVP separator to the sampling apparatus. It was presumed that they were produced by resuspension of the liquid as it passed over the connection between the elbow and the Plexiglas pipe just upstream of the sampling point. Because such droplets are also too big to remain suspended if accidentally released from the exhaust line, they would not contribute to the exposure of an individual more than a few feet away.

3.3 Batch Tank Collection Efficiency

The batch tank collection efficiency was estimated by dividing the amount of Cs transferred from the batch tank to the LRVP seal water by the total amount of Cs collected by the AMS during the run. The amount of Cs transferred from the batch tank was calculated by performing a mass balance on the Rb in the LRVP system to establish the amount of aqueous waste simulant added to the LRVP system.

$$m_{Cs\ Batch} = C_{Cs\ LRVP\ f} V_{LRVP\ f} - C_{Cs\ LRVP\ 0} V_{LRVP\ 0} + C_{Cs\ Cond} V_{Cond} + C_{Cs\ Drain} V_{Drain} \quad (3.2)$$

Where $m_{Cs\ Batch}$ is the total mass of Cs transferred from the batch tank to the LRVP seal water during the test run (mg), $C_{Cs\ LRVP\ f}$ and $V_{LRVP\ f}$ are the LRVP seal water Cs concentration and total volume at the end of the test run (µg/mL and L, respectively), $C_{Cs\ LRVP\ 0}$ and $V_{LRVP\ 0}$ are the LRVP seal water Cs concentration and total volume at the start of the test run (µg/mL and L, respectively), $C_{Cs\ Cond}$ and V_{Cond} are the exhaust line liquid Cs concentration and total volume (µg/mL and L, respectively), and $C_{Cs\ Drain}$ and V_{Drain} are the LRVP drained liquid Cs concentration and volume (µg/mL and L, respectively).

Samples of the LRVP seal water collected before and after the test runs establish $C_{Cs\ LRVP\ f}$ and $C_{Cs\ LRVP\ 0}$.[(a)] Exhaust line liquid was collected and analyzed (giving both $C_{Cs\ Cond}$ and V_{Cond}) for each test run except the first, which had markedly less liquid in the exhaust than subsequent test runs. To establish estimates for $V_{LRVP\ f}$, $V_{LRVP\ 0}$, and V_{Drain}, a material balance on the Rb in the LRVP system is used. Analogous to Eq. (3.2), the Rb material balance is given by

$$0 = C_{Rb\ LRVP\ f} V_{LRVP\ f} - C_{Rb\ LRVP\ 0} V_{LRVP\ 0} + C_{Rb\ Cond} V_{Cond} + C_{Rb\ Drain} V_{Drain} \quad (3.3)$$

where the left side is now zero because there is no Rb being introduced from the batch tank during the run.

Note that during the aqueous simulant tests, the amount of aqueous simulant passed through the batch vessel to the LRVP system was significantly greater than the amount of liquid lost via the exhaust line. The accumulation of liquid in the LRVP system was consequently handled by the system by automatic opening of the drain valve. Specifically, when the seal water level reached the high-level switch (i.e., when the seal water volume reaches about 140 L), the drain valve is automatically opened and seal water is drained out until the liquid level reaches the low-

(a) No LRVP sample was collected before the first test run because the RbCl solution had not been mixed throughout the LRVP system at that time.

level switch (i.e., when the seal water volume reaches about 85 L). Based on this description of the LRVP system, the following additional restraints are imposed:

$$\begin{aligned} 85\text{ L} \;\le\; & V_{LRVP\,f} \;\le\; 140\text{ L}, \\ 85\text{ L} \;\le\; & V_{LRVP\,0} \;\le\; 140\text{ L}, \\ & V_{Drain} = 0 \text{ or } 55\text{ L} \end{aligned} \tag{3.4}$$

Only one LRVP was used in the first test run, with the result that the RbCl added to the LRVP seal water prior to this run was not mixed with the reservoir of water in the second LRVP. This effectively decreased the working volume of seal water during this run by an estimated 20 L. Therefore, for the first test run,

$$\begin{aligned} 65\text{ L} \;\le\; & V_{LRVP\,f} \;\le\; 120\text{ L}, \\ 65\text{ L} \;\le\; & V_{LRVP\,0} \;\le\; 120\text{ L}, \\ & V_{Drain} = 0 \text{ or } 55\text{ L} \end{aligned} \tag{3.5}$$

Eq. (3.2) and (3.3) were solved for each of the test runs, with the restrictions given in Eq. (3.5) imposed on test run CsCl1, and Eq. (3.4) imposed on test runs CsCl2, CsCl3, and CsCl4. Table 3.8 lists the input values and results. Values not directly obtained from sample analyses or test measurements are given in brackets and their origin explained in the table endnotes.

The calculated batch tank collection efficiencies given at the bottom of Table 3.8 indicate that Test Run CsCl1, conducted with a single LRVP, caused the least amount of aqueous waste simulant to be passed through the batch tank. Test runs CsCl2, CsCl3, and CsCl4, each conducted with two LRVPs operating, had an average batch tank collection efficiency of 0.983, and allowed an average of 1.7 wt% of the waste simulant to pass through the batch tank.

3.4 LRVP Seal Water Aerosol in the Exhaust Air Stream

Results given in Tables 3.2 and 3.5 support the premise that the waste aerosol concentration in the exhaust should increase as the concentration of waste in the LRVP seal water increases (see Section 1.2.2). To estimate the likely aerosol concentration in the exhaust line at any time during a retrieval campaign, notably after many batches of waste have been retrieved, it is necessary to establish both the collection efficiency of the batch tank (see Section 3.4) and the amount of LRVP seal water entrained in the exhaust.

If all of the waste particles passing through the batch tank and entering the LRVPs were collected in the LRVP seal water, and the appearance of waste aerosol in the exhaust could be attributed solely to droplets of LRVP seal water entrained in the exhaust, then the waste aerosol concentration in the exhaust should be directly proportional to the concentration of waste in the

Table 3.8. Batch Tank Efficiency Calculation Inputs and Results

Parameter	**Notes**	**Test Run CsCl1**	**Test Run CsCl2**	**Test Run CsCl3**	**Test Run CsCl4**
Initial Seal Water Volume, $V_{LRVP\,0}$, (L)	(a)	[115]	[69]	[103]	[122]
Initial Seal Water Cs Conc., $C_{Cs\,LRVP\,0}$, (µg/mL)		0	0.135	14.9	17.0
Initial Seal Water Rb Conc., $C_{Rb\,LRVP\,0}$ (µg/mL)	(a)	[87]	75.8	49.0	40.4
Exhaust line liquid volume, V_{Cond}, (L)	(b)	[0.45]	0.45	0.55	0.95
Exhaust line liquid Cs Conc., $C_{Cs\,Cond}$, (µg/mL)	(b)	[0.00529]	0.00529	3.16	5.33
Exhaust line liquid Rb Conc., $C_{Rb\,Cond}$, (µg/mL)	(b)	[1.98]	1.98	10.6	12.3
Seal Water Drained Volume, V_{Drain}, (L)		55	0	0	55
Drained Seal Water Cs Conc., $C_{Cs\,Drain}$, (µg/mL)	(c)	[0.135]	--	--	[22.7]
Drained Seal Water Rb Conc., $C_{Rb\,Drain}$, (µg/mL)	(d)	82	--	--	[35]
Final LRVP Seal Water Volume, $V_{LRVP\,f}$, (L)		72	107	125	90
Final Seal Water Cs Conc., $C_{Cs\,LRVP\,f}$, (µg/mL)		0.135	14.9	17.0	22.7
Final Seal Water Rb Conc., $C_{Rb\,LRVP\,f}$, (µg/mL)		75.8	49.0	40.4	33.1
Volume of Seal Water used in sample flush (L)		2.7	3.3	3.7	
Mass of Cs passed from Batch Tank, $m_{Cs\,Batch}$, (mg)		17.1	1,580	590	1,224
Mass of Cs entering Batch Tank (mg)	(e)	[93,440]	[66,950]	[65,136]	[65,317]
Collection Efficiency of Batch Tank		**0.9998**	**0.976**	**0.991**	**0.981**

(a) Just before the start of test run CsCl1 the RbCl solution, containing 9,950 mg of Rb, was added to the LRVP seal water. The values of initial seal water volume and initial seal water Rb concentration for this run may vary as long as $C_{Cs\,LRVP\,0}\,V_{LRVP\,0}$ = 9,950 mg. Subsequent initial seal water volumes were calculated by subtracting the volume of seal water used in sample flush (see Section 3.1) from the calculated final seal water volume of the previous test run.
(b) No exhaust line liquid sample was collected during Test Run CsCl1, in part because little was present to collect. It was assumed in calculations that the exhaust line liquid volume and composition were the same that measured in Test Run CsCl2.
(c) LRVP seal water drained automatically was assumed to have the same Cs concentration as the LRVP seal water sample collected at the end of the test run. This tends to overestimate the amount of Cs lost via the automatic drain and decrease the batch tank collection efficiency.
(d) The Rb concentration in LRVP seal water drained automatically was calculated by assuming the Rb present in the LRVP system was diluted with aqueous waste simulant to a volume of 140 L (the point at which the automatic drain is activated).
(e) Mass of Cs entering batch tank was calculated by multiplying the measured Cs concentration in the aqueous waste simulant (from Table 3.1) by the total volume of simulant collected during the test run (907 L).

LRVP seal water. The volume of LRVP seal water entrained[(a)] in the VRS exhaust (mL/m^3) can be calculated with the following equation:

$$C_{LRVP\ water\ aerosol} = \frac{m_{Cs}}{C_{Cs\ LRVP} V_{Sample}} \quad (3.6)$$

where $C_{Cs\ LRVP}$ is the concentration of Cs in the LRVP seal water (μg/mL).

Note that $C_{Cs\ LRVP}$ increased throughout each test run because waste simulant passed through the batch tank and was added to the LRVP seal water (see Table 3.2). Even if the influx of Cs from the batch tank was constant during the run, the change in $C_{Cs\ LRVP}$ would not be linear because the LRVP seal water volume is also gradually increasing. Compounding this is the fact that during testing approximately 14.5 gal of the LRVP seal water was automatically drained from the separator vessel when the liquid level reached the high-level indicator,[(b)] and no record of these automatic drains is available. In lieu of better data, the measured values of $C_{Cs\ LRVP}$ from LRVP seal water samples collected before and after each run were averaged (see Table 3.2), and used in Eq. (3.6) with m_{Cs} values from Table 3.6 and V_{Sample} from Table 3.5. Results of these calculations are given in the third column of Table 3.9.

Table 3.9. LRVP Seal Water Aerosol Concentration in Exhaust Air Stream

Test Run	**Run Description**	**Aerosol Seal Water Concentration in Exhaust Air Stream (mL/m^3)**	
		From Cs Data	**From Rb Data**
CsCl1	Run with one LRVP	3.9	0.13
CsCl2	Run with two LRVPs	0.066	0.26
CsCl3	Run with two LRVPs	0.12	0.27
CsCl4	Run with two LRVPs	0.37	0.65

The relationship between the mass of Rb in the filter assembly, m_{Rb}, and LRVP seal water Rb concentration, $C_{Rb\ LRVP}$, to the LRVP seal water concentration in the exhaust line is analogous to Eq. (3.6):

(a) Waste or LRVP water that is "entrained" in the exhaust is categorically considered an aerosol here and does not include the droplets and small streams of liquid running along the inside wall of the VRS exhaust line.

(b) The LRVP water level is controlled by adding make-up water when the level drops too low and by draining seal water when the level rises too high. When the seal water reaches the high-level switch, indicating too much seal water present, a drain valve is automatically opened and seal water is drained to a sump until the low-level switch is reached. When the seal water reaches the low-level switch (either during normal operation or when the level was automatically drained) the valve controlling make-up water is automatically opened until the low-level switch is again submerged.

$$C_{LRVP\ water\ aerosol} = \frac{m_{Rb}}{C_{Rb\ LRVP} V_{Sample}} \quad (3.7)$$

Like the Cs concentration, the Rb concentration in the LRVP seal water was also changing during the test runs. The Rb concentration decreased during the run as aqueous waste simulant was carried over from the batch vessel and diluted the Rb. As with Cs, the Rb concentration would not have changed linearly with time. In lieu of better data, the Rb concentration was assumed to be approximately linear, and the $C_{Rb\ LRVP}$ for each test run was calculated by averaging the Rb concentrations measured in the LRVP seal water samples collected before and after the test run. Results of these calculations are given in the last column of Table 3.9.

Results in Table 3.9 from Cs and Rb data should agree. The greatest inconsistency occurs for the first test run, where it appears the value for $C_{Cs\ LRVP}$ is anomalously low, resulting in the high calculated aerosol concentration.

4.0 Dry Waste Simulant Test

One test was run using fine sand as a dry waste simulant. This section discusses the test conditions and presents the results of that test run.

4.1 Aerosol Sample Analyses and Results

The dry waste simulant test run filter sample and the system blank filter sample were both subjected to gravimetric analysis and particle size analysis. The filter assemblies were disassembled and the particulate sample recovered by 222-S Laboratory. Particles on the inside of the sampling probe and upstream half of the filter holder were rinsed off with de-ionized water and added to the upstream filter sample. The samples were incinerated (to burn off the filter itself), cooled, and weighed. Details of the analyses are given by Callaway (2003b). Table 4.1 lists the results, considered accurate to ± 0.5 mg, along with the measured weight of an incinerated clean, unused filter.

Table 4.1. Dry Waste Simulant Filter Sample Gravimetric Analysis Results

Test Run	Description	Mass (mg)	Sample Air Volume (L)	Aerosol Concentration (mg/m^3)
Filter1	System blank	0.8	310	2.6
Filter2	Dry waste simulant test run	8.7	702	9.8[a]
--	Clean, unused filter	0.7	--	--
(a) Value includes correction for 2.6 mg/m^3 of background particles.				

Also listed in Table 4.1 are the sample air volumes for each sample, and the calculated aerosol concentration. Note that the aerosol concentration for the dry waste simulant test run has been corrected for the measured background (system blank) aerosol concentration.

The incinerated samples (ash) and sample rinsate were then added to vials of water, agitated, and transferred to PNNL for particle size analysis. Particle size analysis was conducted at PNNL using a Particle size analyzer.[a] Table 4.2 gives key statistical results for these samples. Numerical results are included in Appendix A.

The aerosol size statistics given in Table 4.2 are based on a count of particles in each size bin of the distribution and indicate that the average particle size is relatively small. However, because the mass of the particles is proportional to the cube of the diameter, the mean particle masses are significantly larger than the mean particle diameters. This is illustrated in Figure 4.1,

(a) Analyses were conducted using a Horiba LA-920 particle size analyzer.

Table 4.2. Dry Waste Simulant Filter Sample Particle Size Analyses

Parameter	System Blank (Filter1)	Dry Waste Simulant Run (Filter2)	Clean Unused Filter
Median particle diameter (µm)	3.4	7.9	34.9
Mean particle diameter (µm)	4.4	9.0	34.9
Mode of particle diameters (µm)	8.17	12.4	42.2

where the total mass of particles as a function of particle size (effective diameter) is plotted for the incinerated dry waste simulant sample (Filter2) and the system blank sample assuming all particles are spherical and have a nominal density of 2.5 g/mL. This figure illustrates that about 80% of aerosol particle mass collected during the dry waste simulant test run was associated with particles greater than 10 µm in diameter. Also, because the system blank and Filter2 samples have comparable aerosol masses below 10 µm, much of the mass of particles smaller than 10 µm in the Filter2 sample is attributable to materials present in the system before dry waste simulant was introduced.

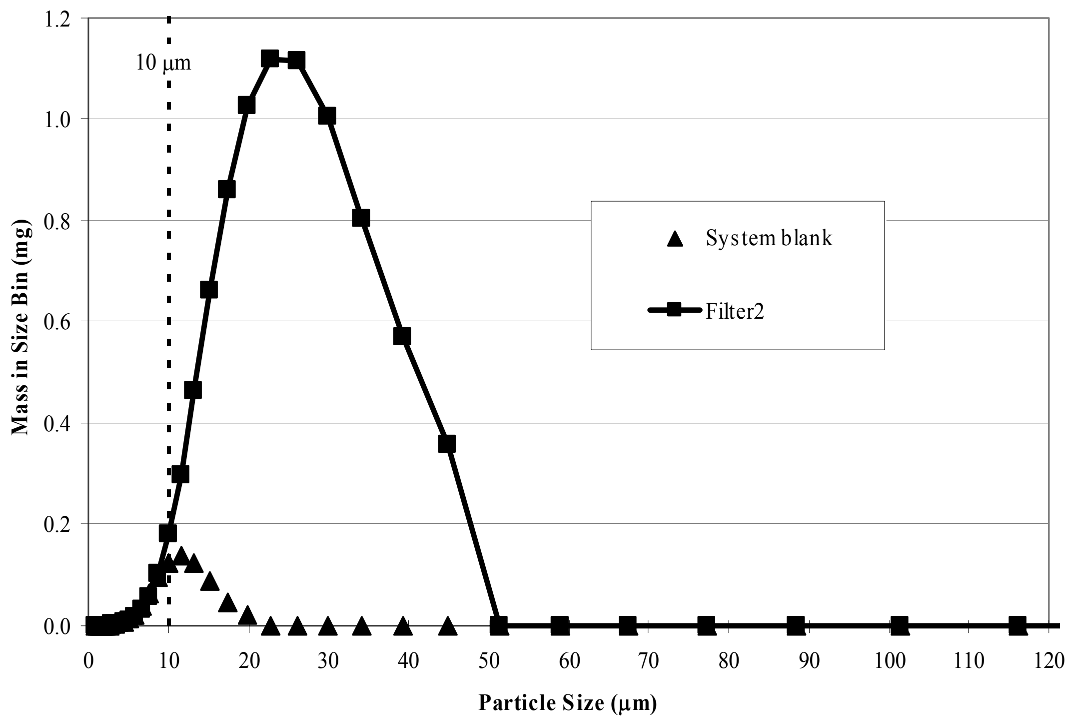


Figure 4.1. Total Mass of Particles as a Function of Particle Size

4.2 Particulates in Exhaust Line Liquid Samples

The fluid running along the inside of the exhaust line during the dry waste simulant test run was collected in a catch container. Two samples were collected. Approximately 23 L of fluid was collected during the 29-minute test run. The samples were collected by first vigorously stirring the fluid catch container to resuspend any settled particles and then submerging the sample vials to flush and fill them. The sample labeled "Cond4" was collected from the initial 15 L of fluid, and the sample labeled "Cond5" was collected from the final 8 L of fluid.

The 222-S Laboratory conducted a gravimetric analysis of sample Cond5 and determined it had a solids content of 25 g/L (Callaway 2003b). As part of the analytical procedure, the Cond5 sample was centrifuged and the liquid decanted to a separate container. It was noted by the analyst that even prolonged centrifugation did not completely remove all suspended particles from the liquid portion of Cond5. Particle size analyses were conducted on Cond4 and both the Cond5 solids and decanted liquid. Table 4.3 lists key statistical parameters from the particle size analyses. Complete analyses are given in Appendix A.

Table 4.3. Size Analyses of Particles in Exhaust Line Liquid

Parameter	**Cond4 Sample Particles**	**Cond5 Sample Centrifuged Solid Particles**	**Cond5 Sample Decanted Liquid Suspended Particles**
Median particle diameter (μm)	10.3	8.9	13.3
Mean particle diameter (μm)	12.7	10.5	13.2
Mode of particle diameters (μm)	12.4	12.4	16.3

A comparison of results in Tables 4.2 and 4.3 (as well as the more detailed analyses given in Appendix A) indicates that the particles collected by the aerosol filter sample had a size distribution very similar to that of the two exhaust line liquid samples, suggesting that the loss of aerosol particles to the exhaust line wall between the outlet of the LRVP separator vessel and the aerosol sampling point did not strongly affect the aerosol sample particle size distribution.

5.0 Conclusions

The tests described in this report have characterized the efficiency with which waste simulants are removed from the entraining air stream in the C-200 VRS under various conditions. The important conclusions from the tests are

1. As expected, operation of the VRS causes a gradual increase in the concentration of aqueous waste simulant in the LRVP seal water. Comparison of the amounts of Rb and Cs tracers in the exhaust line liquid samples suggests that nearly all the aqueous simulant passed through the batch tank to the LRVPs was collected by the LRVP seal water. The LRVPs appear to be highly effective at scrubbing waste particles from the air leaving the batch tank for aqueous waste.
2. Also as expected, aqueous waste simulant aerosol mass concentrations in the exhaust line increased in each successive test run. However, the increases in aerosol concentration were expected to be about proportional to the increases in LRVP seal water waste simulant concentration, and they were not. Instead, the aerosol concentrations increased much faster than the LRVP simulant waste concentrations. This has not been definitively explained, but it is thought to be due to the gradually increasing temperature of the LRVP system and secondary phenomena (e.g., re-entrainment of droplets from exhaust line walls).
3. The dry waste simulant particles collected by the filter samples tended to range in size (effective diameter) from about 1 to 50 μm, and about 80% of the aerosol mass was due to particles greater than 10 μm. The dry waste simulant itself was determined to be composed primarily of much larger particles, having a mean particle size of about 280 μm based on an average of four measurements (see Appendix A). This indicates that the VRS is very effective at collecting waste particles larger than about 50 μm. Visual inspection of the LRVP seal water drained after the tests indicated larger particles were being collected by the LRVP seal water, implying that the 50 μm particle size was essentially the cut size of the LRVP separator vessel. This is supported by similar particle size analyses of the solid particles in the exhaust line liquid samples (Cond4 and Cond5).
4. Batch tank aqueous waste simulant collection efficiency was markedly higher for the test conducted with one LRVP than for the three tests conducted with two LRVPs. The calculated batch tank efficiency with one LRVP was 99.98%, and with two LRVPs the average was about 98.3%. The reason for this difference was not established but could be explained by a nonrepresentative LRVP2 sample or an error in its chemical analysis. Because it is inconsistent with subsequent test runs, it is recommended that the batch efficiency calculated for the CsCl1 test run not be used for safety-related analyses and that the batch tank collection efficiency be assumed to be 98.3% regardless of whether one or two LRVPs are used.

5. The VRS exhaust was estimated to contain between 0.07 to 0.7 mL/m^3 of LRVP seal water as an aerosol, excluding a single anomalously high value associated with Cs measurements in the first test run.

6.0 References

Baide DG. 2003. *Field Data from the C-200 Series Retrieval Project Particulate and Aerosol Tests.* RPP-18229 Rev. 0, CH2M HILL Hanford Group, Inc., Richland, WA.

Baide DG and JL Huckaby. 2003. *C-200 Series Retrieval Project – Test Implementation Plan for Measurement of Particulate and Aerosol Discharge for the Vacuum Retrieval System*. RPP-17356 Rev. 1, CH2M HILL Hanford Group, Inc., Richland, WA.

Belyaev SP and LM Levin. 1974. "Techniques for Collection of Representative Aerosol Samples." *J. Aerosol Science,* 3:127-140.

Brockman JE. 1993. "Sampling and Transport of Aerosols." *Aerosol Measurement—Principles, Techniques, and Applications,* K Willeke and PA Baron, eds. Van Nostrand Reinhold, New York.

Callaway WS. August 12, 2003a. *Test Plan and Procedure: Analytical Support of C-200 Vacuum Retrieval System Testing.* Letter FH-0303138 to JL Huckaby, Pacific Northwest National Laboratory, dated August 12), Fluor Hanford, Richland, Washington.

Callaway WS. September 11, 2003b. *Preparation and Analysis of C-200 Vacuum Retrieval System Test Samples*. Letter report FH-0303567 to DG Baide, CH2M HILL Hanford Group, Inc. Fluor Hanford Inc., Richland, WA.

Creze CM and JR Jewett. 2003. *Characteristics of Waste in the C-200 Series of Hanford Underground Waste Tanks.* RPP-14627 Rev 0, Numatec Hanford Company, Richland, WA.

Appendix

Particle Size Analysis Results

LANE MOUNTAIN COMPANY

P.O. BOX 127
PLANT: VALLEY, WASHINGTON 99181
Phone: 509-937-2221 Fax: 509-937-2523

SCREEN ANALYSIS - % RETAINED
+ or - 5%

U.S. SCREEN SIZE	LM#16	LM# 20/30	LM# 30	LM# 50	LM# 70	LM# 125
12	0.5					
16 or 1.168 MM	11.0					
20 or .883 MM	60.0	2.5				
30 or .589 MM	24.0	29.0	12.0			
40 or .417 MM	2.0	55.0	22.0	24.5		
50 or .297 MM		12.0	24.0	45.5	3.5	1.0
70 or .208 MM			14.0	16.0	32.0	1.5
100 or .147 MM			11.0	7.5	31.0	4.5
140 or .105 MM			9.0	3.5	18.0	25.0
200 or .074 MM				1.5	10.5	39.0
PAN	2.5	1.5	8.0	- 1.5	5.0	29.0
	100.0	100.0	100.0	100.0	100.0	100.0

SILICA INGREDIENTS

CHEMICAL ANALYSIS	PERCENT
SILICON DIOXIDE	99.4
ALUMINUM OXIDE	0.21
IRON OXIDE	0.035
TITANIUM DIOXIDE	0.02
CALCIUM OXIDE	0.10
MAGNESIUM OXIDE	0.00
SODIUM OXIDE	0.00
POTASSIUM OXIDE	0.06
L.O.I. (1200 deg. C)	0.20
	100.0

CHAIN OF CUSTODY/SAMPLE ANALYSIS REQUEST

C.O.C. No. VRS Aerosol COC #4

Page 1 of 1

Collector: W. S. Callaway	Contact/Requestor: J. L. Huckaby	Telephone No.: 375-3623; MSIN: K7-15; FAX: 375-3865
SAF No.: N/A	Sample Origin: 200W/222-SA	Purchase Order/Charge Code: N/A
Project Title: C-200 VRS Testing	Logbook No.: N/A	Ice Chest No.: N/A; Temp.: N/A
Shipped To (Lab): Returned To Client	Method of Shipment: Picked Up by Client at 222-SA	Bill of Lading/Air Bill No.: N/A
Protocol: N/A	Data Turnaround: N/A	Offsite Property No.: N/A

Sample No.	Lab ID	*	Date	Time	No./Type Container	Sample Analysis	Preservative
Filter 1A	S03M000429	SE	8/26/03	14:00	20 mL Glsss	Recovered solids in deionized water.	None
Filter 2A	S03M000430	SE	8/26/03	14:00	20 mL Glass	Recovered solids in deionized water.	None
Cond4	S03M000411	SE	8/26/03	14:00	20 mL Plastic	Original sample slurry.	None
Cond5	S03M000416	SE	8/26/03	14:00	20 mL Glass	Recovered solids in deionized water.	None
Cond5	S03M000412	W	8/26/03	14:00	20 mL Plastic	Decanted liquid from original Cond5 sample slurry.	None
Filter 4A	N/A	SE	8/26/03	14:00	20 mL Glass	Recovered solids in deionized water.	None
Sand1	S03M000415 *	SO	8/26/03	14:00	16 oz Plastic	Five 1/16 splits w/ rotary riffler and balance of original sample.	None
Sand2	S03M000414	SO	8/26/03	14:00	20 mL Plastic	Original sample of test sand.	None
						NOTE: All above samples being returned to client for final disposition.	

POSSIBLE SAMPLE HAZARDS/REMARKS (List all known wastes) MSDS ☐ Yes ☒ No

Quartz sand and dilute aqueous slurries of non-hazardous particulates. No hazards identified.

SPECIAL INSTRUCTIONS

None

* NOTE S03M000415 SAMPLE IS LABELED S03M000413 ON THE BOTTLE. JLH 9/4/03

Hold Time: N/A

Relinquished By (Print)	Sign	Date/Time	Received By (Print)	Sign	Date/Time
W.S. CALLAWAY	W.S. Callaway	8/26/03 14:00	PAUL GRAY	Paul Gray	8/26/03 1400
PAUL GRAY	Paul Gray	8/26/03 1440	Carolyn Nguyen	Carolyn Nguyen	8/26/03 1440

Matrix*

S = Soil		DS = Drum Solids	
SE = Sediment		DL = Drum Liquids	
SO = Solid		T = Tissue	
SL = Sludge		WI = Wipe	
W = Water		L = Liquid	
O = Oil		V = Vegetation	
A = Air		X = Other	

FINAL SAMPLE DISPOSITION — Disposal Method (e.g., Return to customer, per lab procedure, used in process): Return to Customer — Disposed By: W.S. Callaway — Date/Time: 8/26/03 - 14:00

All samples containing hazardous materials shall be picked up by requestor and returned to parent container or site of origin.

A-6003-432 (05/02)

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25
LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309020954183
Sample Name :S03m000429
Material :S03m000429
Source :
Lot Number :1000 24hr's

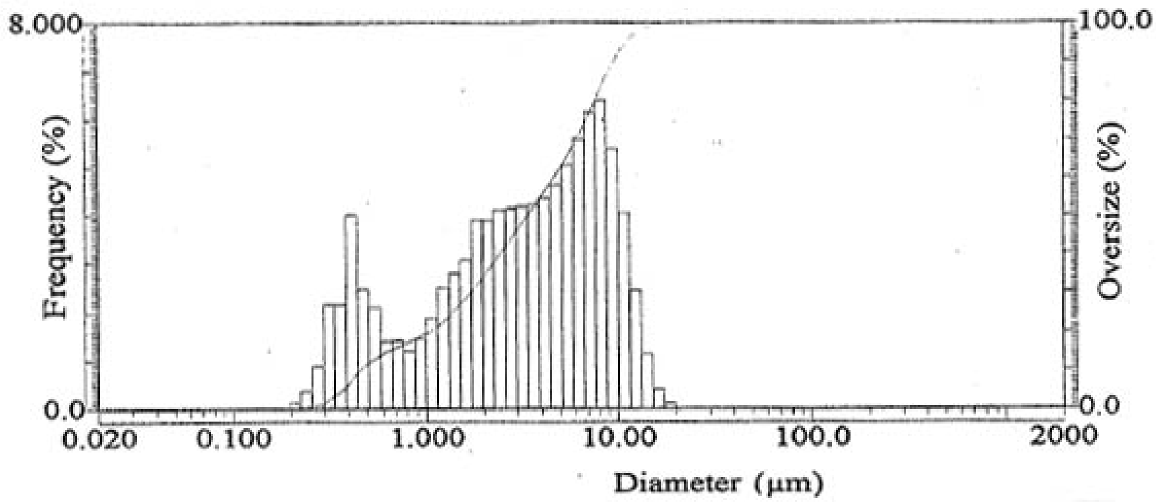
Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 40497(cm² /cm³)
Median : 3.4074(µm)
Mean : 4.3962(µm)
Mode : 8.1711(µm)
Span : 2.6931

Circulation Speed :3
Ultra sonic :00:27 (7)
Laser T% : 98.8(%)
Lamp T% : 97.6(%)
Calc. Level :30
R.R.Index :180a010I
Variance : 12.875(µm²)
S.D. : 3.5881(µm)
CV : 81.6192
Geo. Mean : 2.7885(µm)
Chi-2 : 0.147233

% on Diameter
:(1)5.000 (%)- 0.374(µm)
(2)10.00 (%)- 0.455(µm)
(3)20.00 (%)- 1.036(µm)
(4)30.00 (%)- 1.741(µm)
(5)40.00 (%)- 2.458(µm)
(6)60.00 (%)- 4.660(µm)
(7)70.00 (%)- 6.114(µm)
(8)80.00 (%)- 7.685(µm)
(9)90.00 (%)- 9.631(µm)
(10)95.00 (%)- 11.211(µm)

Diameter on %
:850.0 (µm)- 100.000(%)
600.0 (µm)- 100.000(%)
425.0 (µm)- 100.000(%)
300.0 (µm)- 100.000(%)
212.0 (µm)- 100.000(%)
150.0 (µm)- 100.000(%)
106.0 (µm)- 100.000(%)
75.00 (µm)- 100.000(%)
53.00 (µm)- 100.000(%)
38.00 (µm)- 100.000(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	2.443	12.046	47	11.565	4.046	95.926	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	2.057	14.102	48	13.246	2.419	98.345	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	1.407	15.510	49	15.172	1.125	99.470	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	1.416	16.925	50	17.377	0.409	99.879	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	1.210	18.135	51	19.904	0.121	100.000	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	1.443	19.578	52	22.797	0.000	100.000	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	1.886	21.464	53	26.111	0.000	100.000	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	2.491	23.954	54	29.907	0.000	100.000	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	2.787	26.741	55	34.255	0.000	100.000	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	3.058	29.799	56	39.234	0.000	100.000	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	3.902	33.701	57	44.938	0.000	100.000	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	3.878	37.580	58	51.471	0.000	100.000	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	4.102	41.682	59	58.953	0.000	100.000	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	4.144	45.825	60	67.523	0.000	100.000	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	4.189	50.014	61	77.339	0.000	100.000	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	4.208	54.222	62	88.583	0.000	100.000	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	4.369	58.590	63	101.460	0.000	100.000				
18	0.226	0.124	0.124	41	5.122	4.639	63.230	64	116.210	0.000	100.000				
19	0.259	0.367	0.491	42	5.867	5.062	68.292	65	133.103	0.000	100.000				
20	0.296	0.872	1.363	43	6.720	5.613	73.905	66	152.453	0.000	100.000				
21	0.339	2.127	3.490	44	7.697	6.165	80.070	67	174.616	0.000	100.000				
22	0.389	2.113	5.603	45	8.816	6.405	86.475	68	200.000	0.000	100.000				
23	0.445	4.000	9.602	46	10.097	5.405	91.880	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25

LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309021001184
Sample Name :S03M000430
Material :S03M000430
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

Circulation Speed :3
Ultra sonic :00:40 (7)
Laser T% : 93.1(%)
Lamp T% : 88.2(%)
Calc. Level :30
R.R.Index :180a010I

S.P. Area : 24668(cm² /cm³)
Median : 7.8884(μm)
Mean : 9.0071(μm)
Mode : 12.3628(μm)
Span : 2.2890

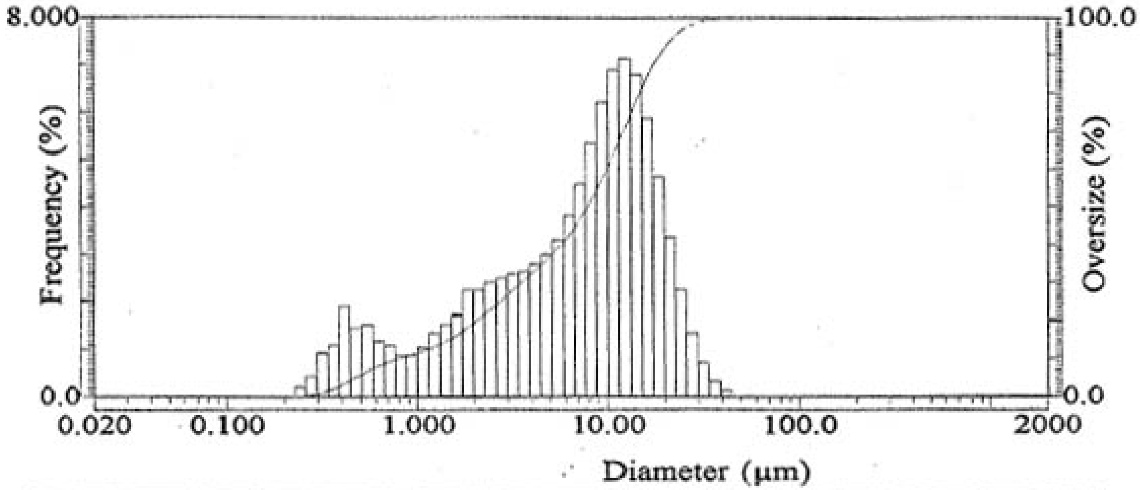
Variance : 52.680(μm²)
S.D. : 7.2581(μm)
CV : 80.5822
Geo. Mean : 5.5569(μm)
Chi-2 : 0.054840

% on Diameter

:(1)5.000 (%)- 0.464(μm)
(2)10.00 (%)- 0.791(μm)
(3)20.00 (%)- 2.056(μm)
(4)30.00 (%)- 3.581(μm)
(5)40.00 (%)- 5.688(μm)
(6)60.00 (%)- 9.968(μm)
(7)70.00 (%)- 12.135(μm)
(8)80.00 (%)- 14.761(μm)
(9)90.00 (%)- 18.847(μm)
(10)95.00 (%)- 22.583(μm)

Diameter on %

:850.0 (μm)- 100.000(%)
600.0 (μm)- 100.000(%)
425.0 (μm)- 100.000(%)
300.0 (μm)- 100.000(%)
212.0 (μm)- 100.000(%)
150.0 (μm)- 100.000(%)
106.0 (μm)- 100.000(%)
75.00 (μm)- 100.000(%)
53.00 (μm)- 100.000(%)
38.00 (μm)- 99.780(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	1.458	6.021	47	11.565	6.866	67.475	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	1.526	7.546	48	13.246	7.127	74.602	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	1.174	8.721	49	15.172	6.766	81.368	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	1.078	9.798	50	17.377	5.858	87.225	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.868	10.666	51	19.904	4.639	91.865	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.879	11.546	52	22.797	3.369	95.234	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	1.047	12.593	53	26.111	2.236	97.470	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	1.346	13.939	54	29.907	1.340	98.810	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	1.520	15.459	55	34.255	0.714	99.524	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	1.711	17.170	56	39.234	0.336	99.859	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	2.220	19.390	57	44.938	0.141	100.000	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	2.220	21.610	58	51.471	0.000	100.000	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	2.385	23.995	59	58.953	0.000	100.000	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	2.476	26.471	60	67.523	0.000	100.000	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	2.575	29.046	61	77.339	0.000	100.000	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	2.633	31.679	62	88.583	0.000	100.000	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	2.780	34.459	63	101.460	0.000	100.000				
18	0.226	0.000	0.000	41	5.122	2.985	37.444	64	116.210	0.000	100.000				
19	0.259	0.219	0.219	42	5.867	3.310	40.755	65	133.103	0.000	100.000				
20	0.296	0.445	0.664	43	6.720	3.795	44.549	66	152.453	0.000	100.000				
21	0.339	0.928	1.592	44	7.697	4.480	49.030	67	174.616	0.000	100.000				
22	0.389	1.074	2.667	45	8.816	5.352	54.382	68	200.000	0.000	100.000				
23	0.445	1.896	4.563	46	10.097	6.206	60.589	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25

LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309171430205
Sample Name :S03M000430 REDO
Material :S03M000430 REDO
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 1.0335E+5(cm²/cm³)
Median : 0.6727(μm)
Mean : 1.0164(μm)
Mode : 0.4146(μm)
Span : 2.7812

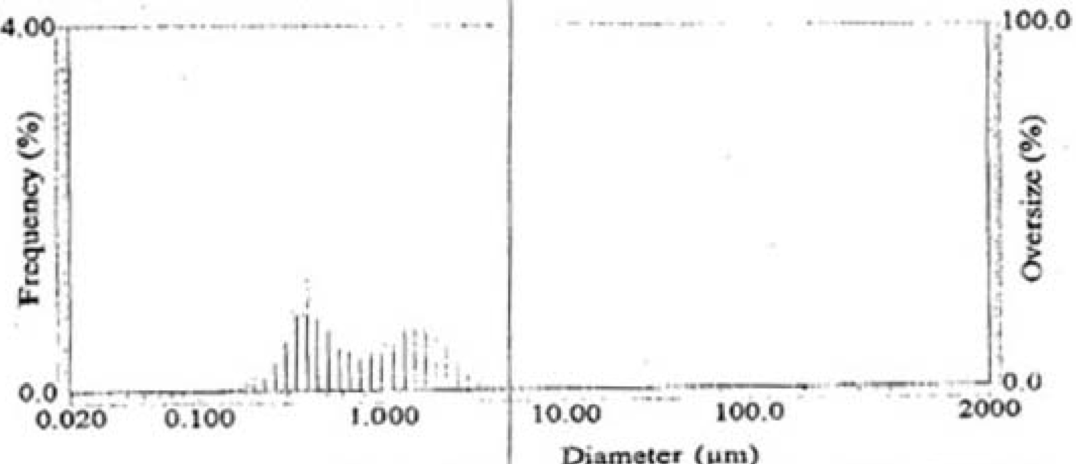
Circulation Speed :3
Ultra sonic :00:14 (7)
Laser T% : 92.9(%)
Lamp T% : 87.8(%)
Calc. Level :30
R.R.Index :180a010i
Variance : 0.6133(μm²)
S.D. : 0.7831(μm)
CV : 77.0474
Geo. Mean : 0.7597(μm)
Chi-2 : 0.187453

% on Diameter

:(1)5.000 (%)- 0.260(μm)
(2)10.00 (%)- 0.300(μm)
(3)20.00 (%)- 0.361(μm)
(4)30.00 (%)- 0.422(μm)
(5)40.00 (%)- 0.503(μm)
(6)60.00 (%)- 1.020(μm)
(7)70.00 (%)- 1.350(μm)
(8)80.00 (%)- 1.723(μm)
(9)90.00 (%)- 2.171(μm)
(10)95.00 (%)- 2.556(μm)

Diameter on %

:850.0 (μm)- 100.000(%)
600.0 (μm)- 100.000(%)
425.0 (μm)- 100.000(%)
300.0 (μm)- 100.000(%)
212.0 (μm)- 100.000(%)
150.0 (μm)- 100.000(%)
106.0 (μm)- 100.000(%)
75.00 (μm)- 100.000(%)
53.00 (μm)- 100.000(%)
38.00 (μm)- 100.000(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	6.849	40.697	47	11.565	0.000	100.000	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	5.486	46.183	48	13.246	0.000	100.000	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	3.661	49.844	49	15.172	0.000	100.000	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	3.546	53.390	50	17.377	0.000	100.000	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	2.875	56.265	51	19.904	0.000	100.000	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	3.272	59.537	52	22.797	0.000	100.000	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	4.149	63.686	53	26.111	0.000	100.000	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	5.339	69.025	54	29.907	0.000	100.000	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	5.581	74.606	55	34.255	0.000	100.000	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	5.554	80.160	56	39.234	0.000	100.000	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	6.425	86.585	57	44.938	0.000	100.000	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	5.046	91.631	58	51.471	0.000	100.000	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	3.836	95.467	59	58.953	0.000	100.000	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	2.427	97.894	60	67.523	0.000	100.000	83	1531.914	0.000	100.000
15	0.150	0.106	0.106	38	3.409	1.304	99.198	61	77.339	0.000	100.000	84	1754.613	0.000	100.000
16	0.172	0.235	0.341	39	3.905	0.579	99.777	62	88.583	0.000	100.000	85	2000.000	0.000	100.000
17	0.197	0.561	0.901	40	4.472	0.223	100.000	63	101.460	0.000	100.000				
18	0.226	1.239	2.141	41	5.122	0.000	100.000	64	116.210	0.000	100.000				
19	0.259	2.670	4.811	42	5.867	0.000	100.000	65	133.103	0.000	100.000				
20	0.296	4.431	9.242	43	6.720	0.000	100.000	66	152.453	0.000	100.000				
21	0.339	7.446	16.688	44	7.697	0.000	100.000	67	174.616	0.000	100.000				
22	0.389	7.095	23.783	45	8.816	0.000	100.000	68	200.000	0.000	100.000				
23	0.445	10.265	34.048	46	10.097	0.000	100.000	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25
LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)-446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309021008185
Sample Name :S03M000411
Material :
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 12872(cm² /cm³)
Median : 10.2814(µm)
Mean : 12.7316(µm)
Mode : 12.4235(µm)
Span : 2.3659

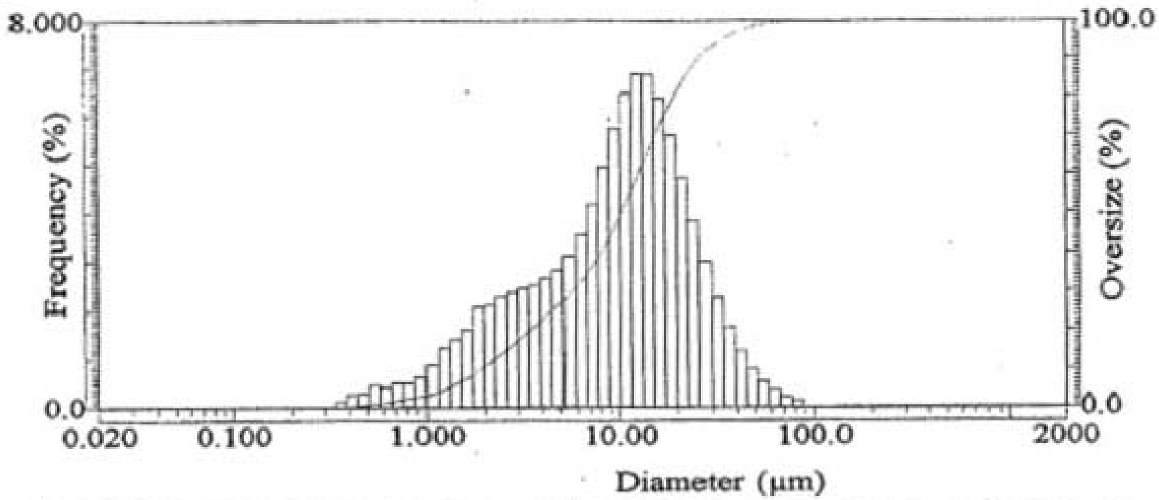
Circulation Speed :3
Ultra sonic :00:13 (7)
Laser T% : 75.8(%)
Lamp T% : 74.9(%)
Calc. Level :30
R.R.Index :180a010I
Variance : 124.86(µm²)
S.D. : 11.1743(µm)
CV : 87.7683
Geo. Mean : 8.4415(µm)
Chi-2 : 0.006617

% on Diameter

:(1)5.000 (%)- 1.272(µm)
(2)10.00 (%)- 1.930(µm)
(3)20.00 (%)- 3.483(µm)
(4)30.00 (%)- 5.683(µm)
(5)40.00 (%)- 8.034(µm)
(6)60.00 (%)- 12.613(µm)
(7)70.00 (%)- 15.389(µm)
(8)80.00 (%)- 19.275(µm)
(9)90.00 (%)- 26.254(µm)
(10)95.00 (%)- 33.980(µm)

Diameter on %

:850.0 (µm)- 100.000(%)
600.0 (µm)- 100.000(%)
425.0 (µm)- 100.000(%)
300.0 (µm)- 100.000(%)
212.0 (µm)- 100.000(%)
150.0 (µm)- 100.000(%)
106.0 (µm)- 100.000(%)
75.00 (µm)- 99.807(%)
53.00 (µm)- 98.863(%)
38.00 (µm)- 96.395(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.292	0.696	47	11.565	6.467	55.606	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	0.458	1.155	48	13.246	6.878	62.484	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	0.435	1.590	49	15.172	6.847	69.331	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	0.500	2.090	50	17.377	6.380	75.711	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.499	2.589	51	19.904	5.618	81.329	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.635	3.224	52	22.797	4.724	86.053	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	0.881	4.105	53	26.111	3.826	89.880	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	1.215	5.320	54	29.907	2.993	92.873	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	1.409	6.729	55	34.255	2.261	95.134	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	1.603	8.332	56	39.234	1.649	96.784	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	2.067	10.399	57	44.938	1.165	97.948	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	2.107	12.506	58	51.471	0.799	98.748	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	2.280	14.786	59	58.953	0.535	99.283	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	2.365	17.152	60	67.523	0.350	99.633	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	2.451	19.603	61	77.339	0.225	99.858	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	2.521	22.124	62	88.583	0.142	100.000	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	2.652	24.776	63	101.460	0.000	100.000				
18	0.226	0.000	0.000	41	5.122	2.836	27.612	64	116.210	0.000	100.000				
19	0.259	0.000	0.000	42	5.867	3.122	30.734	65	133.103	0.000	100.000				
20	0.296	0.000	0.000	43	6.720	3.550	34.284	66	152.453	0.000	100.000				
21	0.339	0.000	0.000	44	7.697	4.156	38.440	67	174.616	0.000	100.000				
22	0.389	0.122	0.122	45	8.816	4.941	43.381	68	200.000	0.000	100.000				
23	0.445	0.282	0.404	46	10.097	5.757	49.138	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25
LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309171417203
Sample Name :S03M000411 REDO
Material :S03M000411 REDO
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.F. Area : 16231(cm² /cm³)
Median : 8.1009(µm)
Mean : 10.0431(µm)
Mode : 12.3136(µm)
Span : 2.3426

Circulation Speed :3
Ultra sonic :00:19 (7)
Laser T% : 56.5(%)
Lamp T% : 54.2(%)
Calc. Level :30
R.R.Index :180a010i

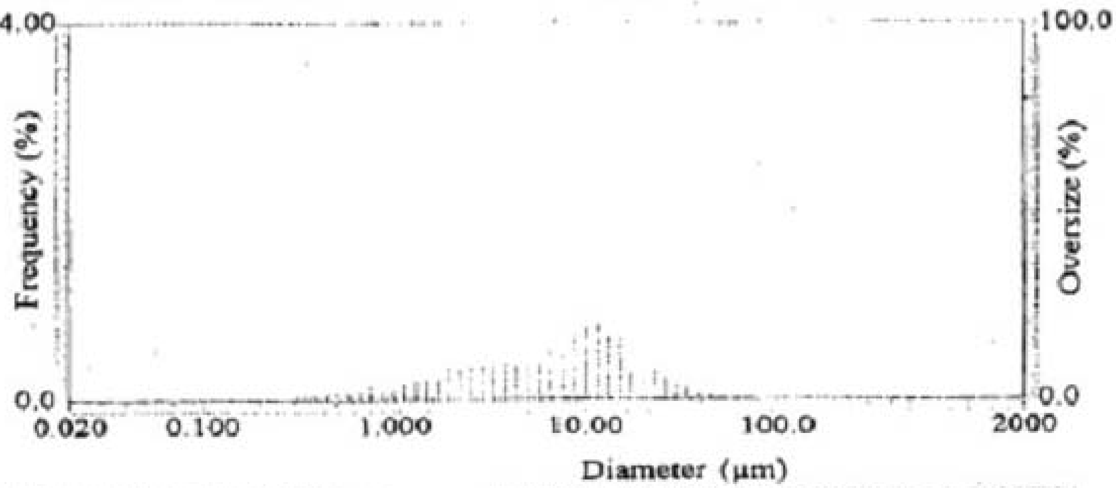
Variance : 80.981(µm²)
S.D. : 8.9989(µm)
CV : 89.6032
Geo. Mean : 6.6108(µm)
Chi-2 : 0.006622

% on Diameter

(1)5.000 (%)- 1.034(µm)
(2)10.00 (%)- 1.564(µm)
(3)20.00 (%)- 2.646(µm)
(4)30.00 (%)- 4.164(µm)
(5)40.00 (%)- 6.103(µm)
(6)60.00 (%)- 10.136(µm)
(7)70.00 (%)- 12.385(µm)
(8)80.00 (%)- 15.322(µm)
(9)90.00 (%)- 20.555(µm)
(10)95.00 (%)- 26.431(µm)

Diameter on %

850.0 (µm)- 100.000(%)
600.0 (µm)- 100.000(%)
425.0 (µm)- 100.000(%)
300.0 (µm)- 100.000(%)
212.0 (µm)- 100.000(%)
150.0 (µm)- 100.000(%)
106.0 (µm)- 100.000(%)
75.00 (µm)- 99.572(%)
53.00 (µm)- 99.457(%)
38.00 (µm)- 98.328(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.462	1.277	47	11.565	6.771	66.580	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	0.671	1.948	48	13.246	6.774	73.353	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	0.594	2.542	49	15.172	6.258	79.611	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	0.679	3.222	50	17.377	5.346	84.957	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.665	3.887	51	19.904	4.273	89.230	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.862	4.748	52	22.797	3.245	92.475	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	1.203	5.951	53	26.111	2.374	94.849	76	592.347	0.000	100.000
8	0.058	0.000	0.000	31	1.318	1.646	7.598	54	29.907	1.888	96.637	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	1.865	9.461	55	34.255	1.175	97.712	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	2.074	11.535	56	39.234	0.806	98.518	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	2.638	14.173	57	44.938	0.549	99.067	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	2.641	16.814	58	51.471	0.374	99.442	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	2.819	19.632	59	58.953	0.257	99.699	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	2.884	22.516	60	67.523	0.176	99.876	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	2.957	25.473	61	77.339	0.124	100.000	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	3.023	28.497	62	88.583	0.000	100.000	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	3.172	31.669	63	101.460	0.000	100.000				
18	0.226	0.000	0.000	41	5.122	3.367	35.016	64	116.210	0.000	100.000				
19	0.259	0.000	0.000	42	5.867	3.720	38.776	65	133.103	0.000	100.000				
20	0.296	0.000	0.000	43	6.720	4.203	42.979	66	152.453	0.000	100.000				
21	0.339	0.115	0.115	44	7.697	4.659	47.638	67	174.616	0.000	100.000				
22	0.389	0.206	0.321	45	8.816	5.850	53.488	68	200.000	0.000	100.000				
23	0.445	0.494	0.815	46	10.097	6.321	59.809	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25
LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309021014186
Sample Name :S03M000416
Material :S03M000416
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 14621(cm²/cm³)
Median : 8.9349(µm)
Mean : 10.5251(µm)
Mode : 12.3771(µm)
Span : 2.2105

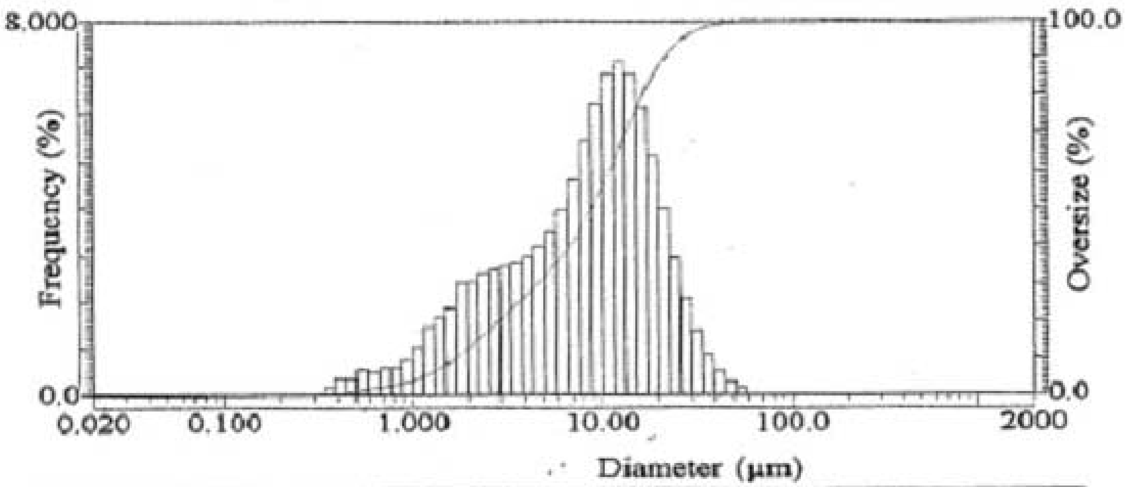
Circulation Speed :3
Ultra sonic :00:18 (7)
Laser T% : 61.8(%)
Lamp T% : 60.2(%)
Calc. Level :30
R.R.Index :180a010I
Variance : 71.089(µm²)
S.D. : 8.4314(µm)
CV : 80.1076
Geo. Mean : 7.1862(µm)
Chi-2 : 0.014247

% on Diameter

(1)5.000 (%)- 1.156(µm)
(2)10.00 (%)- 1.732(µm)
(3)20.00 (%)- 2.957(µm)
(4)30.00 (%)- 4.723(µm)
(5)40.00 (%)- 6.850(µm)
(6)60.00 (%)- 11.010(µm)
(7)70.00 (%)- 13.343(µm)
(8)80.00 (%)- 16.390(µm)
(9)90.00 (%)- 21.483(µm)
(10)95.00 (%)- 26.613(µm)

Diameter on %

850.0 (µm)- 100.000(%)
600.0 (µm)- 100.000(%)
425.0 (µm)- 100.000(%)
300.0 (µm)- 100.000(%)
212.0 (µm)- 100.000(%)
150.0 (µm)- 100.000(%)
106.0 (µm)- 100.000(%)
75.00 (µm)- 100.000(%)
53.00 (µm)- 99.877(%)
38.00 (µm)- 96.830(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.365	0.868	47	11.565	6.877	62.491	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	0.558	1.446	48	13.246	7.136	69.629	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	0.513	1.959	49	15.172	6.877	76.507	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	0.601	2.561	50	17.377	6.137	82.644	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.586	3.138	51	19.904	5.107	87.761	74	451.856	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.759	3.897	52	22.797	3.997	91.748	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	1.000	4.957	53	26.111	2.960	94.708	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	1.459	6.416	54	29.907	2.078	96.786	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	1.673	8.089	55	34.255	1.380	98.167	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	1.883	9.972	56	39.234	0.868	99.034	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	2.412	12.384	57	44.938	0.517	99.551	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	2.435	14.819	58	51.471	0.292	99.843	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	2.616	17.434	59	58.953	0.167	100.000	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	2.692	20.126	60	67.523	0.000	100.000	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	2.773	22.899	61	77.339	0.000	100.000	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	2.840	25.740	62	88.583	0.000	100.000	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	2.980	28.720	63	101.460	0.000	100.000				
18	0.226	0.000	0.000	41	5.122	3.180	31.900	64	116.210	0.000	100.000				
19	0.259	0.000	0.000	42	5.867	3.493	35.392	65	133.103	0.000	100.000				
20	0.296	0.000	0.000	43	6.720	3.958	39.349	66	152.453	0.000	100.000				
21	0.339	0.000	0.000	44	7.697	4.606	43.954	67	174.616	0.000	100.000				
22	0.389	0.154	0.154	45	8.816	5.428	49.383	68	200.000	0.000	100.000				
23	0.445	0.369	0.523	46	10.097	6.232	55.615	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25

LA-920 systems for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename	:200308280816182
ID#	:200309171410202
Sample Name	:S03M000416 REDO
Material	:S03M000416 REDO
Source	:
Lot Number	:1000 24hr's
Form of Distribution	:Standard
Distribution Base	:Volume
Sampling Times	:10

Circulation Speed :3
Ultra sonic :00:17 (7)
Laser T% : 68.9(%)
Lamp T% : 67.8(%)
Calc. Level :30
R.R.Index :160a010I

S.P. Area : 14946(cm² /cm³)
Median : 8.5149(µm)
Mean : 10.7771(µm)
Mode : 12.3180(µm)
Span : 2.3471

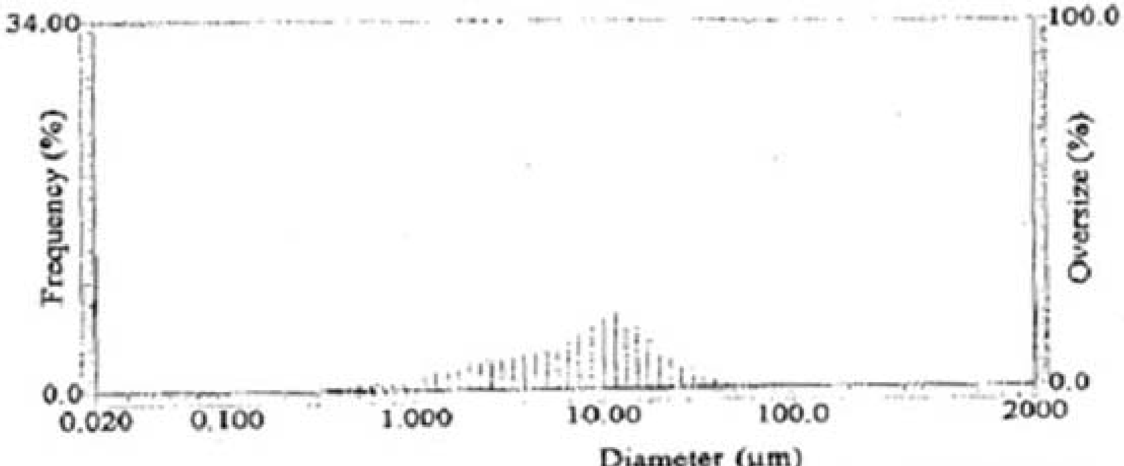
Variance : 107.27(µm²)
S.D. : 10.3572(µm)
CV : 96.1040
Geo. Mean : 7.0620(µm)
Chi-2 : 0.006250

% on Diameter

(1)5.000 (%)-	1.139(µm)	(6)60.00 (%)-	10.536(µm)
(2)10.00 (%)-	1.704(µm)	(7)70.00 (%)-	12.633(µm)
(3)20.00 (%)-	2.887(µm)	(8)80.00 (%)-	15.946(µm)
(4)30.00 (%)-	4.544(µm)	(9)90.00 (%)-	21.669(µm)
(5)40.00 (%)-	6.533(µm)	(10)95.00 (%)-	28.695(µm)

Diameter on %

850.0 (µm)-	100.000(%)	150.0 (µm)-	100.000(%)
600.0 (µm)-	100.000(%)	106.0 (µm)-	100.000(%)
425.0 (µm)-	100.000(%)	75.00 (µm)-	99.692(%)
300.0 (µm)-	100.000(%)	53.00 (µm)-	99.003(%)
212.0 (µm)-	100.000(%)	38.00 (µm)-	97.364(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.363	0.938	47	11.565	6.869	64.716	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	0.573	1.508	48	13.246	6.892	71.607	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	0.520	2.028	49	15.172	6.305	77.982	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	0.600	2.629	50	17.377	5.474	83.400	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.596	3.224	51	19.904	4.466	87.866	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.775	4.000	52	22.797	3.371	91.236	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	1.087	5.086	53	26.111	2.500	93.736	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	1.494	6.580	54	29.907	1.815	95.553	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	1.709	8.289	55	34.255	1.301	96.854	78	777.141	0.000	100.000
10	0.078	0.000	0.000	33	1.729	1.920	10.210	56	39.234	0.928	97.782	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	2.460	12.670	57	44.938	0.664	98.446	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	2.491	15.160	58	51.471	0.480	98.927	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	1.887	17.047	59	58.953	0.343	99.270	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	2.978	20.025	60	67.523	0.262	99.540	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	2.877	23.502	61	77.339	0.197	99.737	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	2.966	25.469	62	88.583	0.149	99.886	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	3.133	28.602	63	101.460	0.114	100.000				
18	0.226	0.000	0.000	41	5.122	3.363	31.966	64	116.210	0.000	100.000				
19	0.259	0.000	0.000	42	5.867	3.709	35.675	65	133.103	0.000	100.000				
20	0.296	0.000	0.000	43	6.720	4.206	39.881	66	152.453	0.000	100.000				
21	0.339	0.000	0.000	44	7.697	4.880	44.761	67	174.616	0.000	100.000				
22	0.389	0.182	0.182	45	8.816	6.695	51.456	68	200.000	0.000	100.000				
23	0.445	0.393	0.575	46	10.097	6.391	57.847	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25
LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309021021187
Sample Name :S03M000412
Material :S03M000412
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 9921.4(cm² /cm³)
Median : 13.2895(μm)
Mean : 13.2034(μm)
Mode : 16.2781(μm)
Span : 1.5041

Circulation Speed :3
Ultra sonic :00:12 (7)
Laser T% : 99.1(%)
Lamp T% : 98.8(%)
Calc. Level :30
R.R.Index :180a010I

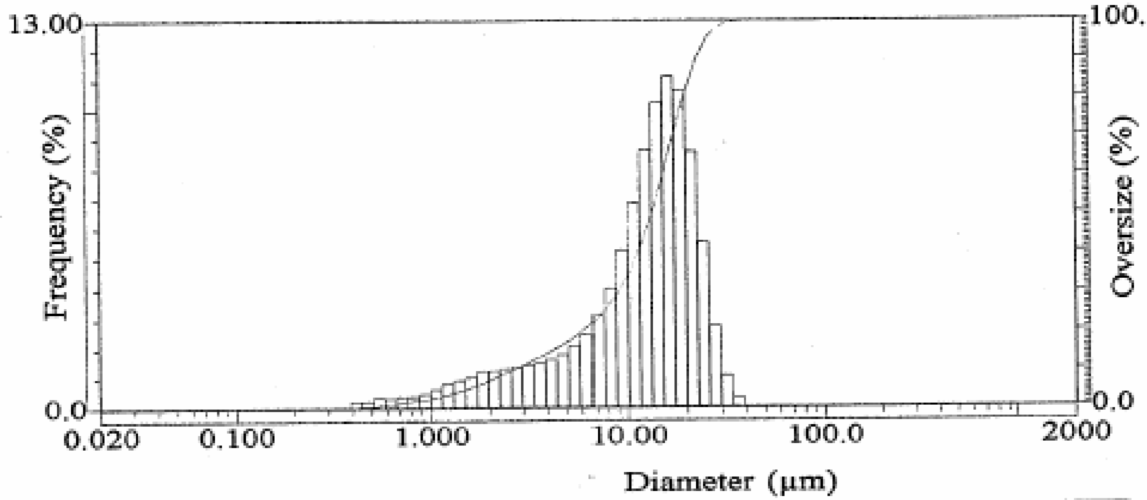
Variance : 54.177(μm²)
S.D. : 7.3605(μm)
CV : 55.7469
Geo. Mean : 10.2462(μm)
Chi-2 : 0.144217

% on Diameter

:(1)5.000 (%)- 1.558(μm)
(2)10.00 (%)- 2.698(μm)
(3)20.00 (%)- 6.037(μm)
(4)30.00 (%)- 9.037(μm)
(5)40.00 (%)- 11.304(μm)
(6)60.00 (%)- 15.175(μm)
(7)70.00 (%)- 17.145(μm)
(8)80.00 (%)- 19.466(μm)
(9)90.00 (%)- 22.686(μm)
(10)95.00 (%)- 25.577(μm)

Diameter on %

:850.0 (μm)- 100.000(%)
600.0 (μm)- 100.000(%)
425.0 (μm)- 100.000(%)
300.0 (μm)- 100.000(%)
212.0 (μm)- 100.000(%)
150.0 (μm)- 100.000(%)
106.0 (μm)- 100.000(%)
75.00 (μm)- 100.000(%)
53.00 (μm)- 100.000(%)
38.00 (μm)- 99.925(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.224	0.447	47	11.565	6.837	41.149	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	0.363	0.810	48	13.246	8.605	49.754	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	0.343	1.153	49	15.172	10.229	59.983	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	0.387	1.540	50	17.377	11.121	71.103	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.385	1.925	51	19.904	10.641	81.744	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.471	2.395	52	22.797	8.562	90.307	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	0.626	3.022	53	26.111	5.537	95.843	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	0.822	3.844	54	29.907	2.775	98.618	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	0.922	4.766	55	34.255	1.063	99.682	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	1.016	5.782	56	39.234	0.318	100.000	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	1.250	7.032	57	44.938	0.000	100.000	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	1.254	8.287	58	51.471	0.000	100.000	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	1.333	9.619	59	58.953	0.000	100.000	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	1.376	10.996	60	67.523	0.000	100.000	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	1.436	12.432	61	77.339	0.000	100.000	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	1.508	13.940	62	88.583	0.000	100.000	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	1.636	15.576	63	101.460	0.000	100.000				
18	0.226	0.000	0.000	41	5.122	1.815	17.392	64	116.210	0.000	100.000				
19	0.259	0.000	0.000	42	5.867	2.084	19.476	65	133.103	0.000	100.000				
20	0.296	0.000	0.000	43	6.720	2.485	21.961	66	152.453	0.000	100.000				
21	0.339	0.000	0.000	44	7.697	3.090	25.051	67	174.616	0.000	100.000				
22	0.389	0.000	0.000	45	8.816	3.986	29.036	68	200.000	0.000	100.000				
23	0.445	0.222	0.222	46	10.097	5.276	34.312	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25

LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename	**:200308280816182**
ID#	**:200309171424204**
Sample Name	**:S03M000412 REDO**
Material	**:S03M000412 REDO**
Source	**:**
Lot Number	**:1000 24hr's**

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 15599(cm² /cm³)
Median : 8.2352(μm)
Mean : 7.9258(μm)
Mode : 10.7130(μm)
Span : 1.4347

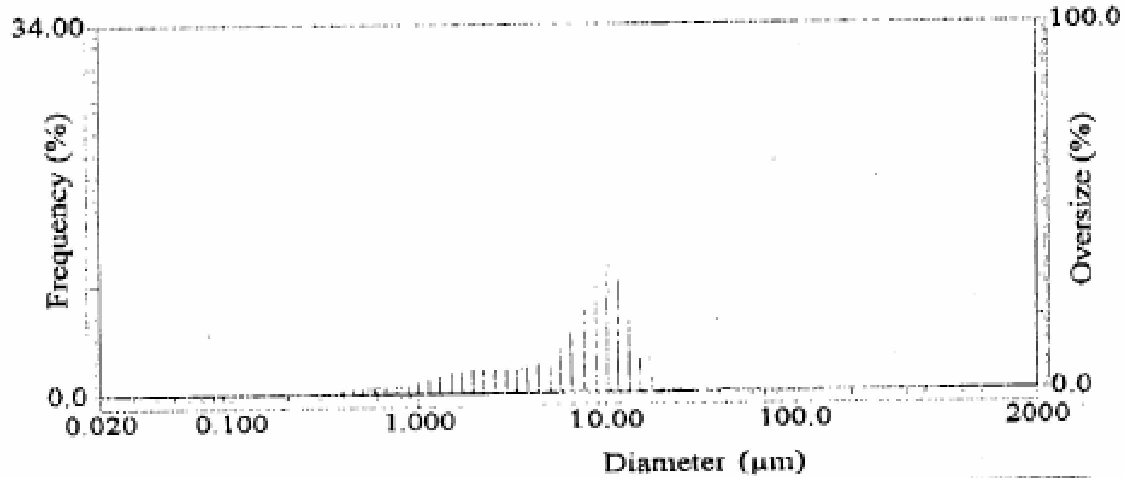
Circulation Speed :3
Ultra sonic :00:15 (7)
Laser T% : 99.3(%)
Lamp T% : 99.3(%)
Calc. Level :30
R.R.Index :180a010i
Variance : 19.185(μm²)
S.D. : 4.3801(μm)
CV : 55.2632
Geo. Mean : 6.1720(μm)
Chi-2 : 0.165876

% on Diameter

(1)5.000 (%)- 1.068(μm)	(6)60.00 (%)- 9.334(μm)
(2)10.00 (%)- 1.638(μm)	(7)70.00 (%)- 10.460(μm)
(3)20.00 (%)- 3.150(μm)	(8)80.00 (%)- 11.710(μm)
(4)30.00 (%)- 5.374(μm)	(9)90.00 (%)- 13.453(μm)
(5)40.00 (%)- 7.016(μm)	(10)95.00 (%)- 14.947(μm)

Diameter on %

850.0 (μm)- 100.000(%)	150.0 (μm)- 100.000(%)
600.0 (μm)- 100.000(%)	106.0 (μm)- 100.000(%)
425.0 (μm)- 100.000(%)	75.00 (μm)- 100.000(%)
300.0 (μm)- 100.000(%)	53.00 (μm)- 100.000(%)
212.0 (μm)- 100.000(%)	38.00 (μm)- 100.000(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.418	1.169	47	11.565	12.250	79.061	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	0.592	1.761	48	13.246	10.204	89.265	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	0.564	2.325	49	15.172	6.445	95.710	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	0.653	2.978	50	17.377	2.995	98.705	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.663	3.640	51	19.904	1.026	99.731	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.845	4.485	52	22.797	0.269	100.000	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	1.147	5.632	53	26.111	0.000	100.000	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	1.539	7.172	54	29.907	0.000	100.000	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	1.719	8.890	55	34.255	0.000	100.000	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	1.848	10.739	56	39.234	0.000	100.000	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	2.232	12.971	57	44.938	0.000	100.000	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	2.088	15.059	58	51.471	0.000	100.000	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	2.076	17.135	59	58.953	0.000	100.000	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	2.015	19.150	60	67.523	0.000	100.000	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	2.028	21.178	61	77.339	0.000	100.000	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	2.128	23.306	62	88.583	0.000	100.000	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	2.415	25.722	63	101.460	0.000	100.000				
18	0.226	0.000	0.000	41	5.122	2.932	28.654	64	116.210	0.000	100.000				
19	0.259	0.000	0.000	42	5.867	3.811	32.465	65	133.103	0.000	100.000				
20	0.296	0.000	0.000	43	6.720	5.214	37.679	66	152.453	0.000	100.000				
21	0.339	0.129	0.129	44	7.697	7.312	44.991	67	174.616	0.000	100.000				
22	0.389	0.214	0.343	45	8.816	10.053	55.044	68	200.000	0.000	100.000				
23	0.445	0.408	0.751	46	10.097	11.767	66.811	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25

LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309021028188
Sample Name :Filter 4A
Material :Filter 4A
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 4323.4(cm² /cm³)
Median : 34.9200(μm)
Mean : 34.9008(μm)
Mode : 42.2104(μm)
Span : 1.4527

Circulation Speed :3
Ultra sonic :00:10 (7)
Laser T% : 98.9(%)
Lamp T% : 98.7(%)
Calc. Level :30
R.R.Index :180a010I

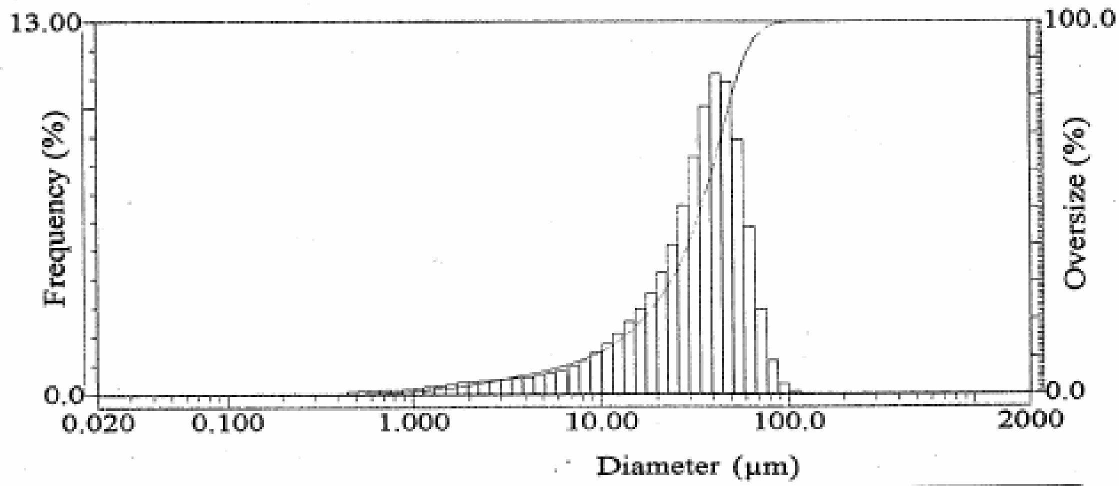
Variance : 367.77(μm²)
S.D. : 19.1773(μm)
CV : 54.9480
Geo. Mean : 27.0764(μm)
Chi-2 : 0.156942

% on Diameter

:(1)5.000 (%)- 3.861(μm)
(2)10.00 (%)- 8.791(μm)
(3)20.00 (%)- 16.745(μm)
(4)30.00 (%)- 23.698(μm)
(5)40.00 (%)- 29.727(μm)
(6)60.00 (%)- 39.898(μm)
(7)70.00 (%)- 45.050(μm)
(8)80.00 (%)- 51.020(μm)
(9)90.00 (%)- 59.520(μm)
(10)95.00 (%)- 66.905(μm)

Diameter on %

:850.0 (μm)- 100.000(%)
600.0 (μm)- 100.000(%)
425.0 (μm)- 100.000(%)
300.0 (μm)- 100.000(%)
212.0 (μm)- 100.000(%)
150.0 (μm)- 100.000(%)
106.0 (μm)- 99.928(%)
75.00 (μm)- 97.679(%)
53.00 (μm)- 82.623(%)
38.00 (μm)- 56.253(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.109	0.109	47	11.565	1.757	13.227	70	262.376	0.000	100.000
2	0.026	0.000	0.000	25	0.584	0.147	0.255	48	13.246	2.115	15.342	71	300.518	0.000	100.000
3	0.029	0.000	0.000	26	0.669	0.147	0.403	49	15.172	2.510	17.851	72	344.206	0.000	100.000
4	0.034	0.000	0.000	27	0.766	0.159	0.561	50	17.377	2.955	20.807	73	394.244	0.000	100.000
5	0.039	0.000	0.000	28	0.877	0.159	0.720	51	19.904	3.496	24.302	74	451.556	0.000	100.000
6	0.044	0.000	0.000	29	1.005	0.181	0.901	52	22.797	4.210	28.513	75	517.200	0.000	100.000
7	0.051	0.000	0.000	30	1.151	0.221	1.121	53	26.111	5.206	33.719	76	592.387	0.000	100.000
8	0.058	0.000	0.000	31	1.318	0.275	1.396	54	29.907	6.573	40.293	77	678.504	0.000	100.000
9	0.067	0.000	0.000	32	1.510	0.311	1.708	55	34.255	8.284	48.577	78	777.141	0.000	100.000
10	0.076	0.000	0.000	33	1.729	0.350	2.057	56	39.234	10.041	58.618	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	0.426	2.484	57	44.938	11.183	69.801	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	0.445	2.929	58	51.471	10.906	80.707	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	0.485	3.414	59	58.953	8.884	89.591	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	0.515	3.929	60	67.523	5.803	95.393	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	0.545	4.474	61	77.339	2.955	98.348	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	0.573	5.047	62	88.583	1.171	99.519	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	0.612	5.659	63	101.460	0.375	99.894				
18	0.226	0.000	0.000	41	5.122	0.660	6.319	64	116.210	0.106	100.000				
19	0.259	0.000	0.000	42	5.867	0.729	7.048	65	133.103	0.000	100.000				
20	0.296	0.000	0.000	43	6.720	0.828	7.876	66	152.453	0.000	100.000				
21	0.339	0.000	0.000	44	7.697	0.973	8.849	67	174.616	0.000	100.000				
22	0.389	0.000	0.000	45	8.816	1.175	10.025	68	200.000	0.000	100.000				
23	0.445	0.000	0.000	46	10.097	1.445	11.470	69	229.075	0.000	100.000				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25

LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309021035189
Sample Name :S03M000413
Material :S03M000413
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

Circulation Speed :3
Ultra sonic :00:20 (7)
Laser T% : 89.0(%)
Lamp T% : 91.6(%)
Calc. Level :30
R.R.Index :180a010I

S.P. Area : 286.24(cm² /cm³)
Median : 227.2407(μm)
Mean : 248.3427(μm)
Mode : 215.8097(μm)
Span : 1.0968

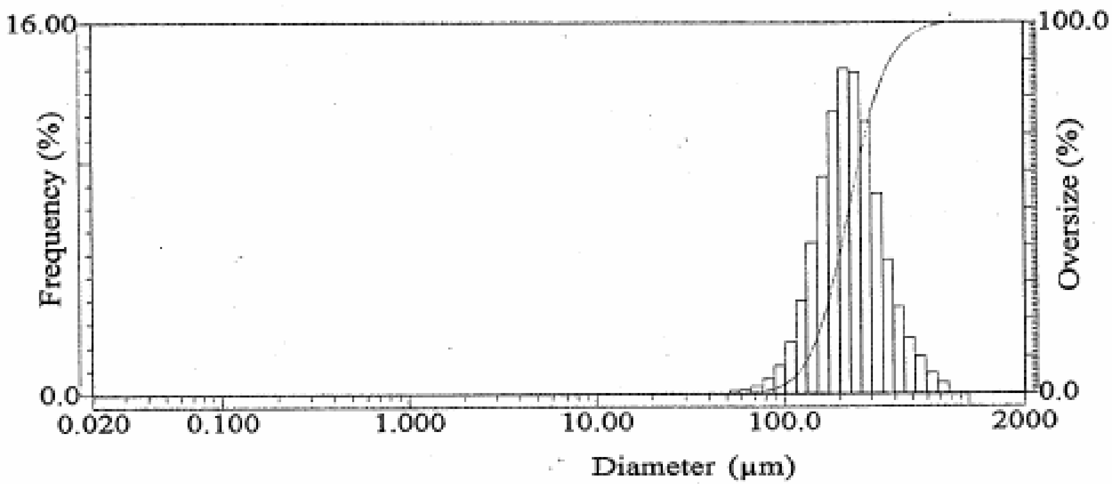
Variance : 11564(μm²)
S.D. : 107.5371(μm)
CV : 43.3019
Geo. Mean : 228.1476(μm)
Chi-2 : 0.036716

% on Diameter

:(1)5.000 (%)- 117.183(μm)
(2)10.00 (%)- 136.611(μm)
(3)20.00 (%)- 163.345(μm)
(4)30.00 (%)- 185.434(μm)
(5)40.00 (%)- 206.297(μm)
(6)60.00 (%)- 250.538(μm)
(7)70.00 (%)- 278.837(μm)
(8)80.00 (%)- 317.527(μm)
(9)90.00 (%)- 385.842(μm)
(10)95.00 (%)- 461.298(μm)

Diameter on %

:850.0 (μm)- 100.000(%)
600.0 (μm)- 98.702(%)
425.0 (μm)- 92.968(%)
300.0 (μm)- 76.341(%)
212.0 (μm)- 42.820(%)
150.0 (μm)- 14.468(%)
106.0 (μm)- 3.245(%)
75.00 (μm)- 0.593(%)
53.00 (μm)- 0.027(%)
38.00 (μm)- 0.000(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.000	0.000	47	11.565	0.000	0.000	70	262.376	13.895	64.726
2	0.026	0.000	0.000	25	0.584	0.000	0.000	48	13.246	0.000	0.000	71	300.518	11.764	76.490
3	0.029	0.000	0.000	26	0.669	0.000	0.000	49	15.172	0.000	0.000	72	344.206	8.653	85.143
4	0.034	0.000	0.000	27	0.766	0.000	0.000	50	17.377	0.000	0.000	73	394.244	5.773	90.916
5	0.039	0.000	0.000	28	0.877	0.000	0.000	51	19.904	0.000	0.000	74	451.556	3.707	94.623
6	0.044	0.000	0.000	29	1.005	0.000	0.000	52	22.797	0.000	0.000	75	517.200	2.398	97.021
7	0.051	0.000	0.000	30	1.151	0.000	0.000	53	26.111	0.000	0.000	76	592.387	1.598	98.619
8	0.058	0.000	0.000	31	1.318	0.000	0.000	54	29.907	0.000	0.000	77	678.504	0.888	99.507
9	0.067	0.000	0.000	32	1.510	0.000	0.000	55	34.255	0.000	0.000	78	777.141	0.493	100.000
10	0.076	0.000	0.000	33	1.729	0.000	0.000	56	39.234	0.000	0.000	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	0.000	0.000	57	44.938	0.000	0.000	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	0.000	0.000	58	51.471	0.000	0.000	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	0.000	0.000	59	58.953	0.126	0.126	82	1337.481	0.000	100.000
14	0.131	0.000	0.000	37	2.976	0.000	0.000	60	67.523	0.199	0.325	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	0.000	0.000	61	77.339	0.346	0.672	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	0.000	0.000	62	88.583	0.642	1.314	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	0.000	0.000	63	101.460	1.213	2.527				
18	0.226	0.000	0.000	41	5.122	0.000	0.000	64	116.210	2.227	4.754				
19	0.259	0.000	0.000	42	5.867	0.000	0.000	65	133.103	4.003	8.757				
20	0.296	0.000	0.000	43	6.720	0.000	0.000	66	152.453	6.488	15.243				
21	0.339	0.000	0.000	44	7.697	0.000	0.000	67	174.616	9.355	24.599				
22	0.389	0.000	0.000	45	8.816	0.000	0.000	68	200.000	12.196	36.794				
23	0.445	0.000	0.000	46	10.097	0.000	0.000	69	229.075	14.037	50.831				

HORIBA LA-920 *for Windows(TM) [WET(LA-920)] Ver.3.23*
LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309171437206
Sample Name :S03M000413 REDO
Material :S03M000413 REDO
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 306.40(cm² /cm³)
Median : 212.0615(µm)
Mean : 234.4115(µm)
Mode : 213.6801(µm)
Span : 1.1547

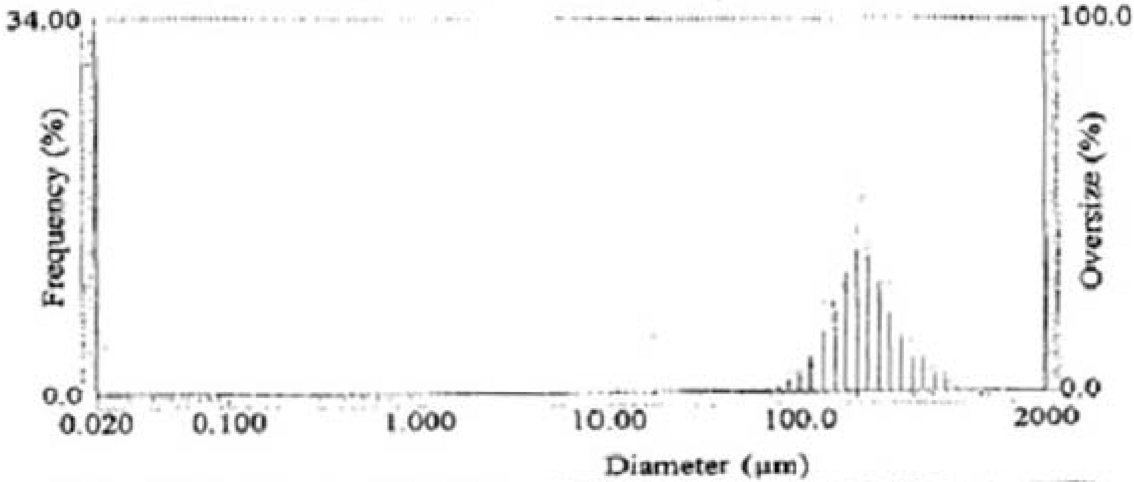
Circulation Speed :3
Ultra sonic :03:05 (7)
Laser T% : 83.6(%)
Lamp T% : 90.1(%)
Calc. Level :30
R.R.Index :180a010I
Variance : 11407(µm²)
S.D. : 106.8027(µm)
CV : 45.5621
Geo. Mean : 213.9496(µm)
CHI-2 : 0.023800

% on Diameter

(1)5.000 (%)- 107.762(µm)
(2)10.00 (%)- 125.956(µm)
(3)20.00 (%)- 151.492(µm)
(4)30.00 (%)- 172.081(µm)
(5)40.00 (%)- 191.600(µm)
(6)60.00 (%)- 234.591(µm)
(7)70.00 (%)- 261.316(µm)
(8)80.00 (%)- 299.045(µm)
(9)90.00 (%)- 370.832(µm)
(10)95.00 (%)- 447.633(µm)

Diameter on %

850.0 (µm)- 100.000(%)
600.0 (µm)- 98.817(%)
425.0 (µm)- 93.821(%)
300.0 (µm)- 80.235(%)
212.0 (µm)- 49.971(%)
150.0 (µm)- 19.405(%)
106.0 (µm)- 4.615(%)
75.00 (µm)- 0.784(%)
53.00 (µm)- 0.033(%)
38.00 (µm)- 0.000(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.000	0.000	47	11.565	0.000	0.000	70	262.376	12.580	70.375
2	0.026	0.000	0.000	25	0.584	0.000	0.000	48	13.246	0.000	0.000	71	300.518	9.987	80.362
3	0.029	0.000	0.000	26	0.669	0.000	0.000	49	15.172	0.000	0.000	72	344.206	7.065	87.427
4	0.034	0.000	0.000	27	0.766	0.000	0.000	50	17.377	0.000	0.000	73	394.244	4.686	92.114
5	0.039	0.000	0.000	28	0.877	0.000	0.000	51	19.904	0.000	0.000	74	451.556	3.084	95.198
6	0.044	0.000	0.000	29	1.005	0.000	0.000	52	22.797	0.000	0.000	75	517.200	2.086	97.284
7	0.051	0.000	0.000	30	1.151	0.000	0.000	53	26.111	0.000	0.000	76	592.387	1.457	98.741
8	0.058	0.000	0.000	31	1.318	0.000	0.000	54	29.907	0.000	0.000	77	678.504	0.809	99.550
9	0.067	0.000	0.000	32	1.510	0.000	0.000	55	34.255	0.000	0.000	78	777.141	0.450	100.000
10	0.076	0.000	0.000	33	1.729	0.000	0.000	56	39.234	0.000	0.000	79	890.116	0.000	100.000
11	0.087	0.000	0.000	34	1.981	0.000	0.000	57	44.938	0.000	0.000	80	1019.515	0.000	100.000
12	0.100	0.000	0.000	35	2.269	0.000	0.000	58	51.471	0.000	0.000	81	1167.725	0.000	100.000
13	0.115	0.000	0.000	36	2.599	0.000	0.000	59	58.953	0.152	0.152	82	1337.451	0.000	100.000
14	0.131	0.000	0.000	37	2.976	0.000	0.000	60	67.523	0.260	0.412	83	1531.914	0.000	100.000
15	0.150	0.000	0.000	38	3.409	0.000	0.000	61	77.339	0.452	0.993	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	0.000	0.000	62	88.583	0.830	1.823	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	0.000	0.000	63	101.460	1.770	3.592				
18	0.226	0.000	0.000	41	5.122	0.000	0.000	64	116.210	3.171	5.763				
19	0.259	0.000	0.000	42	5.867	0.000	0.000	65	133.103	6.456	12.219				
20	0.296	0.000	0.000	43	6.720	0.000	0.000	66	152.453	8.162	20.380				
21	0.339	0.000	0.000	44	7.697	0.000	0.000	67	174.616	10.781	31.162				
22	0.389	0.000	0.000	45	8.816	0.000	0.000	68	200.000	12.924	44.085				
23	0.445	0.000	0.000	46	10.097	0.000	0.000	69	229.075	13.709	57.794				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.3.25

LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309021042190
Sample Name :S03M000414
Material :S03M000414
Source :
Lot Number :1000 24hr's

Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 311.79(cm² /cm³)
Median : 232.9810(μm)
Mean : 305.1232(μm)
Mode : 214.2213(μm)
Span : 2.1273

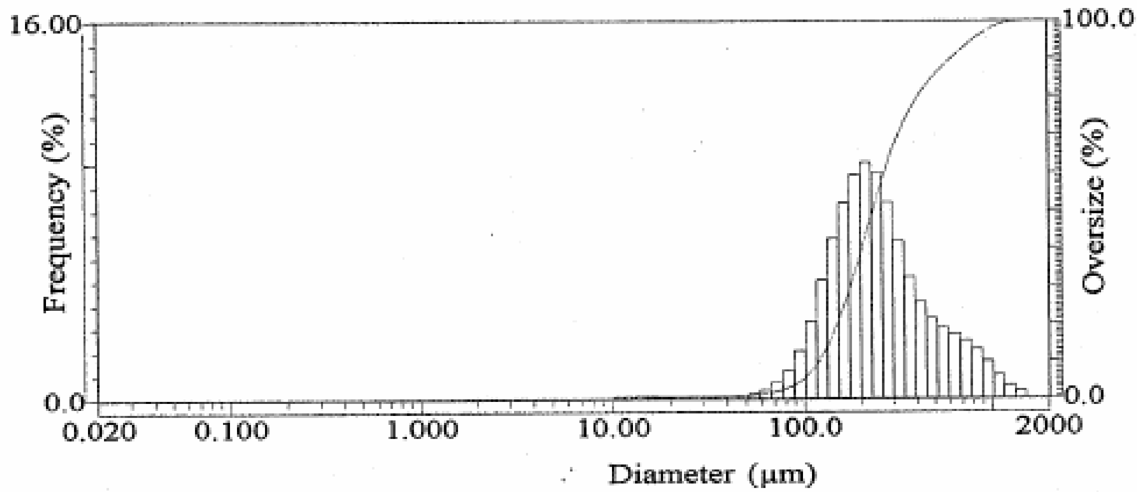
Circulation Speed :3
Ultra sonic :00:12 (7)
Laser T% : 80.3(%)
Lamp T% : 85.6(%)
Calc. Level :30
R.R.Index :180a010I
Variance : 50707(μm²)
S.D. : 225.1814(μm)
CV : 73.8002
Geo. Mean : 245.7035(μm)
Chi-2 : 0.066973

% on Diameter

:(1)5.000 (%)- 97.016(μm)
(2)10.00 (%)- 119.388(μm)
(3)20.00 (%)- 149.715(μm)
(4)30.00 (%)- 176.496(μm)
(5)40.00 (%)- 203.385(μm)
(6)60.00 (%)- 269.138(μm)
(7)70.00 (%)- 320.606(μm)
(8)80.00 (%)- 411.342(μm)
(9)90.00 (%)- 615.016(μm)
(10)95.00 (%)- 805.258(μm)

Diameter on %

:850.0 (μm)- 95.836(%)
600.0 (μm)- 89.501(%)
425.0 (μm)- 80.988(%)
300.0 (μm)- 66.692(%)
212.0 (μm)- 43.069(%)
150.0 (μm)- 20.096(%)
106.0 (μm)- 6.748(%)
75.00 (μm)- 2.256(%)
53.00 (μm)- 1.130(%)
38.00 (μm)- 0.755(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.000	0.000	47	11.565	0.102	0.102	70	262.376	9.631	58.431
2	0.026	0.000	0.000	25	0.584	0.000	0.000	48	13.246	0.114	0.216	71	300.518	8.367	66.798
3	0.029	0.000	0.000	26	0.669	0.000	0.000	49	15.172	0.120	0.336	72	344.206	6.716	73.514
4	0.034	0.000	0.000	27	0.766	0.000	0.000	50	17.377	0.119	0.455	73	394.244	5.201	78.716
5	0.039	0.000	0.000	28	0.877	0.000	0.000	51	19.904	0.113	0.568	74	451.556	4.106	82.822
6	0.044	0.000	0.000	29	1.005	0.000	0.000	52	22.797	0.105	0.673	75	517.200	3.415	86.236
7	0.051	0.000	0.000	30	1.151	0.000	0.000	53	26.111	0.000	0.673	76	592.387	3.007	89.243
8	0.058	0.000	0.000	31	1.318	0.000	0.000	54	29.907	0.000	0.673	77	678.504	2.740	91.983
9	0.067	0.000	0.000	32	1.510	0.000	0.000	55	34.255	0.000	0.673	78	777.141	2.467	94.450
10	0.076	0.000	0.000	33	1.729	0.000	0.000	56	39.234	0.107	0.780	79	890.116	2.099	96.550
11	0.087	0.000	0.000	34	1.981	0.000	0.000	57	44.938	0.128	0.908	80	1019.515	1.580	98.130
12	0.100	0.000	0.000	35	2.269	0.000	0.000	58	51.471	0.169	1.077	81	1167.725	1.003	99.133
13	0.115	0.000	0.000	36	2.599	0.000	0.000	59	58.953	0.248	1.325	82	1337.481	0.557	99.690
14	0.131	0.000	0.000	37	2.976	0.000	0.000	60	67.523	0.400	1.724	83	1531.914	0.310	100.000
15	0.150	0.000	0.000	38	3.409	0.000	0.000	61	77.339	0.687	2.411	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	0.000	0.000	62	88.583	1.206	3.617	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	0.000	0.000	63	101.460	2.064	5.681				
18	0.226	0.000	0.000	41	5.122	0.000	0.000	64	116.210	3.309	8.990				
19	0.259	0.000	0.000	42	5.867	0.000	0.000	65	133.103	5.080	14.070				
20	0.296	0.000	0.000	43	6.720	0.000	0.000	66	152.453	6.844	20.914				
21	0.339	0.000	0.000	44	7.697	0.000	0.000	67	174.616	8.336	29.249				
22	0.389	0.000	0.000	45	8.816	0.000	0.000	68	200.000	9.509	38.758				
23	0.445	0.000	0.000	46	10.097	0.000	0.000	69	229.075	10.042	48.800				

HORIBA LA-920 for Windows(TM) [WET(LA-920)] Ver.) 23

LA-920 system for Windows

Horiba Laboratory
Laboratory Manager
17671 Armstrong Avenue
Irvine, CA 92614
Phone: (800)446-7422
Fax: (949)250-0924

Filename :200308280816182
ID# :200309171444207
Sample Name :S03M000414 REDO
Material :S03M000414 REDO
Source :
Lot Number :1000 24hr's
Form of Distribution :Standard
Distribution Base :Volume
Sampling Times :10

S.P. Area : 284.65(cm² /cm³)
Median : 231.6550(µm)
Mean : 328.0391(µm)
Mode : 187.9211(µm)
Span : 2.6061

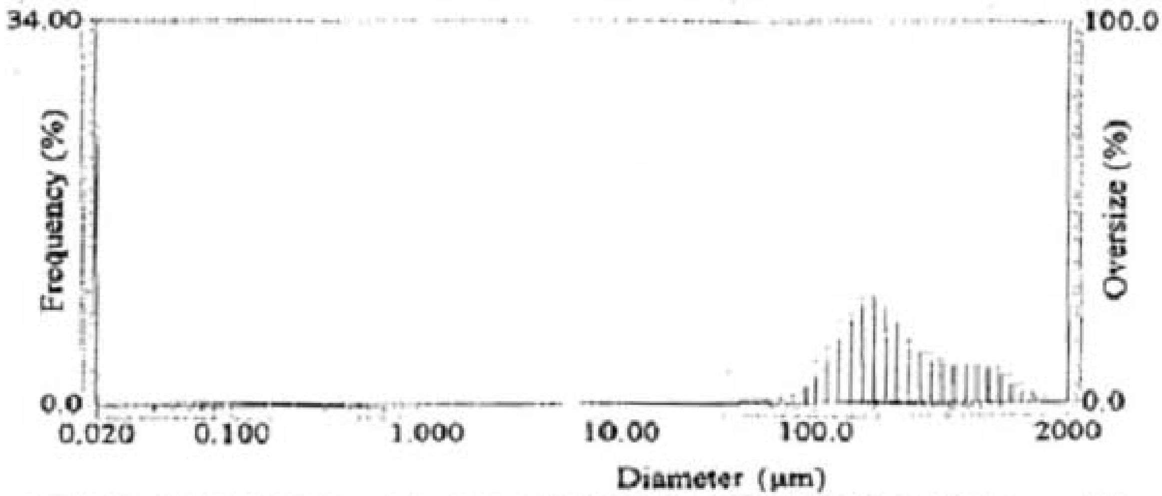
Circulation Speed :3
Ultra sonic :00:10 (7)
Laser T% : 80.6(%)
Lamp T% : 85.7(%)
Calc. Level :30
R.R.Index :180a0101
Variance : 65942(µm²)
S.D. : 256.7909(µm)
CV : 78.2806
Geo. Mean : 257.9717(µm)
Chi-2 : 0.132941

% on Diameter

(1)5.000 (%)- 99.617(µm)
(2)10.00 (%)- 119.028(µm)
(3)20.00 (%)- 147.056(µm)
(4)30.00 (%)- 172.981(µm)
(5)40.00 (%)- 199.899(µm)
(6)60.00 (%)- 272.703(µm)
(7)70.00 (%)- 339.029(µm)
(8)80.00 (%)- 475.114(µm)
(9)90.00 (%)- 721.176(µm)
(10)95.00 (%)- 903.379(µm)

Diameter on %

850.0 (µm)- 93.734(%)
600.0 (µm)- 85.593(%)
425.0 (µm)- 77.055(%)
300.0 (µm)- 64.968(%)
212.0 (µm)- 44.081(%)
150.0 (µm)- 21.073(%)
106.0 (µm)- 6.507(%)
75.00 (µm)- 1.480(%)
53.00 (µm)- 0.300(%)
38.00 (µm)- 0.000(%)



No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %	No.	Diameter		Under %
1	0.022	0.000	0.000	24	0.510	0.000	0.000	47	11.565	0.000	0.000	70	262.376	8.531	57.990
2	0.026	0.000	0.000	25	0.584	0.000	0.000	48	13.246	0.000	0.000	71	300.518	7.068	65.058
3	0.029	0.000	0.000	26	0.669	0.000	0.000	49	15.172	0.000	0.000	72	344.206	5.564	70.621
4	0.034	0.000	0.000	27	0.766	0.000	0.000	50	17.377	0.000	0.000	73	394.244	4.385	75.006
5	0.039	0.000	0.000	28	0.877	0.000	0.000	51	19.904	0.000	0.000	74	451.656	3.676	78.698
6	0.044	0.000	0.000	29	1.005	0.000	0.000	52	22.797	0.000	0.000	75	517.200	3.336	82.035
7	0.051	0.000	0.000	30	1.151	0.000	0.000	53	26.111	0.000	0.000	76	592.387	3.250	85.286
8	0.058	0.000	0.000	31	1.318	0.000	0.000	54	29.907	0.000	0.000	77	678.504	3.265	88.551
9	0.067	0.000	0.000	32	1.510	0.000	0.000	55	34.255	0.000	0.000	78	777.141	3.225	91.776
10	0.076	0.000	0.000	33	1.729	0.000	0.000	56	39.234	0.000	0.000	79	890.116	2.966	94.742
11	0.087	0.000	0.000	34	1.981	0.000	0.000	57	44.938	0.106	0.106	80	1019.310	2.371	97.113
12	0.100	0.000	0.000	35	2.269	0.000	0.000	58	51.471	0.151	0.257	81	1167.725	1.564	98.677
13	0.115	0.000	0.000	36	2.599	0.000	0.000	59	58.953	0.239	0.495	82	1337.481	0.851	99.527
14	0.131	0.000	0.000	37	2.976	0.000	0.000	60	67.523	0.411	0.906	83	1531.914	0.473	100.000
15	0.150	0.000	0.000	38	3.409	0.000	0.000	61	77.339	0.742	1.648	84	1754.613	0.000	100.000
16	0.172	0.000	0.000	39	3.905	0.000	0.000	62	88.583	1.343	2.991	85	2000.000	0.000	100.000
17	0.197	0.000	0.000	40	4.472	0.000	0.000	63	101.460	2.322	5.314				
18	0.226	0.000	0.000	41	5.122	0.000	0.000	64	116.210	3.699	9.013				
19	0.259	0.000	0.000	42	5.867	0.000	0.000	65	133.103	5.594	14.607				
20	0.296	0.000	0.000	43	6.720	0.000	0.000	66	152.453	7.344	21.950				
21	0.339	0.000	0.000	44	7.697	0.000	0.000	67	174.616	8.649	30.599				
22	0.389	0.000	0.000	45	8.816	0.000	0.000	68	200.000	9.436	40.036				
23	0.445	0.000	0.000	46	10.097	0.000	0.000	69	229.075	9.424	49.459				

Distribution

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	Dennis Irby	H6-60		Bill Callaway	T6-07
	Yusuf Noorani	H6-60			
	Jian-Shun Shuen	H6-60	10	Pacific Northwest National Laboratory	
8	CH2M HILL Hanford Group			Sheila Bennett	K7-90
				Jim Huckaby (5)	K7-15
	Dan Baide	S7-70		John Glissmeyer	K3-45
	Blaine Barton	S7-90		Paul Gray	K3-54
	Paul Branson	S7-12		Information Release (2)	K1-06
	John Harris III	S7-90			
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	Dave Smet	S7-65			
	Ryan Smith	S7-90			