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# Large Tank Experimental Data for Validation of the FLUENT CFD Model of Pulsed Jet Mixers

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June 2003

WTP
Project
Report

Battelle – Pacific Northwest Division
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Battelle - Pacific Northwest Division
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# Completeness of Testing

*This report describes the results of work and testing specified by TP-RPP-WTP-051. The work and any associated testing followed the quality assurance requirements outlined in the Test Specification/Plan. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Test plan results are reported. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.*

**Approved:**

Gordon H. Beeman, Manager | Date
WTP R&T Support Project

# Summary

Battelle–Pacific Northwest Division (PNWD) was contracted to provide Bechtel National Incorporated (BNI) with simulant mixing tests results for the validation of the FLUENT CFD (computational fluid dynamics) model of the pulsed jet mixing (PJM) systems. Several hundred of these PJMs are expected to be used in the U.S. Department of Energy (DOE) River Protection Project (RPP) Waste Treatment Plant (WTP). Section 5 of the Research and Technology Plan (BNI 2002) identifies the research needs for pulsed jet mixers. The generation of experimental data for CFD model validation is addressed in Scoping statement B-55, which is included in Appendix C of the Research and Technology Plan.

## Objectives

The three objectives of the work performed included:

1. Reconfiguring the large tank test stand to be as geometrically symmetric as possible and determining the as-built dimensions of the test system
2. Conducting hydrodynamic tests to check for symmetry of the fluid flow in the tank
3. Performing mixing tests to generate concentration and velocity data using glass-bead/water simulants with a nominal volume mean particle size of 10 and 35 μm at varying solids loading and/or modes of PJM operation.

All of the objectives have been met.

## Conduct of Test

This report summarizes the modifications made to be the large tank test configuration to make it geometrically symmetric and presents the experimental data generated after the modifying the test system. Specifically, the data presented in this report includes: 1) as-built dimensions of the test configuration after PJM realignment, 2) hydrodynamic velocity data, and 3) velocity and density data with a simulant consisting of glass-beads in water with a nominal volume mean particle size of 10 and 35 μm.

## Results and Performance against Objectives

In order to locate the PJMs symmetrically within the tank, the following adjustments were made: 1) squaring the PJMs along the mounting structure near the top of the tank and 2) adding two additional tie beams and squaring the PJMs at the tie-beams which connect the pulse tubes at ~ 72 in from the tank floor. All attempts to square the PJMs within the tank were made to within a tolerance of ± 0.5 in (± 0.0127 m). In addition to squaring the PJMs in the tank, the Atomic Energy Agency (AEA) staff adjusted the drive and suction pressures of the jet pump pair (JPP) control module and fine tuned the PRESCON™ controller programming to operate the PJMs in an as close to a synchronous and prototypical manner as possible.

Hydrodynamic velocity profiles measured in the tank indicated that despite a significant improvement, some asymmetries in the flow field are still present. These asymmetries were found to be

due to both geometric dissimilarities and the differences in the individual pulse tubes operation. With BNI's concurrence, further improvements in the symmetry were not pursued due to budget and time constraints.

Simulant mixing data (i.e., concentration and velocity profiles) were determined using glass-beads with nominal volume mean particle size of 10 and 35 μm at varying solids loading and/or modes of PJM operation. Because of the large size of the data files containing the results, they are presented as the Excel spreadsheets on a CD included with this report.

## Quality Requirements

PNWD implemented the RPP-WTP quality requirements by performing work in accordance with the quality assurance project plan (QAPjP) approved by the RPP-WTP Quality Assurance (QA) organization. This work was conducted to the quality requirements of NQA-1-1989 and NQA-2a-1990, Part 2.7 as instituted through PNWD's Waste Treatment Plant Support Project (WTPSP) Quality Assurance Requirements and Description Manual.

PNWD addressed verification activities by conducting an independent technical review of the final data report in accordance with procedure QA-RPP-WTP-604. This review verified that the reported results were traceable and that inferences and conclusions were soundly based.

## Issue

There were no design or operations issues associated with the testing and/or the results presented in this report. However, care must be exercised in using the data presented in this report to draw broad conclusions regarding the PJM performance in vessels with significantly larger dimensions than the test vessel. Extrapolation of these results to actual waste behavior is also not recommended as some of these slurries exhibit non-Newtonian rheology. Such conclusions should be supported by additional data such as those obtained experimentally with validated simulants and from a validated CFD model.

# Acknowledgements

The authors would like to thank Mike White and Bill Combs for all their help with the test system configuration, simulant preparation, and assistance during all phases of the testing. In addition, we would like to thank Cameron Bates and Franz Nigl for their support in putting the data packages together. Finally, we wish to acknowledge Perry Meyer for his thorough review of the data presented in this report.

# Terms and Abbreviations

| | |
|---|---|
| AEA | Atomic Energy Agency |
| BNFL | British Nuclear Fuel Limited, Inc. |
| BNI | Bechtel National Inc. |
| CFD | computational fluid dynamics |
| DACS | Data Acquisition and Control Software |
| DAS | Data Acquisition System |
| DOE | U.S. Department of Energy |
| E | east |
| EM | electromagnetic |
| FY | fiscal year |
| JPPs | jet pump pairs |
| LTTS | large-tank test stand |
| N | north |
| PJM | pulsed jet mixer |
| PNWD | Battelle-Pacific Northwest Division |
| PVC | polyvinyl chloride |
| QAPjP | quality assurance project plan |
| QA | Quality Assurance |
| RPP | River Protection Project |
| S | south |
| SS | stainless steel |
| W | west |
| WTP | Waste Treatment Plant |
| WTPSP | Waste Treatment Plant Support Project |

# Unit Abbreviations

| | |
|---|---|
| °C | degrees Centigrade |
| CFM | cubic feet per minute |
| cm | centimeter |
| D | diameter |
| deg | degree |
| ft | feet |
| g | gram |
| gal | gallon |
| H | height |
| hr | hour |
| ID | internal diameter |
| in | inch |
| L | liter |
| lb | pound |
| µm | micrometer |
| m | meter |
| min | minute |
| OD | outer diameter |
| PSD | particle size distribution |
| psi | pounds per square inch |
| psia | pounds per square inch, absolute |
| psig | pounds per square inch, gauge |
| s or sec | second |
| SP GR | specific gravity |
| wt% | weight percent |

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# 1.0 Introduction

## 1.1 Background

During FY 01, experiments were performed by Battelle–Pacific Northwest Division (PNWD) in the large 12.75-ft (3.8862 m) internal diameter (ID) x 15-ft (4.572 m) H, four pulsed jet mixer (PJM) test system available in the 336 Test Facility. The objective of those tests was to generate hydrodynamic and simulant mixing data for the validation of the TEMPEST[a] computational fluid dynamics (CFD) model for the pulsed jet mixing systems. Analysis of the data revealed the existence of large asymmetries in the fluid flow due to protrusions along the floor of the tank made the data unsuitable for validation of the CFD model[b].

During early to middle of FY 02, attempts were made to improve the quality of the experimental data within the constraints of the task budget. This included: 1) operating the PJMs under gravity refill to keep the cycle time constant and 2) removing protrusions in the tank that caused asymmetries in the flow fields. However, there were certain other variables that still affected the flow symmetry in the tank. For example, the four PJMs were not situated exactly in the center of each quadrant of the tank (one was closer to the wall than the others). Also, the pulse tube nozzles were not exactly at the same distance from the tank floor. In addition, since the jet pump pairs (JPPs) regulating the airflow to the pulse tubes were not identical, the drive times were not identical. Finally, there were two tie beams located midway between the top and bottom of the tank, which were used to provide additional support to the pulse tubes. All of these factors still contributed to asymmetries in the fluid flow patterns within the tank. Also, after the initial modifications, only the hydrodynamic tests, but not the simulant mixing tests, were repeated due to budget constraints.

During the end of FY02, Bechtel National Inc. (BNI) requested PNWD to repeat the simulant mixing tests after reconfiguring the test stand to as geometrically symmetric as possible because of the importance of the simulant mixing data to the code validation. This included: 1) aligning the PJMs in order to maintain the same off-wall and off-floor distances, 2) adding equal length tie beams to connect the PJMs at approximately the tank mid section, and 3) enabling adjustment of the air pressure to the JPPs to minimize asymmetric firing of the PJMs. In addition to the above modifications, BNI has also requested the modification of the test system to fire the PJMs under vacuum refill in order to maintain prototypical operation. Finally, BNI has requested that the simulant mixing tests be conducted with glass-beads simulants of ~10 and 35 μm volume mean particle size and different solids loading and PJM operation conditions.

The information regarding the modifications made to the large tank test configuration and the experimental data generated after the modifying the test system are presented in this report.

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(a) TEMPEST (which stands for Transient Energy Momentum and Pressure Equations Solution in Three Dimensions) is a CFD model developed by the Pacific Northwest National Laboratory to address the complex multiphase fluid flow phenomena encountered with highly radioactive waste at the Hanford Site.

(b) Geometric similarity is important because time varying transients are very difficult and extremely time consuming to model since they require full 3D simulations.

## 1.2 Scope of the Project

The scope of the work presented in this report involves the large-tank experimental testing conducted after the test system has been modified to minimize asymmetries of the flow patterns in the tank. The data presented in this report includes: 1) as-built dimensions of the test configuration after PJM realignment, 2) hydrodynamic velocity data, and 3) velocity and density data with glass-beads of nominal volume mean particle size of 10 and 35 μm.

# 2.0 Large Tank Test Stand Modifications

In this section, a description of the large tank test stand (LTTS) and the work done to modify the PJM location in the tank to improve the geometric similarity of the test system are presented.

## 2.1 Large Tank and PJM Test Stand Description

The description of the large tank test system has been presented before (Bontha et al. 2000 and 2002) but for continuity sake is presented again.

The tank (generally referred to as the supernate tank), in which the PJM system is located, is one of the three large-scale tanks available for PNWD clients to evaluate their test equipment and processes. The LTTS tank is a cylindrical steel vessel of 12.75 ft (3.87 m) internal diameter (ID) and 15 ft (4.57 m) depth and is shown in Figure 2.1. The bottom of the tank is elliptically (2:1) shaped with minimum and maximum radii of 3.2 ft (0.971 m) and 12.75 ft (3.87 m), respectively.

The PJM system consisted of four pulse tubes each with a cylindrical section of 10 ft (3.05 m) length, 2 ft (0.610 m) internal diameter, and 0.25 inch (6.35E-03 m) wall thickness. Each tube is elliptically (2:1) rounded at the top end with an opening for a 2 inch (5.10E-02 m) flange connection. The bottom end of the pulse tube was tapered down at an included angle of 60º to a 4 inch (0.102 m) nozzle. The overall height of the pulse tube was approximately 12 ft (3.66 m) and is shown in Figure 2.2.

The pulsed-jet tubes are held in place using cross beams, which traverse the diameter of the tank and are welded to the tank sides (see Figure 2.3). In addition to the support beams on the top on the tank, there are two tie beams connecting the pulse tubes (in pairs). These beams provide additional support to the tubes and prevent their vibration during the PJM operation. These tie beams are situated at ~ 6 ft (1.83 m) from the tank floor (as measured from the center). The pulsed jet tubes were positioned approximately at the center of the four quadrants of the supernate tank at ~ 9 inch (0.229 m) from the floor of the tank. The pulse tubes are connected to 2-inch (0.0508 m) pipe couplings that enable the insertion of level gauges and attachment of the air/vacuum lines that are required for the PJM operation.

A catwalk or observation bridge was present at a height of 3 ft (0.914 m) from the top of the tank. The bridge contained a 2 ft x 2.5 ft (0.610 m x 0.762 m) port (covered) for the installation of test equipment. Another catwalk (not shown in Figure 2.1) was present at an elevation of ~ 40 ft (12.19 m) from the top of the tank and was used to support the air hoses to the pulse tubes.

Transfer pipes (also not shown in the figures) at the top and at the bottom of the tank enable the addition or removal of material to and from the tank during loading or disposal operations. The supernate tank is positioned on three load gauges, which can be used to determine the weight of the tank and its contents.

Though all the testing and in the results presented in this report, the pulse tubes were labeled using the alphabetical letters A, B, C, and D and their positions located in the tank based on an approximate geographical North direction perpendicular to the catwalk on top of the tank. This labeling with respect to the catwalk on top of the tank and the North direction are shown in Figure 2.4.

## 2.2 Initial Estimate of PJM Locations in the Tank

Prior to the start of any realignment of the PJMs in the tank, an estimation of the symmetric locations of the PJMs within the tank was made based on the existing configuration. This is schematically shown in Figure 2.5. This was used as the target for the realignment of the pulse tubes in the tank.

In all of the sketches presented in this section a mark was made along the rim of the tank near pulse tube B in order to locate all measurements to a common reference point. The location of the reference point was determined by drawing a string between the pipe couplings (securing the level probes as discussed in the next section) on pulse tubes B and D. The string line passed on the NW side of pulse tube D pipe coupling and the SE side of the pulse tube B pipe coupling securing the level probes to the 2-inch (0.0508 m) pipe crosses at the top of the pulse tubes. A laser guide was directed along the string line, and the laser projection point on the tank wall was marked. A carpenter square was used to transfer the point marked on the wall to the rim of the tank. The location of the reference mark with respect to the tank wall is shown in Figure 2.6.

In Figure 2.6, based on circumferential measurements (average tank diameter = 153.7 inches [3.90398 m]), the angles $\theta_{AB}$ and $\theta_{BC}$ were calculated to be 90.6º and 89.4º, respectively. However, based on dimensions from tank drawings (tank diameter assumed = 153 inches [3.8862 m]): $\theta_{AB}$ = 90.9º and $\theta_{BC}$ = 89.8º. These slight differences are within ***the accuracy of the measurements, which unless otherwise noted for all the distance measurements presented in this section, was within ± 0.25 inches (± 6.35E-03 m).***

## 2.3 Realignment of the Pulse Tubes

In order to locate the PJMs symmetrically within the tank, the following adjustments were made: 1) squaring the PJMs along the mounting structure near the top of the tank and 2) adding two additional tie beams and squaring the PJMs at the tie-beams which connect the pulse tubes at ~ 72 inches (1.8288 m) from the tank floor. All attempts to square the PJMs within the tank were made to within a ***tolerance of ± 0.5 inches*** (± 0.0127 m).

## 2.4 As-Built Dimensions of the LTTS

After the modifications to the LTTS were made, the as-built dimensions of the LTTS were measured in terms of: 1) the wall to wall distances between the PJMs and 2) the distances between the tank wall and the walls of the PJM. These measured distances and a pulse tube outer diameter (OD) of 24.5 inches (0.6223 m) were then used to calculate the distances between: 1) the center to center of the PJMs and 2) tank wall to center of the PJMs. These distances are shown schematically in Figures 2.7 to 2.8 at two elevations corresponding to: 1) the top flanges to the PJMs and 2) the beginning of the nozzle section of the PJMs.

The distances of the spans between the PJM nozzles are shown in Figure 2.9. Here the spans were calculated based on the measured average internal diameters of the nozzles of 3.937, 3.958, 3.884, and 3.967 inches [0.0999998, 0.1005332, 0.0986536, and 0.1007618 m] for pulse tube A, B, C, and D, respectively. Note the nozzle diameters were measured using a micrometer.

The location of the as-built nozzle from the as-built body of the PJMs was measured using a plumb line dropped from the top center of each of the PJMs and through the nozzles at the bottom. These measurements are shown in Figure 2.10. In this figure, the crosses represent the location of the plumb line from the edge of the nozzle closest to the string. The distances shown in this figure are the distance from the closest edge of the nozzle to the string. The information in Figure 2.10 was overlaid on the "ideal"[a] location of the PJM nozzles as shown in Figure 2.11. Here the "X" and "Y" distances represent the deviation of the measured nozzle center (represented by dashed circles) from "ideal" nozzle center location (represented by solid circles).

The as-built measurements made on the PJMs pertaining to the conical section of the pulse tubes as shown in Figure 2.12 and 2.13. The measured distances and angles referred to in these figures are listed in Tables 2.1 and 2.2. The measurements made involving the height of the center of the nozzle from the floor of the tank as shown in Figure 2.14 are summarized in Table 2.3.

**Table 2.1**. PJM Measured Cone Dimensions and Taper Angles as defined in Figure 2.12 and 2.13 (All Distances Were Measured to a Tolerance of ± 0.25 inches [± 0.00635 m])

| PJM Tube Designation | Direction from Tube Center | Horizontal distance (in) | Vertical Distance (in) | Hypotenuse "H" (in) | Measured Angle θ (deg) |
|---|---|---|---|---|---|
| A | North | 10 ¼ | 17 1/8 | 20 | 61 |
| A | East | 10 ¼ | 17 1/8 | 20 | 60 |
| A | South | 10 ¼ | 17 1/8 | 20 | 60 |
| A | West | 10 | 17 1/8 | 19 7/8 | 61 |
| B | North | 10 ¼ | 17 ¼ | 20 | 61 |
| B | East | 10 1/8 | 17 1/8 | 20 | 61 |
| B | South | 10 ¼ | 17 1/8 | 20 | 59 |
| B | West | 10 ¼ | 17 1/8 | 20 | 60 |
| C | North | 10 ½ | 17 ¼ | 20 1/8 | 61 |
| C | East | 10 ¼ | 17 3/8 | 20 | 60 |
| C | South | 10 ¼ | 17 ¼ | 20 1/8 | 60 |
| C | West | 10 ¼ | 17 ¼ | 20 | 60 |
| D | North | 10 ¼ | 16 7/8 | 19 7/8 | 59 |
| D | East | 10 ¼ | 17 1/8 | 19 7/8 | 60 |
| D | South | 10 ½ | 17 1/8 | 20 | 61 |
| D | West | 10 ½ | 17 | 19 7/8 | 61 |

(a) Here the ideal location is based on the assumption that all PJMs are vertically aligned and free from fabrication defects.

**Table 2.2**. Orientation of the Plane of the Discharge Nozzle As defined in Figure 2.13 (All Distances Were Measured to a Tolerance of ± 0.25 inches [± 0.00635 m])

| PJM Tube Designation | Diameter Orientation | Elevated Side | Measured Angle $\alpha$ (deg) |
|---|---|---|---|
| A | East/West | N/A | 0 |
| A | North/South | N/A | 0 |
| B | East/West | N/A | 0 |
| B | North/South | South | 1 |
| C | East/West | N/A | 0 |
| C | North/South | N/A | 0 |
| D | East/West | West | 1 |
| D | North/South | N/A | 0 |
| N/A = not applicable. | | | |

**Table 2.3**. PJM Nozzle Heights from the Tank Floor as Defined in Figure 2.14 (All Nozzle Heights Were Measured to a Tolerance of ± 0.1 inches [± 0.00254 m])

| Pulse Tube Designation | Distance from Tank Floor (inches) |
|---|---|
| A | 8 9/16 |
| B | 9 1/16 |
| C | 9 1/16 |
| D | 9 3/8 |

**Figure 2.1**. Photograph of the Tank Containing the Pulsed Jet Mixers

**Figure 2.2**. Photograph of the One of the Pulse Tube Included in the Large Tank Test System


**Figure 2.3**. Photograph of the Top View of the LTTS Showing the Structure Used to Support the PJMs

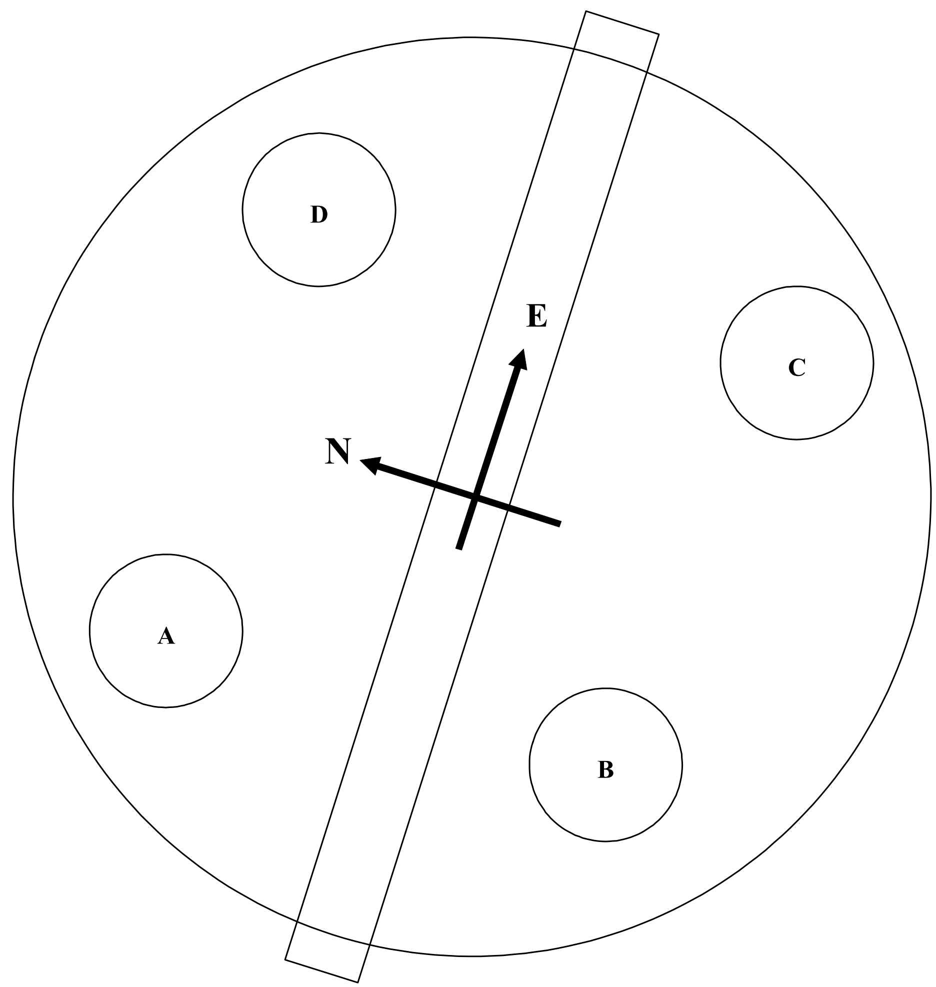


**Figure 2.4**. Schematic Showing the PJM Location in the Tank With Respect to the Labeling Use in the Present Testing

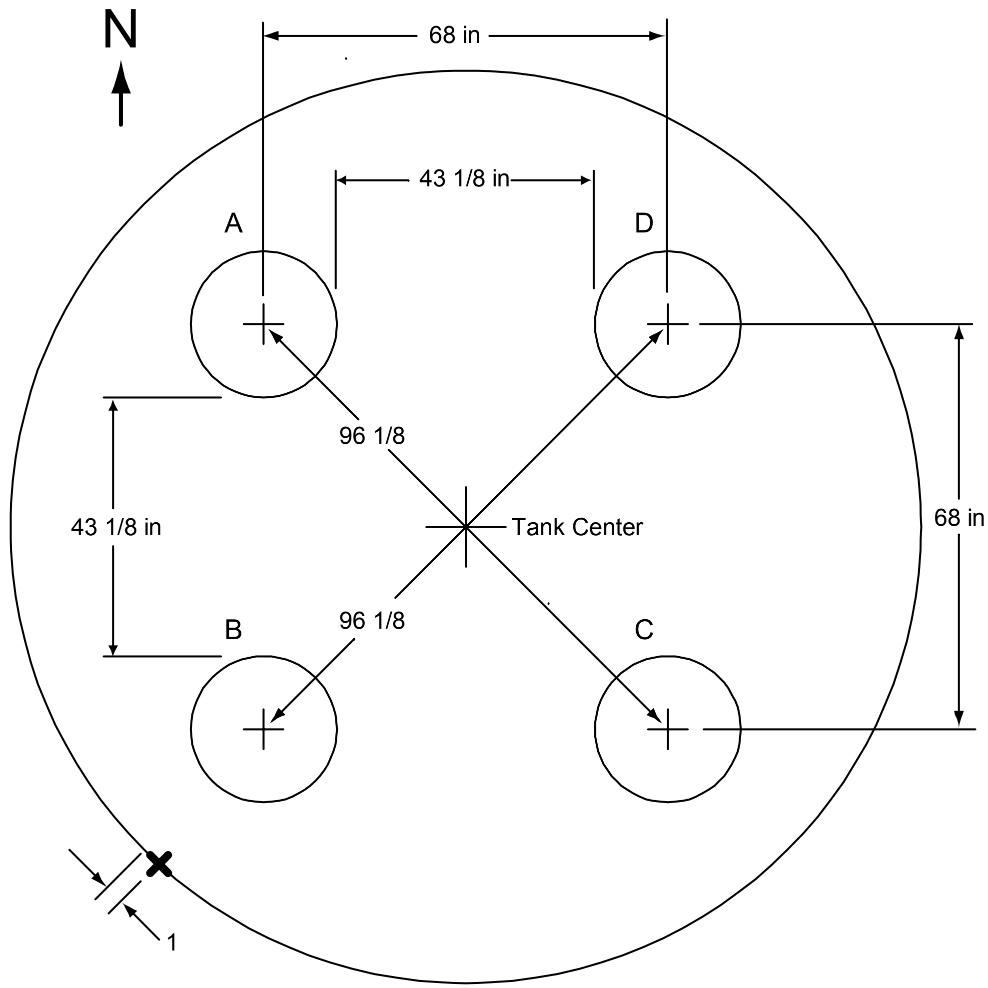


**Figure 2.5**. Initial Estimated Location of the PJMs in the LTTS

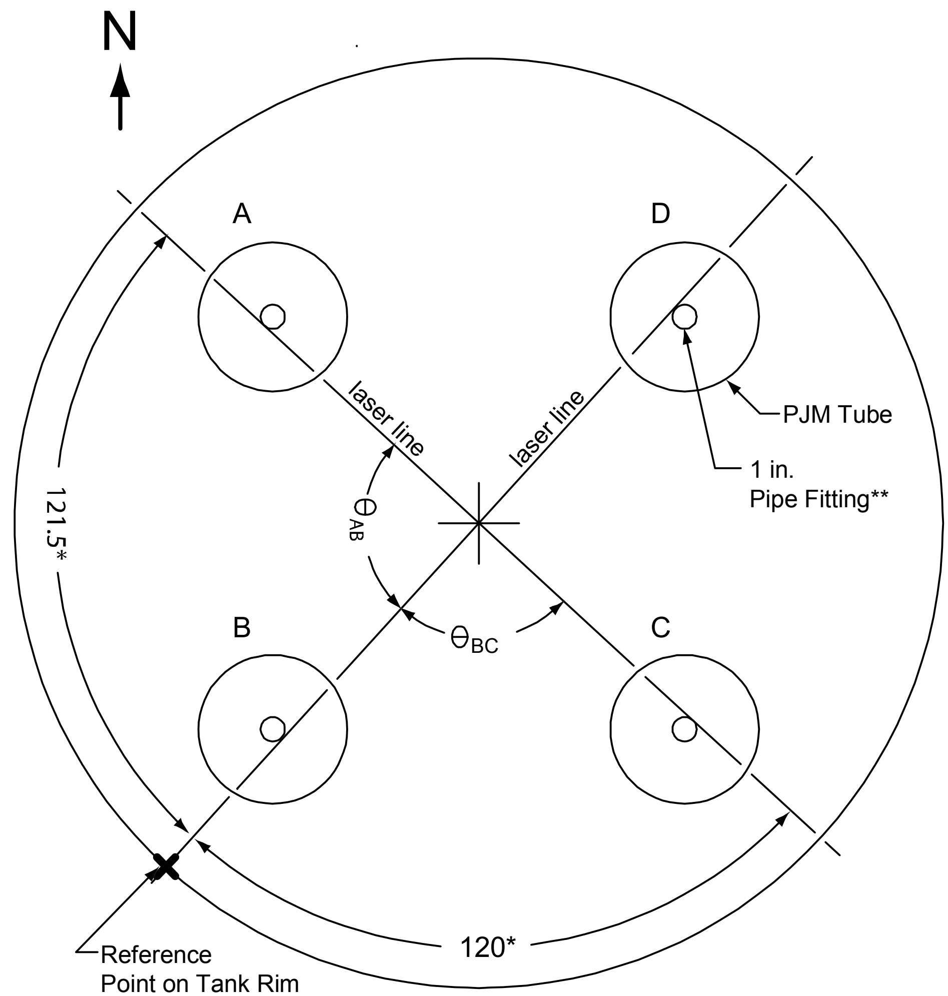


**Figure 2.6**. Positions of PJM Tubes with Respect to Tank Rim (* Measurements taken from inside of tank rim; ** 1 inch [0.00254 m] Threaded Fitting on Level Probe Rod for Securing to Access T in Head Cap)

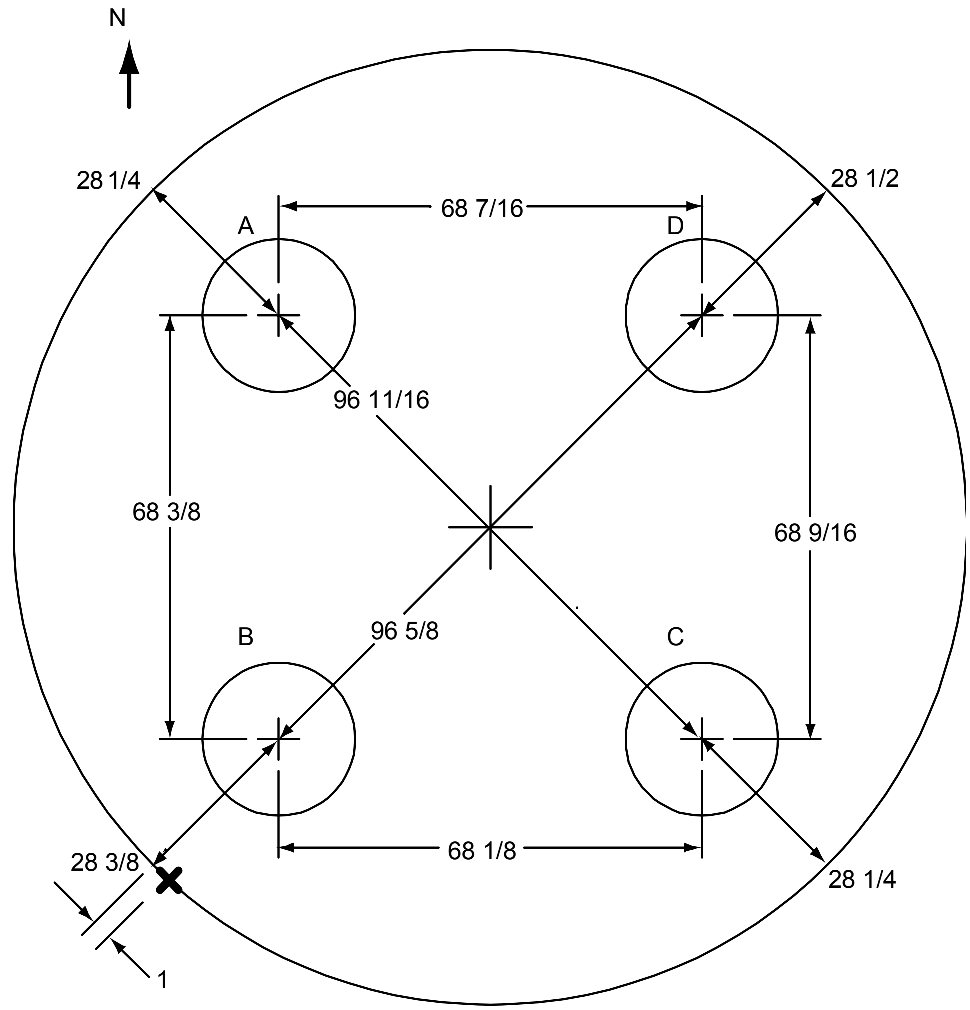


**Figure 2.7**. Distances of the PJM Center to PJM Center and PJM Center to Tank Wall at the Top of the PJM Flange Connections @~ 166 inches [~ 4.2164 m] Elevation (All Distances are Reported to a Tolerance of ± 0.25 inches [± 0.00635 m])

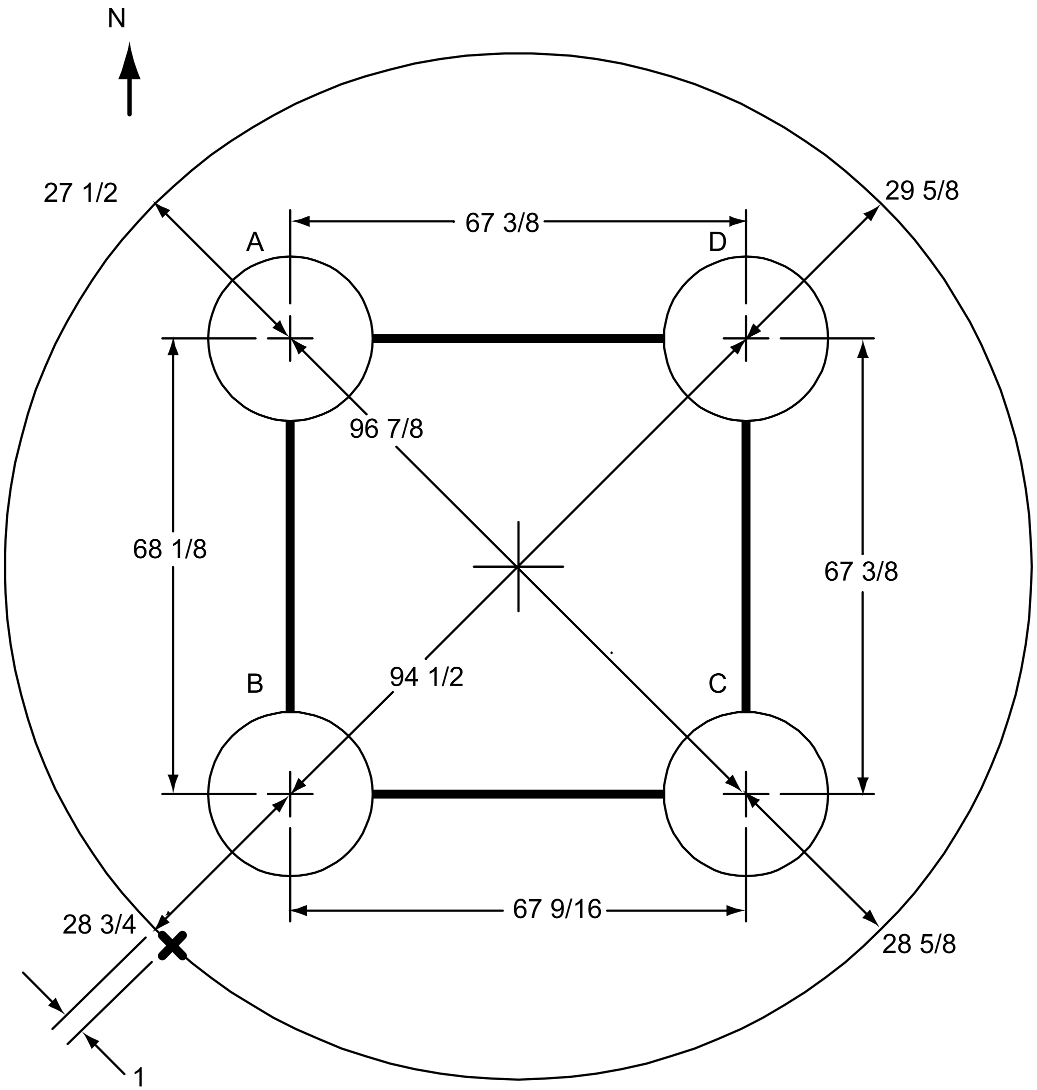


**Figure 2.8**. Distances of the PJM Center to PJM Center and PJM Center to Tank Wall at the Bottom of the PJMs Just above the Weld to the Cone @ ~ 30 inches [~ 0.762 m] Elevation (All Distances are Reported to a Tolerance of ± 0.25 inches [± 0.00635 m])

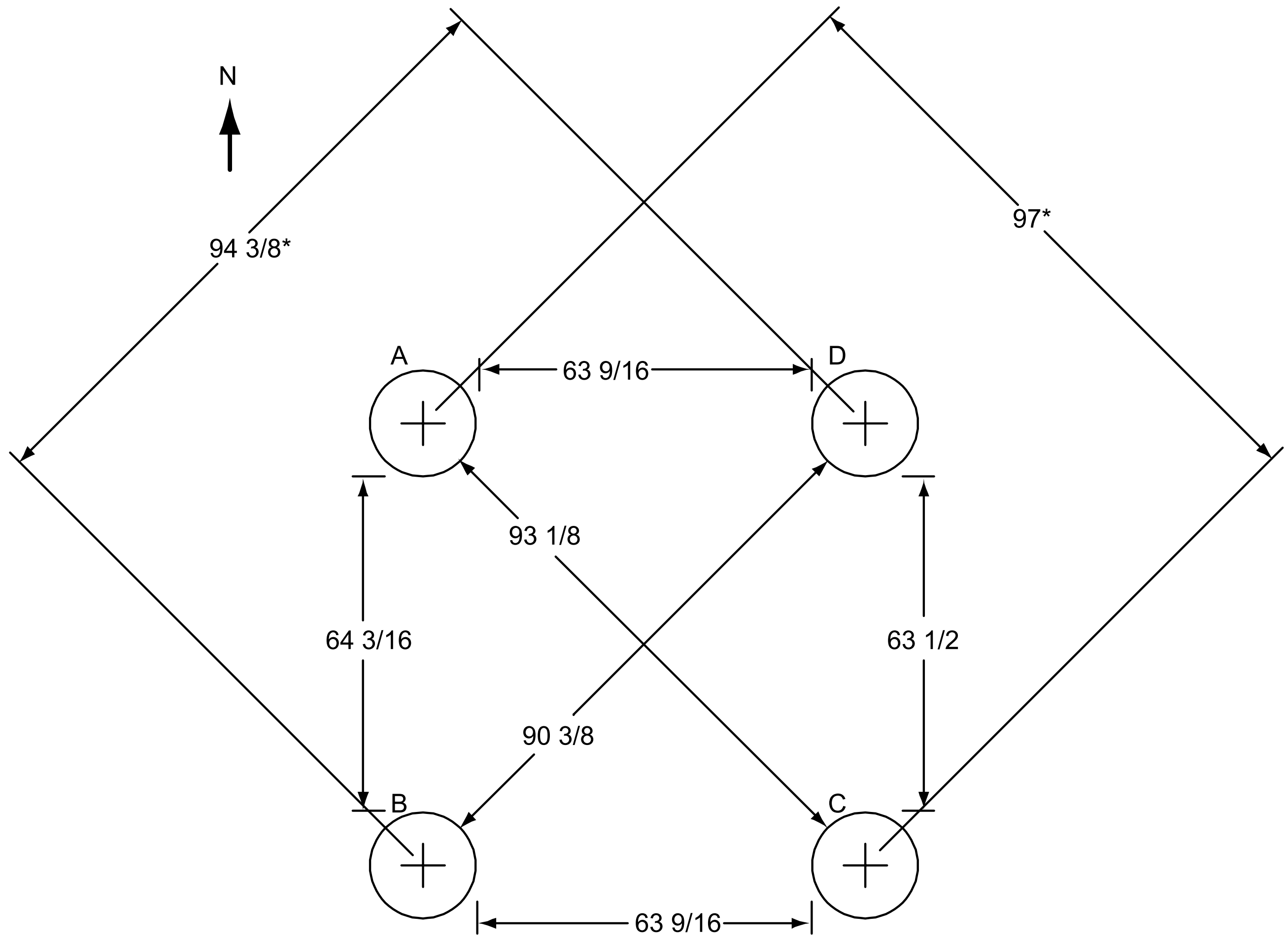


**Figure 2.9**. Distances of the Spans between the PJM Nozzles (All Distances are Reported to a Tolerance of ± 0.25 inches [± 0.00635 m])

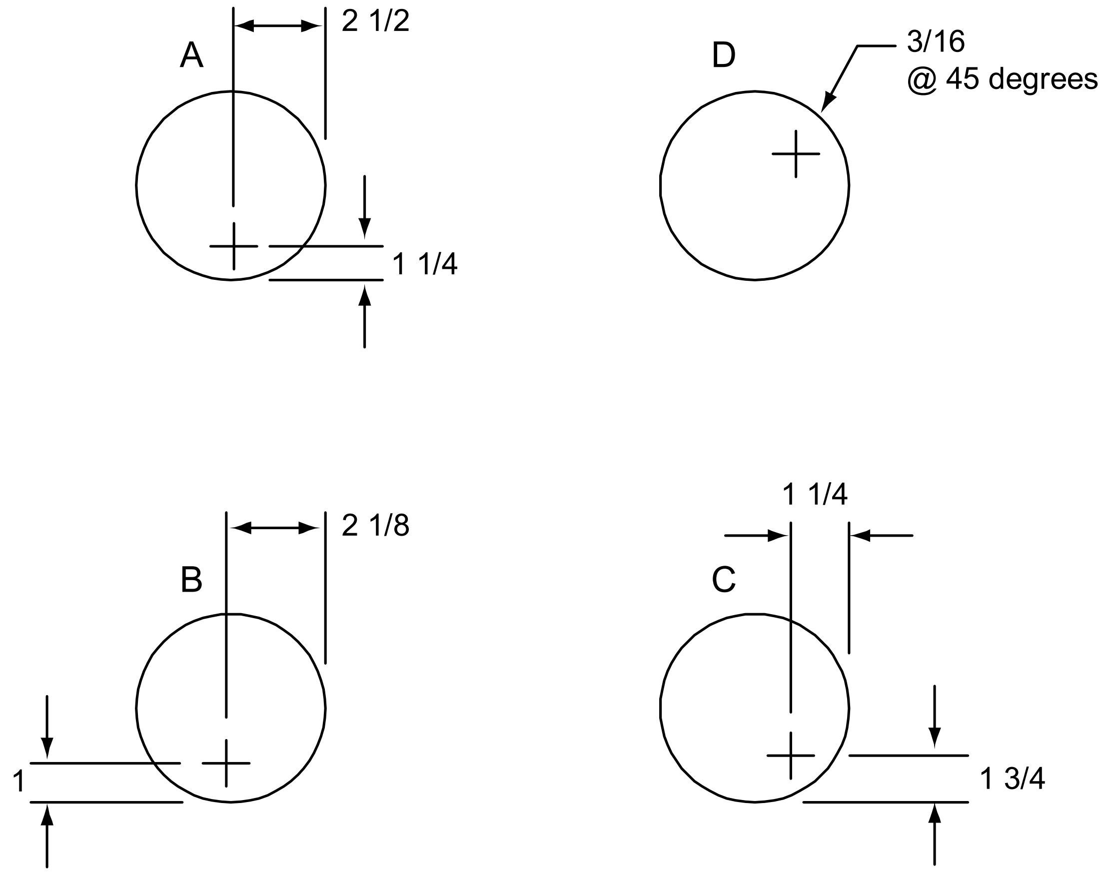


**Figure 2.10**. Measurement of PJM "As-Built" Nozzle With Respect To PJM "As-Built" Tube Bodies (All Distances are Reported to a Tolerance of ± 0.25 inches [± 0.00635 m])

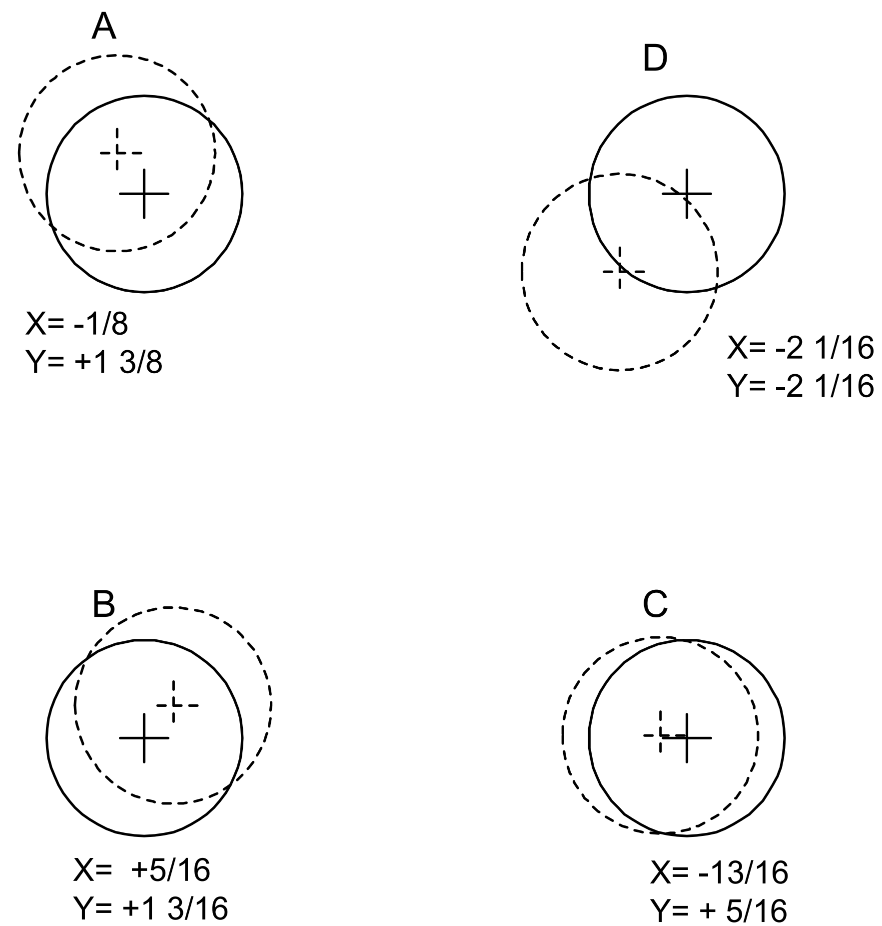


**Figure 2.11**. Measurement of "As-Built" to "Ideal" Nozzle Locations (All Distances are Reported to a Tolerance of ± 0.25 inches [± 0.00635 m])

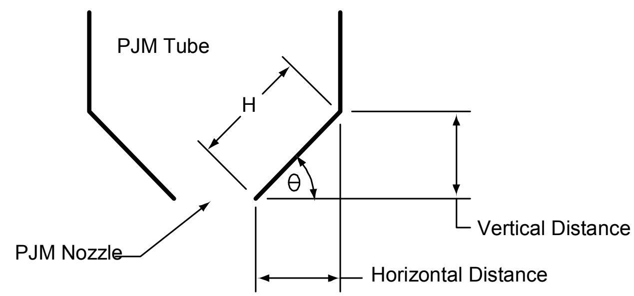


**Figure 2.12**. Measurements Made Relative to the PJM Cone

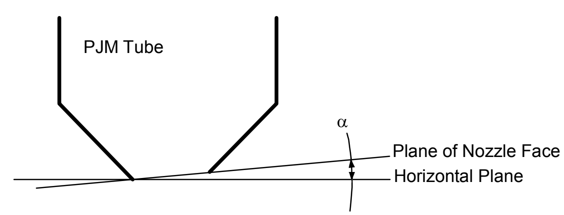


**Figure 2.13**. Measurements Made Relative to the PJM Cone Orientation

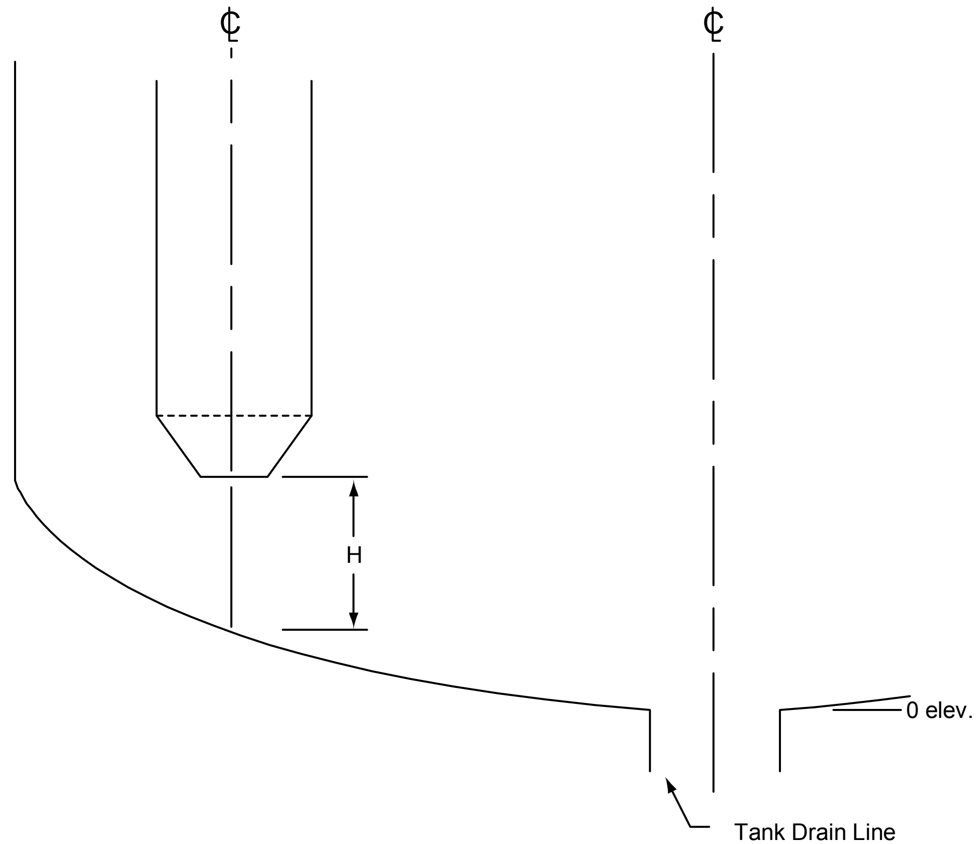


**Figure 2.14**. Nozzle Height Measurement from Tank Bottom Head

# 3.0 Experimental Approach

As discussed in Section 1.0, the primary data needed to support the validation of the FLUENT CFD model of the pulsed jet mixing systems included: 1) velocity measurements during the hydrodynamic (water only) tests and 2) velocity and density data measurements with nominal 10 and 35 μm volume mean particle size glass-beads at different solids loading and/or PJM operation conditions. In addition to the velocity and/or density measurements, additional data such as the liquid level changes in the pulse tube were also essential for computing the fluid velocities out of the nozzles of the PJMs. Finally, the pressure inside the pulse tubes and in the drive/suction lines of the JPPs were needed for operating the PJMs in a symmetric and prototypical manner.

In this section, the experimental approaches used to measure the various items discussed above are presented.

## 3.1 Velocity Measurement

The local velocity values in the large tank during the PJM operation were measured using 3.2 cm (1.259 inches) disc-shaped Valeport 802 electromagnetic (EM) flow sensors. The Valeport EM flow sensors were chosen for this application primarily because of the ruggedness of the probes and their applicability for measuring velocities in the presence of solids in the test system (i.e., for fluid velocity measurement during the simulant tests conducted in the LTTS). In addition, Valeport sensors also had the advantage of measuring the flow in two dimensions. In this application, the local velocity changes were measured vertically and azimuthally.

During the hydrodynamic (water only) tests, velocity measurements were made at 5 verticals, collecting 25 velocity measurements at each elevation (1 at the tank center line and 24 around a core with a 12.5 inches (0.3175 m) radius in increments of 15º). This was done primarily to check for symmetry of the fluid flow in the tank after the PJM realignment. During the simulant tests, however, velocity measurements were focused primarily at the tank centerline at the same five elevations as used in the hydrodynamic tests.

The velocity mapping was achieved by horizontally mounting the velocity probes (which are located at the end of a 12.5-inch [0.3175 m] extension rod) to a 0.75-inch (0.01905 m) stainless steel (SS) pipe approximately 20 ft long. The spacing between each velocity probe was 24 inches (0.6096 m), and the lowest probe was located at an elevation of 30 inches (0.762 m) as measured from the floor of the tank at the tank centerline. This is schematically shown in Figure 3.1. The probes were numbered 1 to 5 starting with 1 at the top (126 inch [3.2004 m] elevation) and 5 at the lowest point (30 inch [0.762 m] elevation). In order to stabilize the probe support and the probes in the tank, the probe support was anchored at the bottom of the tank and at the top to the tank-bridge. The arrangement was such that the velocity probe could be slid radially-outward (by 12 inches [0.3048 m]) to bring the velocity sensor heads to the tank centerline or rotated to map the velocity at different angular positions around a circle of 12.5 inch (0.3175 m) radius.

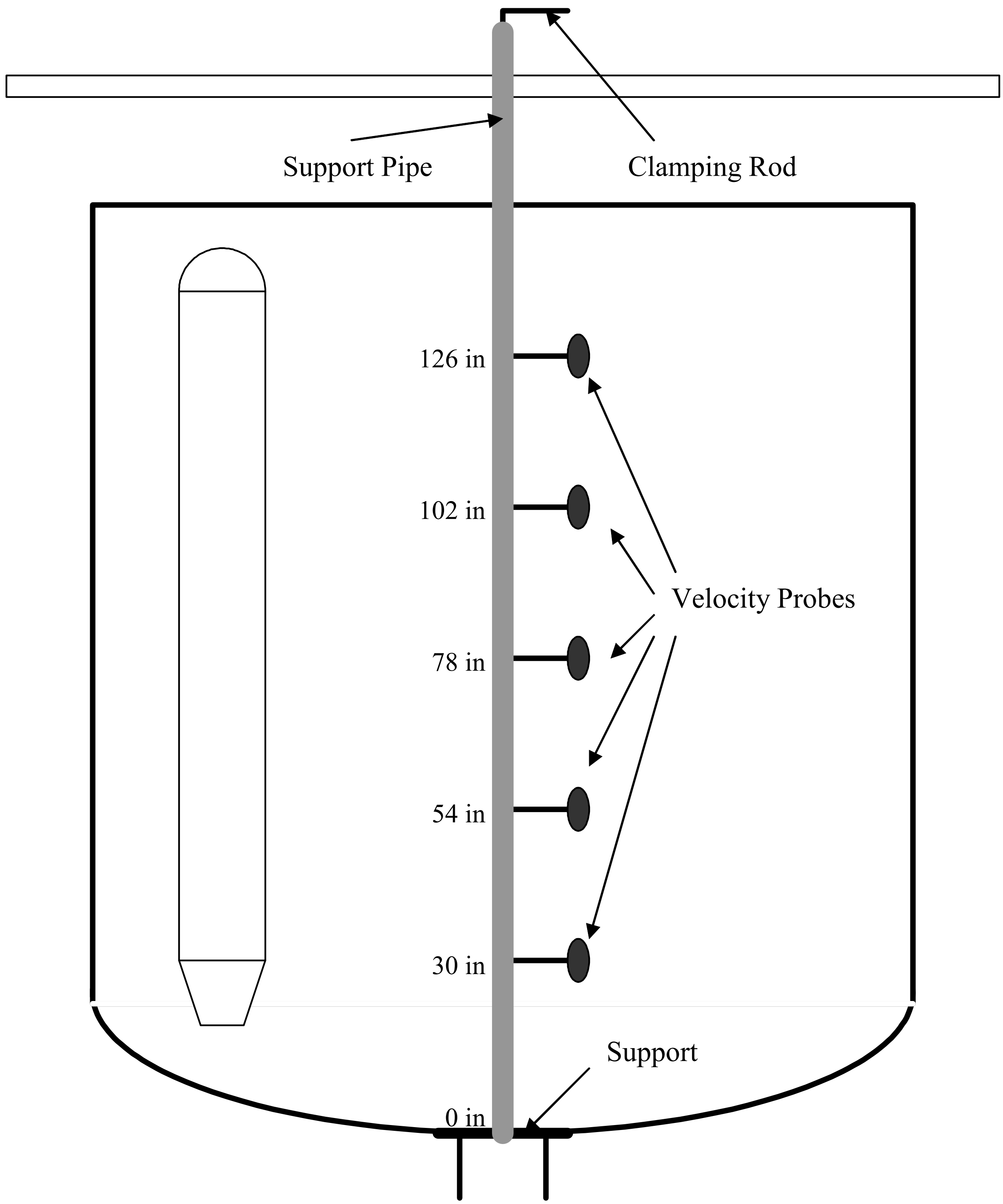


**Figure 3.1**. Schematic of the Velocity Probe Support Used in the Large Tank Test Stand

Figure 3.2, which shows the top view of the velocity probe assembly, illustrates the how the velocity probe angle is measured. Here the reference 0 deg plane is located in the East direction with the center of the mast located at the center of the tank or 12 inches (0.3048 m) westward from the tank center. This creates a bias of +3.4º inches (+0.08636 m) the angles presented in this report when measured from the center of the mast to the center of the sensor head.

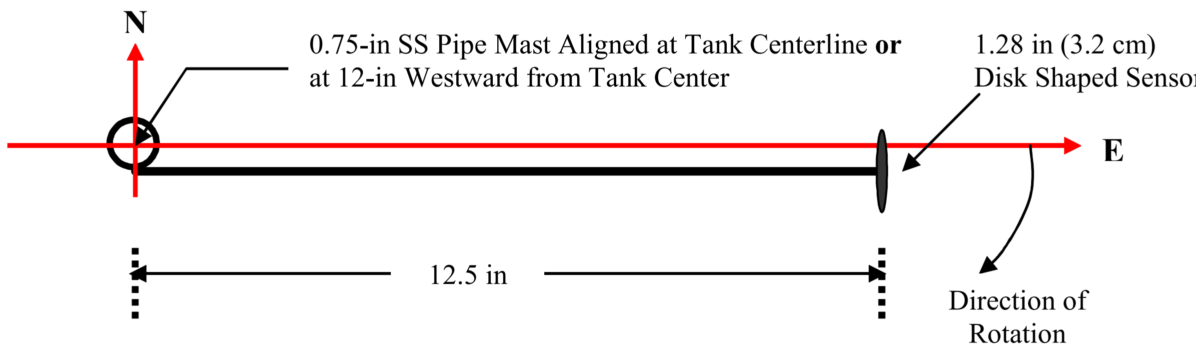


**Figure 3.2**. Top View of the Velocity Probe Holder Assembly

## 3.2 Density Measurement

During the simulant tests, the density of the slurry at various locations within the tank was monitored continuously during the PJM operation using a set of three MicroMotion Coriolis mass flow meters. The continuous slurry density monitoring equipment, shown schematically in Figure 3.3, consists of three recirculation pumps and three MicroMotion sensors. Slurry from the tank enters a pump inlet through one of the three 20 ft (6.096 m) long, 1 inch (2.54E-02 m) SS tubes located at the radial positions of 0, 3, and 5.75 ft (0, 0.914, and 1.753 m), respectively.

Each sample line had a provision so the height at which the sample is collected can be adjusted upward from a minimum of 3 inches (7.62E-02 m) from the floor of the tank. After the circulating sample stream was analyzed by the MicroMotion sensor, it was returned back to the tank. Using this configuration, density measurements were made at various depths and lateral positions to obtain a topographical representation of the slurry concentration profiles within the tank during the mixer operation.

Each MicroMotion sample loop had a 3-way valve assembly which enabled diverting the sample into a receiver vessel. Such an arrangement enabled the collection of grab samples which can be used to confirm the MicroMotion sampler readouts or to determine the PSD for assessing effectiveness of mixing and determining solids stratification.

## 3.3 Pulse Tube Liquid Level Measurement

The change of the liquid height in each pulse tube was individually measured using 12-ft (3.6576 m) long Teflon coated capacitance liquid level sensors (fabricated by DrexelBrook Inc.). These sensors were

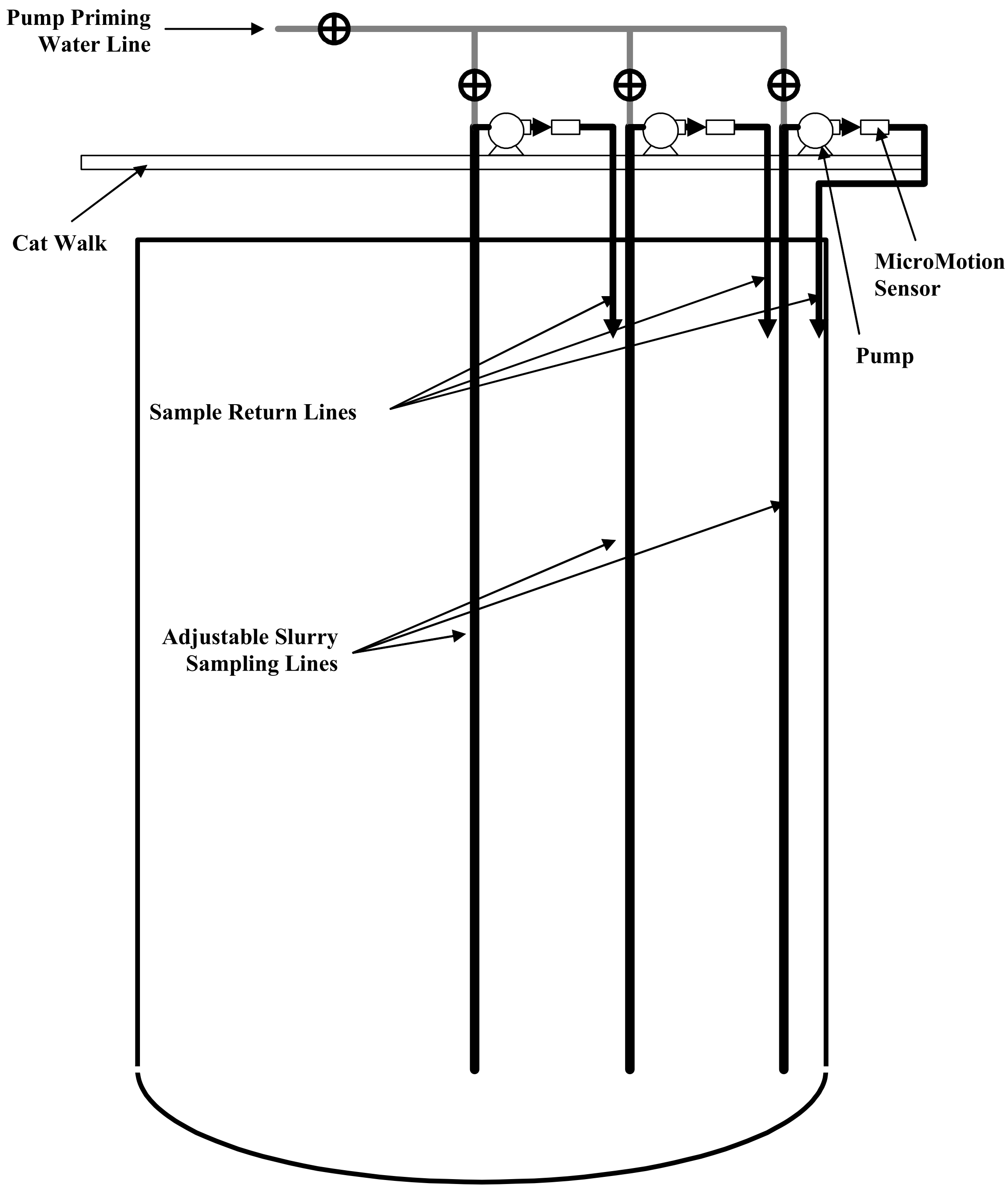


**Figure 3.3**. Schematic of the Sampling System Used to Continuously Monitor the Density in the Tank During the Large Tank Simulant Testing

mounted in the center of each pulse tube through one end of a "T"-fitting attached to the 2-inch flange connector at the top of the pulse tube.

During the PJM operation, liquid/slurry completely fills the pulse tubes with the liquid/slurry entering ~15 ft into the air/vacuum lines. This was done by the AEA engineers to ensure that all PJMs fire at the same time. Once the liquid/slurry enters the air/vacuum line, the level probe reading gets saturated at the maximum value of 140 inches [(a)] (3.556 m). This should however make negligible contribution to the nozzle velocities since the liquid volume is relatively small fraction of the total pulse tube volume (2.5 gal vs. 250 gal or ~ 1%).

## 3.4 Pulse Tube and JPP Pressure Measurements

In order to ensure that all the PJMs are operated (as close as possible) in an identical manner, the pressure inside each PJMs/JPP was individually measured using pressure transducers mounted on top of the pulse tube and at the air inlets to the drive and suction sides of the JPPs. Although independent pressure measurements within the PJMs and the JPP control module were made during the testing, the control of the PJMs was done using AEA proprietary PRESCON™ control system. In other words, the drive, vent, and suction times were set in the PRESCON controller to cycle the PJMs repeatedly at a period of 45 seconds.

## 3.5 PJM Operation

The large tank PJMs were operated using prototypical systems, i.e., using a combination of JPPs and solenoid valves to regulate the suction and discharge of the liquid to and from the pulse tubes. The JPPS were connected to the pulse tubes using 2 inch (5.08E-02 m) ID, wire reinforced, polyvinyl chloride (PVC) tubing.

A compressor/accumulator combination was used to regulate the airflow to the jet pump pairs. The compressor chosen for the present study based on the requirements for the airflow to the JPPs was a diesel powered compressor capable of delivering 1300 CFM at an operating pressure of 100 psig (8 bar). The accumulator was an ASME standard 240 gal (1000 L) Brunner vertical air receiver tank with pressure relief valves and timed electronic drain valve. Both the compressor and the accumulator were located outside the 336 Building.

The sequence of operation and cycle frequency of the PJMs was controlled by a PRESCON™ controller; an Atomic Energy Agency (AEA) Technology proprietary control system. PRESCON™ monitors pressure signals using pressure transmitters, which are a part of the JPP control module. PRESCON™ enables various combinations of pulse tube operation (i.e., all four at a time, two at a time, or one at a time) and cycle times. Prior to the start of the testing, AEA staff reprogrammed the

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(a) This is less than the 144 inch (3.6576 m) size of the level probes since 4 inches (0.1016 m) of the level probe sensor is concealed behind the fittings used to fasten the probe to the PJMs.

PRESCON™ and in addition adjusted the air pressures to the drive/vent sides of the JPP to: 1) set cycle times close to prototypical operation conditions[a] and 2) drive/refill the four PJMs in a "near" identical manner[b].

## 3.6 Data Acquisition and Storage

All data from the experiments, which included date, time, liquid levels, pressures, velocities[c,d], densities[e], mass flow rates[f], and temperature, were monitored continuously and recorded digitally on a computer using DASYLab, Version 5.5 data acquisition software installed on a Micron Millennia XRU PC running Windows 98.

The Data Acquisition System (DAS) sampled all channels at 32 Hz frequency and averaged the data over one second intervals. These one-second averages were electronically recorded in the data log files. The electronic data files were saved as ASCII or text files. Each electronic entry in the file included a date/time stamp and the file also included a header which at a minimum contains information regarding the test objective and the location of the velocity and density probes.

All data from the experiments were transferred on to zip disks and stored in duplicate. For data examination and "reasonableness" checks, data files were then copied into separate Excel spreadsheets. These Excel spreadsheets are presented on the CD included as an attachment to this report.

The Excel spreadsheets have the same header information and data label information as the data log files which are listed in Rows 1 to 11 of each file. Row 12 of the Excel files contains the labels of the various items recorded in each column. A description of the various column labels used in the Excel spreadsheets containing the experimental data from the present testing is listed in Table 3.1.

## 3.7 Data Quality

Of the various sensors used in the present testing, some measurements were made for helping the experimentalists operate the equipment in as near a symmetric manner as possible while other

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(a) A cycle time of 45 s (~10 s drive and 35 s of vent/refill) was used during all testing.

(b) It was found to be extremely difficult to tune the PRESON™ to operate the PJMs in a truly identical manner due to the different performance characteristics of the JPPs and the difficulty in balancing the pressure/air flow conditions in air/vacuum lines of the PJMs. The tuning eventually achieved was the best possible with the current equipment.

(c) Of the five velocity sensors, the one present at the 126-inch (3.2004 m) elevation (Probe 1) was of an earlier model of the Valeport unit which had a built-in signal lag time of 6 seconds before the signal was transmitted to the data acquisition board. Therefore, all vertical and azimuthal velocity data for this sensor should be shifted back by 6 s to directly correlate the measured velocities to the pulse tube operation cycle.

(d) The vertical velocities in the downward direction and azimuthal velocities in the counter clockwise direction are treated and logged as positive values.

(e) It should be noted that the calibrations of the MicroMotion density meter included at the 5.75 ft (1.7526 m) radial position (Sensor 1) indicated a 0.002 specific gravity offset, thus 0.002 should be added to all raw values measured by this sensor.

(f) In addition to the density of the sample, the MicroMotion sensors also measure the mass flow rates in each density sampling loops. This information was also recorded in the data log files.

data/information was collected in accordance with the project/task requirements. The former set of data is classified as "Data for Information Only" and the later is defined as "Reportable Data". The difference between the two classifications is that:

- ❖ The sensors/instruments for "Reportable Data" were calibrated or performance checked in accordance to the WTP project QA requirements [a,b]
- ❖ The sensors for "Data for Information Only" utilized only the vendor provided calibration certificates (these calibrations do not necessarily meet the WTP project QA requirements)

The various instruments, functions, quality of the data (i.e., reportable/For Information only), service or organization performing the calibration or performance check, range of validity of the instrument output are listed in Table 3.2. It can be seen from Table 3.2 that the calibration of MicroMotion density[c] and the DrexelBrook Level[d] sensors were performed by the users (i.e., the PNWD staff involved in the PJM testing).

After the performance check of the level sensors and during the subsequent hydrodynamic testing, it was realized that the level sensor span drifted by ~ +6 inches (0.1524 m). The cause of the span drift is not known but it is speculated that this was due to the change in the liquid conductivity resulting from the decrease in pH due to the solubilization of $CO_2$ from the atmosphere during the PJM operation. For this reason, the reading of each level probe and the stationary height of the liquid/slurry in the tank was recorded prior to the start of each days test. Based on this information, the average span drift in the level probes in pulse tube A, B, C, and D over the duration of the testing was determined to be +4.3, +4.3, +4.6, and +4.4 inches (0.10922, 0.10922, 0.11684, and 0.11176 m), respectively. On the other hand, the maximum drift for the four level probes was +7.2, +7.5, +8.5, and +8.1 inches (0.18288, 0.1905, 0.2159, and 0.20574 m), respectively.

## 3.8 Measurement Uncertainties, Noise Levels, and Scale Factor/Bias Errors

The DAS software has a feature allowing input scaling to be directly entered, individually and uniquely, for each channel. Each analog input channel to the DAS uses an industry-standard 5B module that converts the applied input signal (whether it be 4-20 mA, ± 5 V, thermocouple) to an analog voltage in the range of 0-5 V, which the analog input channel "sees". As an example, the scaling for one of the Valeport 802 velocity sensor/signal conditioner units is illustrated in Table 3.3.

The Valeport 802 signal conditioner outputs over a nominal range of ± 5 Volts. From the tow tank calibration performed by Northwest Research Associates in Bellevue, WA, it was determined that for this

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(a) PNWD implemented the RPP-WTP quality requirements by performing work in accordance with the quality assurance project plan (QAPjP) approved by the RPP-WTP Quality Assurance (QA) organization. This work was conducted to the quality requirements of NQA-1-1989 and NQA-2a-1990, Part 2.7 as instituted through PNWD's Waste Treatment Plant Support Project (WTPSP) Quality Assurance Requirements and Description Manual.

(b) List of project approved calibration services is available at http://bss-ams.pnl.gov/quality/esl.

(c) User calibration was necessary for the MicroMotion density sensors due to the fact that there was no QA service that met the project requirements to calibrate the sensors.

(d) The DrexelBrook capacitance level probes required a user calibration since the sensitivity of the probes was dependent on the capacitance characteristics of the medium/environment in which the measurements were made.

particular sensor this corresponds to a linear variation between -5.4997 m/s to + 5.2003 m/s[(a)]. These two extreme velocity points are linearly[(b)] translated to 0V and + 5V, respectively, by the 5B module as inputted to the DAS analog input channel. This analog input scaling, set for each individual channel's unique calibration, tends to greatly eliminate scale factor and bias errors.

**Table 3.1**. Description of the Various Column Labels Used in the Excel Spreadsheets Containing the Experimental Data from the Present Testing

| Excel Col. | Variable Label | Description | Measured Unit |
|---|---|---|---|
| A | Date | Date the Experiment was Conducted | Day/Month/Year |
| B | Time | Time at which the data was logged | Hr: Min: Sec |
| C | Velo. 1-X | Azimuthal Velocity Component of Probe 1 at 126 inch Elevation | m/s |
| D | Velo. 1-Y | Vertical Velocity Component of Probe 1 at 126 inch Elevation | m/s |
| E | Velo. 2-X | Azimuthal Velocity Component of Probe 2 at 102 inch Elevation | m/s |
| F | Velo. 2-Y | Vertical Velocity Component of Probe 2 at 102 inch Elevation | m/s |
| G | Velo. 3-X | Azimuthal Velocity Component of Probe 3 at 78 inch Elevation | m/s |
| H | Velo. 3-Y | Vertical Velocity Component of Probe 3 at 78 inch Elevation | m/s |
| I | Velo. 4-X | Azimuthal Velocity Component of Probe 4 at 54 inch Elevation | m/s |
| J | Velo. 4-Y | Vertical Velocity Component of Probe 4 at 54 inch Elevation | m/s |
| K | Velo. 5-X | Azimuthal Velocity Component of Probe 5 at 30 inch Elevation | m/s |
| L | Velo. 5-Y | Vertical Velocity Component of Probe 5 at 30 in Elevation | m/s |
| M[(a)] | Q 1 | Mass Flow Rate of MicroMotion Sensor 1 @ R = 5.5-ft | L/min |
| N[(a)] | S.G. 1 | Density of MicroMotion Sensor 1 @ R = 5.5-ft | $g/cm^3$ |
| O[(a)] | Q 2 | Mass Flow Rate of MicroMotion Sensor 2 @ R = 3-ft | L/min |
| P[(a)] | S.G. 2 | Density of MicroMotion Sensor 2 @ R = 3-ft | $g/cm^3$ |
| Q[(a)] | Q 3 | Mass Flow Rate of MicroMotion Sensor 3 @ R = 0-ft | L/min |
| R[(a)] | S.G. 3 | Density of MicroMotion Sensor 3 @ R = 0-ft | $g/cm^3$ |
| S | Level A | Level of the Liquid in Pulse Tube A | Inches |
| T | Level B | Level of the Liquid in Pulse Tube B | Inches |
| U | Level C | Level of the Liquid in Pulse Tube C | Inches |
| V | Level D | Level of the Liquid in Pulse Tube D | Inches |
| W | P.T. P. A | Pressure in Pulse Tube A | psia |
| X | P.T. P. B | Pressure in Pulse Tube B | psia |
| Y | P.T. P. C | Pressure in Pulse Tube C | psia |
| Z | P.T. P. D | Pressure in Pulse Tube D | psia |
| AA | Manif. P. A | Manifold Drive Pressure on JPP for Pulse Tube A | psia |
| AB | Manif. P. B | Manifold Drive Pressure on JPP for Pulse Tube B | psia |
| AC | Manif. P. C | Manifold Drive Pressure on JPP for Pulse Tube C | psia |
| AD | Manif. P. D | Manifold Drive Pressure on JPP for Pulse Tube D | psia |
| AE | Temp. 1 | Temperature in Tank | ºC |
| AF | Temp. 2 | Ambient Temperature | ºC |
| AG | S.N. Tank Wt. | Gross Weight of Tank and its Contents | lbs |
| (a) Density and mass flow rate data recorded in these columns during the hydrodynamic tests are irrelevant to the tests. | | | |

(a) Note – Although the calibration data was extrapolated to ~ ±5 m/s (the full range of the velocity probes), the velocity data is only applicable to ± 2.5 m/s, which is the range over which the probes were calibrated.

(b) Note – A linear translation was utilized since the Valeport calibration was linear. The DAS system also allows for non-linear calibration curves.

The Measurement Computing PCI-DAS6402/16 analog input board used in the DAS has 16 bit resolution (.001526% resolution). Based on this, the resolutions for the inputs from the various sensors are shown in Table 3.4. The actual system resolution/accuracy is, however, limited by the sensors and signal conditioning, which are summarized in Table 3.5. See Appendix A for more details about the different sensors used to measure the reportable data.

**Table 3.2**. Data Quality, Mechanism of Calibration/Performance Checking, and Range of Applicability of Data Obtained from the Various Sensors Used in the Testing

| Manufacturer | Function/Measured Variable | Data Quality | Calibrated or Performance Checked By | Range |
|---|---|---|---|---|
| Valeport | Velocity (Vertical and Azimuthal) | Reportable Data | Calibrated/Northwest Research Associates, Bellevue, WA [a] | ± 2.5 m/s |
| MicroMotion | Density | Reportable Data | Performance Check/User[b] | 0.99 – 1.5 $g/cm^3$ [c, d] |
| DrexelBrook | Level | Reportable Data | Performance Check/User[b] | 0 – 140 in [e] |
| Type K T/C | Ambient Temperature | Reportable Data | Calibrated/Battelle Calibration Services | 0 – 50 ºC |
| Type K T/C | Slurry/Liquid Temperature | Reportable Data | Calibrated/Battelle Calibration Services | 0 – 50 ºC |
| Sartorius | Weighing Balance[f] | Reportable Data | Calibrated/Quality Control Services, Portland, OR | 0 – 200 g |
| Inscale | Platform Scale[g] | Reportable Data | Calibrated/Quality Control Services, Portland, OR | 0 – 5000 lbs |
| Measurement Computing | DAS - Analog Input Board PCI-DAS6402/16 | Reportable Data | Calibrated/Battelle Calibration Services | All Channels |
| MicroMotion | Flow Rate | Data For Info Only | Calibrated/Fischer Rosemount[h] | 0 – 100 L/min |
| Cecomp | Pulse Tube Pressure | Data For Info Only | Calibrated/Cecomp[h] | 0 – 100 psi |
| Cecomp | JPP Module Pressure | Data For Info Only | Calibrated/Cecomp[h] | 0 – 100 psi |
| Hardy Instruments | Tank Weight | Data For Info Only | Calibrated/Hardy Instruments[h] | 0 – 300,000 Lbs |

(a) Project approved calibration service.
(b) All user calibrations were performed using procedures or test instructions that were determined to meet the project QA requirements by PNWD QA personnel
(c) The MicroMotion sensors performance was checked using three density standards of specific gravities of 0.99, 1.07, and 1.12 $g/cm^3$. The sensor output which varies linearly with density is valid over the range of 0 to 5 $g/cm^3$.
(d) The MicroMotion sensors density readings during the testing were also check periodically using grab samples collected from each sampling system bypass line.
(e) Performance check of the level probe sensors was done to ±1/4 in. with each probe installed in the pulse tube system.
(f) Sample weights and volumes determined using standard laboratory glassware were used to determine the density of the samples used for MicroMotion density sensors performance check.
(g) This balance was used to determine the mass of glass beads added to the tank. This along with the volume determined from the dimensions of the tank and height of fill were used to determine the concentration of the solids in tank.
(h) Vendor provided calibration.

**Table 3.3**. Instrument Output and DAS Channel Scaling of One of the Valeport Sensors

| Instrument Signal Conditioner Output | DAS Channel Scaling | | | |
|---|---|---|---|---|
| | Sensor | | Hardware | |
| | Low | High | Low | High |
| ± 5 V | -5.4997 m/s | +5.2003 m/s | 0 V | 5 V |

**Table 3.4**. DAS Resolution for Inputs from Various Sensors

| Sensor | Input Range to DAS | DAS Resolution |
|---|---|---|
| Valeport Velocity Sensors | ± 5 m/s | 7.63E-05 m/s |
| MicroMotion Density | 0.9 – 1.5 g/cm$^3$ | 2.29E-05 g/cm$^3$ |
| MicroMotion Flow Rate | 0 – 100 L/min | 0.001526 L/min |
| DrexelBrook Level Sensor | 0 – 140 in | 2.20E-03 in |
| Cecomp Pressure Sensor | 0 – 100 psia | 1.53E-03 psia |
| Type K T/C | 0 – 50 ºC | 7.63E-04 ºC |
| Load Gages for Tank Weight | 0 – 300K lbs | 5 lbs |

**Table 3.5**. Accuracy of the Sensors and the Corresponding Signal Conditioning Equipment Used in the Large Tank Testing

| Variable | Manufacturer | Sensor Model | Transmitter Model | Accuracy |
|---|---|---|---|---|
| Velocity | Valeport | 3.2 cm Discus | 802 | ± 5.0E-03 m/s + 1% of Each Axis |
| Density (Sensor 1) | MicroMotion | D100 | RFT 9739 | ± 0.001 g/cm$^3$ |
| Density (Sensors 2 & 3) | MicroMotion | CMF 100 | RFT 9739 | ± 0.0005 g/cm$^3$ |
| Level Probes | DrexelBrook | 700-0002-057 | 408-8232-001 | 0.25% of Span = 0.35 inches for the 140 inch span |
| Pulse Tube Pressure | Cecomp Electronics | DPG100 | F4DR | ± 0.25% of Full Scale = 0.25 psi for a span of 100 psi |
| Temperature | Omega | Type K T/C | - | ± 2.2 ºC |

# 4.0 Results: Hydrodynamic Tests

The primary focus of the hydrodynamic tests was to determine the symmetry of the velocity flow fields in the tank after the PJMs realignment and fine tuning the PRESCON™ programming for control of the PJMs operation. These results are presented as Excel spreadsheets in the CD included along with this report.

In this section, the nomenclature used in the description of the files containing the data and a brief discussion of the results in terms of the flow field symmetry are presented.

## 4.1 Nomenclature Used

The Excel spreadsheets containing the hydrodynamic test data is stored in the folder "021108 DATA". The file list is summarized in Table 4.1.

**Table 4.1**. Summary of the Files Containing the Hydrodynamic Test Data

| File Name | Clock Time | | Velocity Probe Position | |
|---|---|---|---|---|
| | Start | Finish | Direction | Radial Position (in) |
| 021108A.xls[(a)] | 09:09:59 | 09:19:50 | 0° (East) | 12 |
| 021108B.xls[(a)] | 09:29:26 | 09:50:09 | 0° (East) | 12 |
| 021108C.xls[(a)] | 09:52:45 | 10:34:15 | 30° | 12 |
| 021108D.xls[(a)] | 10:36:50 | 11:16:50 | 60° | 12 |
| 021108E.xls[(a)] | 11:18:36 | 12:01:45 | 90° (South) | 12 |
| 021108F.xls[(a)] | 12:02:45 | 12:25:20 | 120° | 12 |
| 021108G.xls[(a)] | 12:30:30 | 12:52:30 | 150° | 12 |
| 021108I.xls[(a)] | 13:14:50 | 13:36:55 | 180° (West) | 12 |
| 021108J.xls[(b)] | 13:49:20 | 14:04:35 | 210° | 12 |
| 021108K.xls | 14:06:40 | 14:29:40 | 240° | 12 |
| 021108L.xls[(c)] | 14:31:00 | 14:59:55 | 270° (North) | 12 |
| 021108M.xls | 15:01:50 | 15:26:05 | 300° | 12 |
| 021108N.xls | 15:34:05 | 15:56:10 | 330° | 12 |
| 021108O.xls | 16:12:30 | 16:36:50 | 0° (East) | 12 |
| 021108P.xls | 16:39:40 | 17:29:15 | 45° | 12 |
| 021108Q.xls | 17:33:30 | 17:55:00 | 135° | 12 |
| 021108R.xls | 17:56:45 | 18:18:03 | 225° | 12 |
| 021108S.xls | 18:21:35 | 18:43:28 | 315° | 12 |
| 021108T.xls | 18:52:20 | 19:14:40 | 0° (East) | 0 |
| 021108U.xls | 19:16:30 | 19:38:10 | 180° (West) | 24 |

(a) Velocity probe No. 1 data invalid, wire was broken.
(b) Velocity probe wire repaired; data valid from here onwards.
(c) Data for Columns S through AG missing.

During each run, a minimum of 25 cycles of data was collected to enable computation of the cycle average velocity profiles in the tank. However, during several measurements, more than 25 cycles of data was collected due to repeated shutdown/restart of the PRESCON™ controller as a result of clogged air regulators on the JPP control module[(a)].

## 4.2 Velocity Profiles and Flow Field Symmetry

The cycle averaged vertical velocities at the tank center line region, and the five elevations where the measurements were made are shown in Figure 4.1. It can be seen from this figure that as the elevation increases and the magnitude of the velocity decreases.

Although the data in Figure 4.1 shows the general trends of the velocity profiles, it does not provide any information regarding the symmetry of the flow field in the tank. This effect is illustrated in Figures 4.2 through 4.5 showing the contour maps of the cycle averaged vertical velocities in the tank at 8 s after the start of a typical pulse and at elevations of 30, 54, 78, and 102 inches (0.762, 1.3716, 1.9812, and 2.5908 m), respectively. In all of these figures, the pulse tubes A, B, C, and D are located in the NW, SW, SE, and NE directions, respectively, at a radial position of ~4.25 ft (~1.2954 m).

It can be seen from Figure 4.2 that although the flow is slightly skewed towards pulse tubes A and B, the velocities are reasonably symmetric and peak velocities occur at the tank center. However as the velocity fields are examined at higher elevations (see Figures 4.3 to 4.5), the asymmetric behavior becomes more pronounced. However, in all cases, the peak velocities are still close to the tank center regions.

Although the geometric dissimilarity (presented in Section 3.0) still causes some asymmetry in the flow, the differences in the individual pulse tubes operation also contributes to the asymmetric flow. This is illustrated in Figure 4.6 in terms of the cycle averaged liquid levels in the pulse tubes. It can be seen from this figure that pulse tubes B and D drive much harder than pulse tubes A and C. Although AEA staff attempted to minimize the differences in the liquid level changes in the pulse tubes, inherent system and PRESCON™ controller limits did not enable further improvements in the synchronous firing of the PJMs.

At this point, BNI decided that further improvements in the symmetry are not possible within the budget and time constraints and gave the go ahead for the simulant tests. These results are presented in the next section.

(a) Cleaning the air regulators after the completion of the hydrodynamic tests essentially eliminated the controller shutdown problem during the simulant runs.

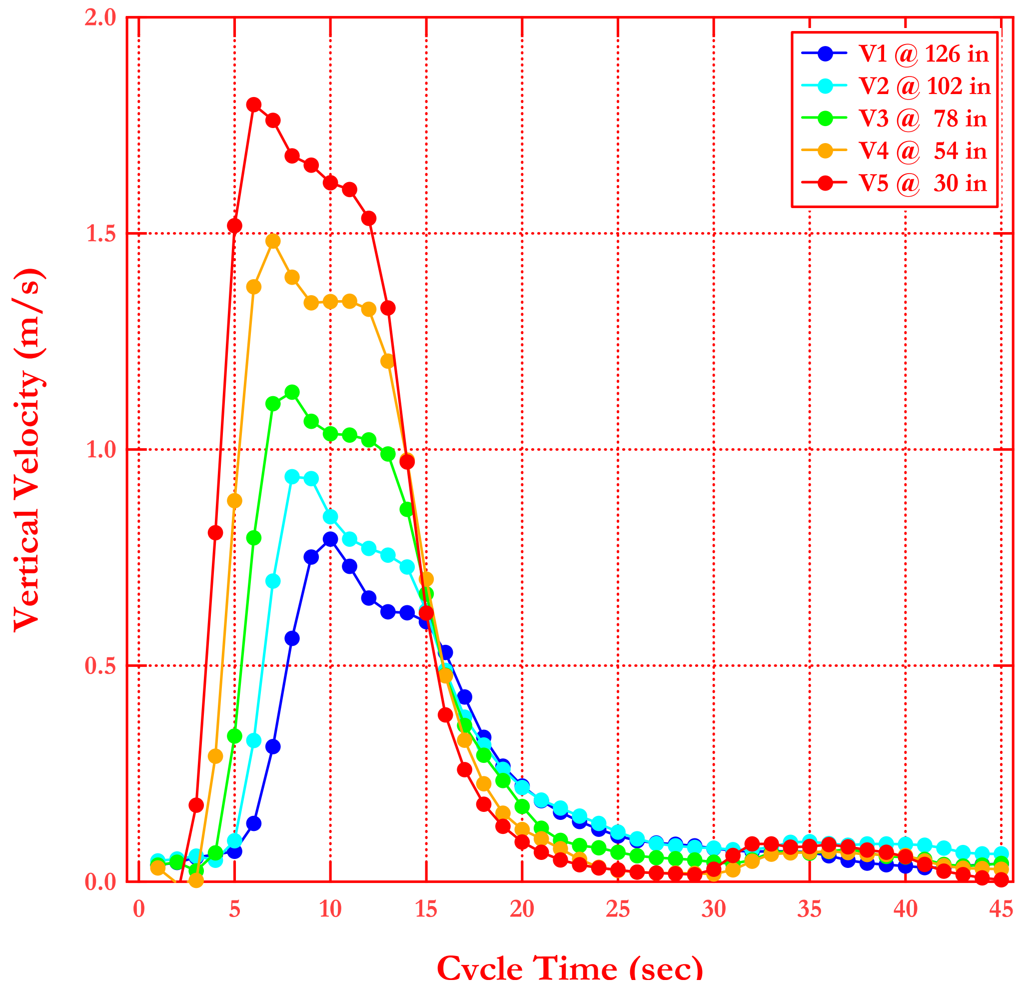


**Figure 4.1**. Time Averaged Vertical Velocity Profiles at the Tank Centerline

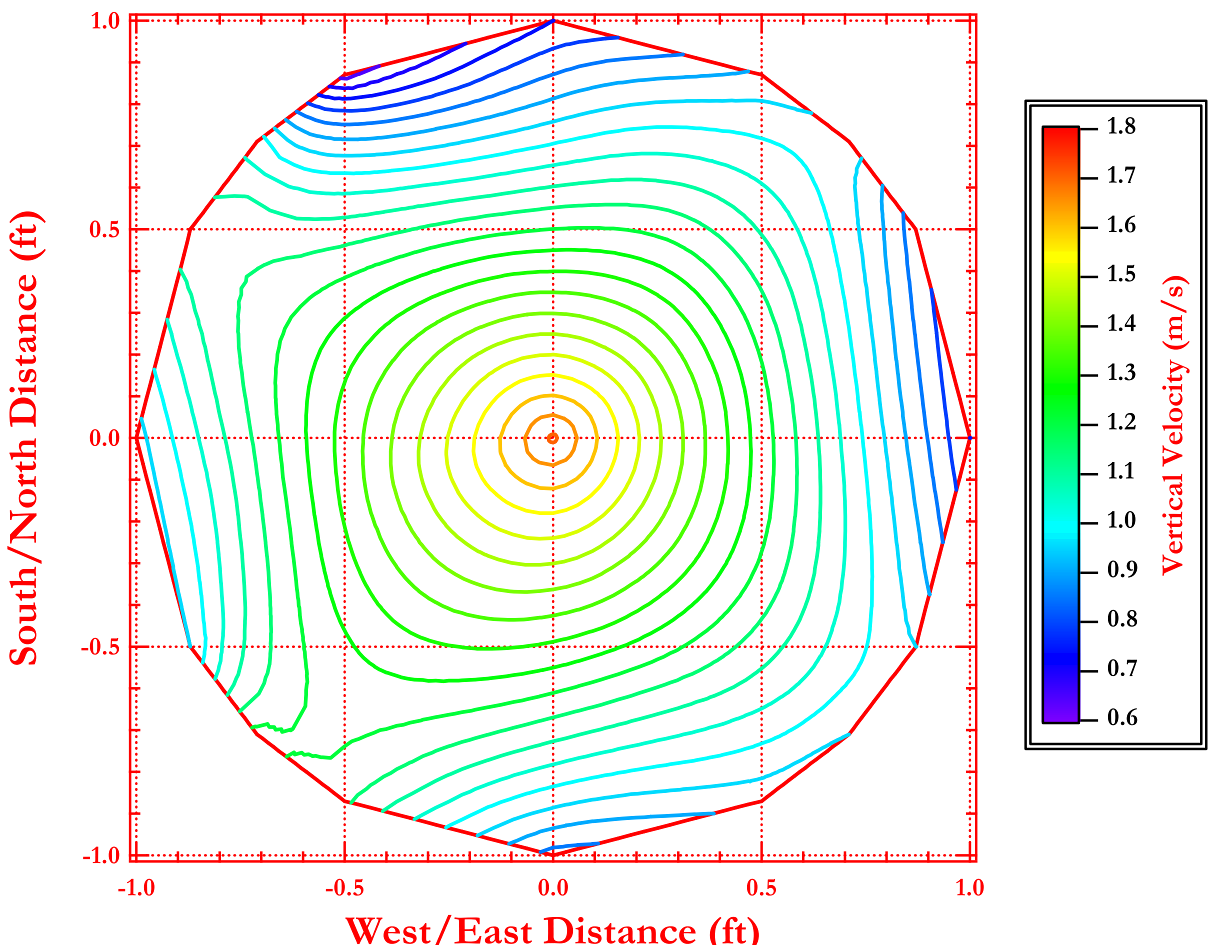


**Figure 4.2**. Contour Map Showing the Fluid Velocities in a 2-ft Diameter Core Around the Center of the Tank and an Elevation of 30 inches (0.762 m)

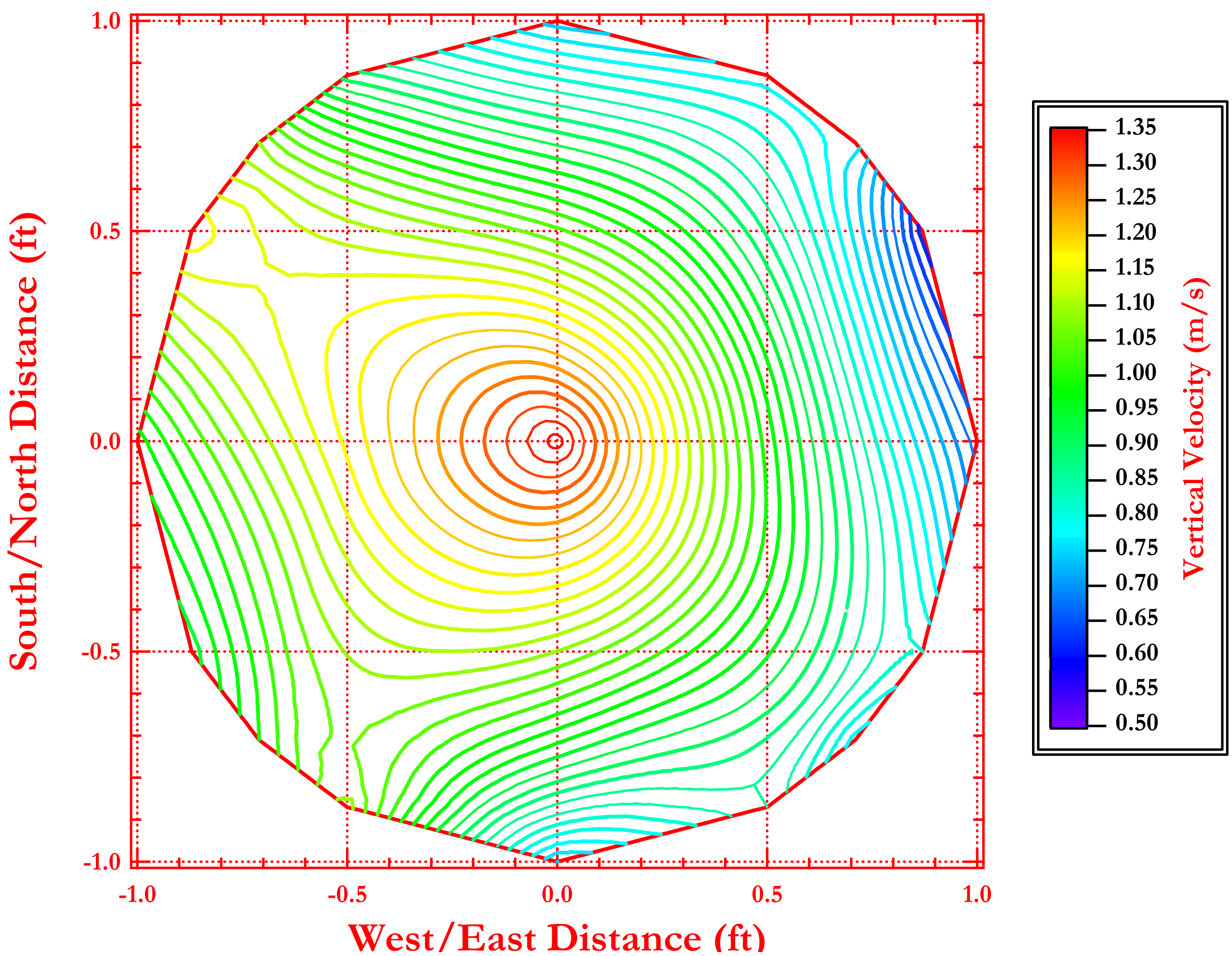


**Figure 4.3**. Contour Map Showing the Fluid Velocities in a 2-ft Diameter Core Around the Center of the Tank and an Elevation of 54 inches (1.3716 m)

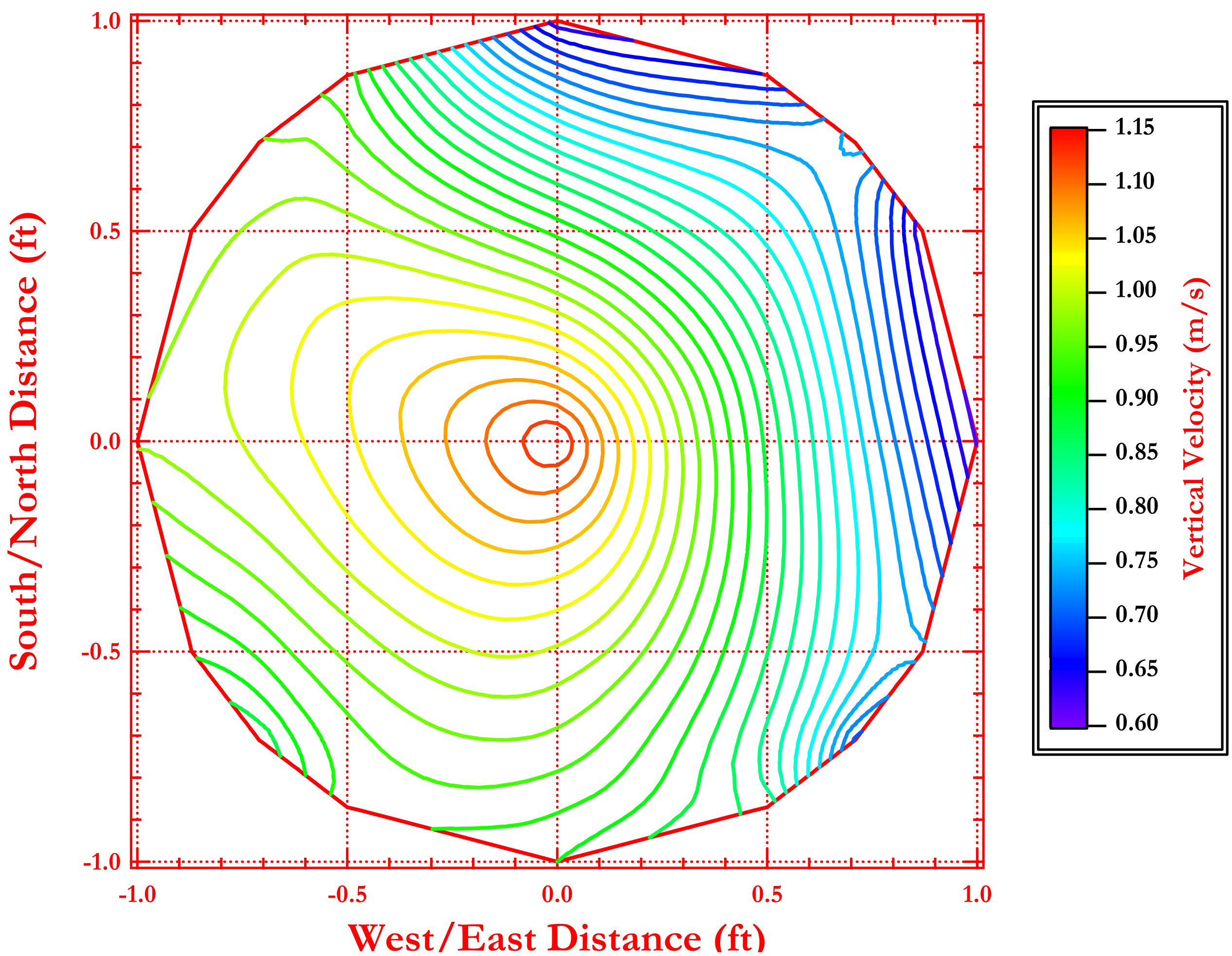


**Figure 4.4**. Contour Map Showing the Fluid Velocities in a 2-ft Diameter Core Around the Center of the Tank and an Elevation of 78 inches (1.9812 m)

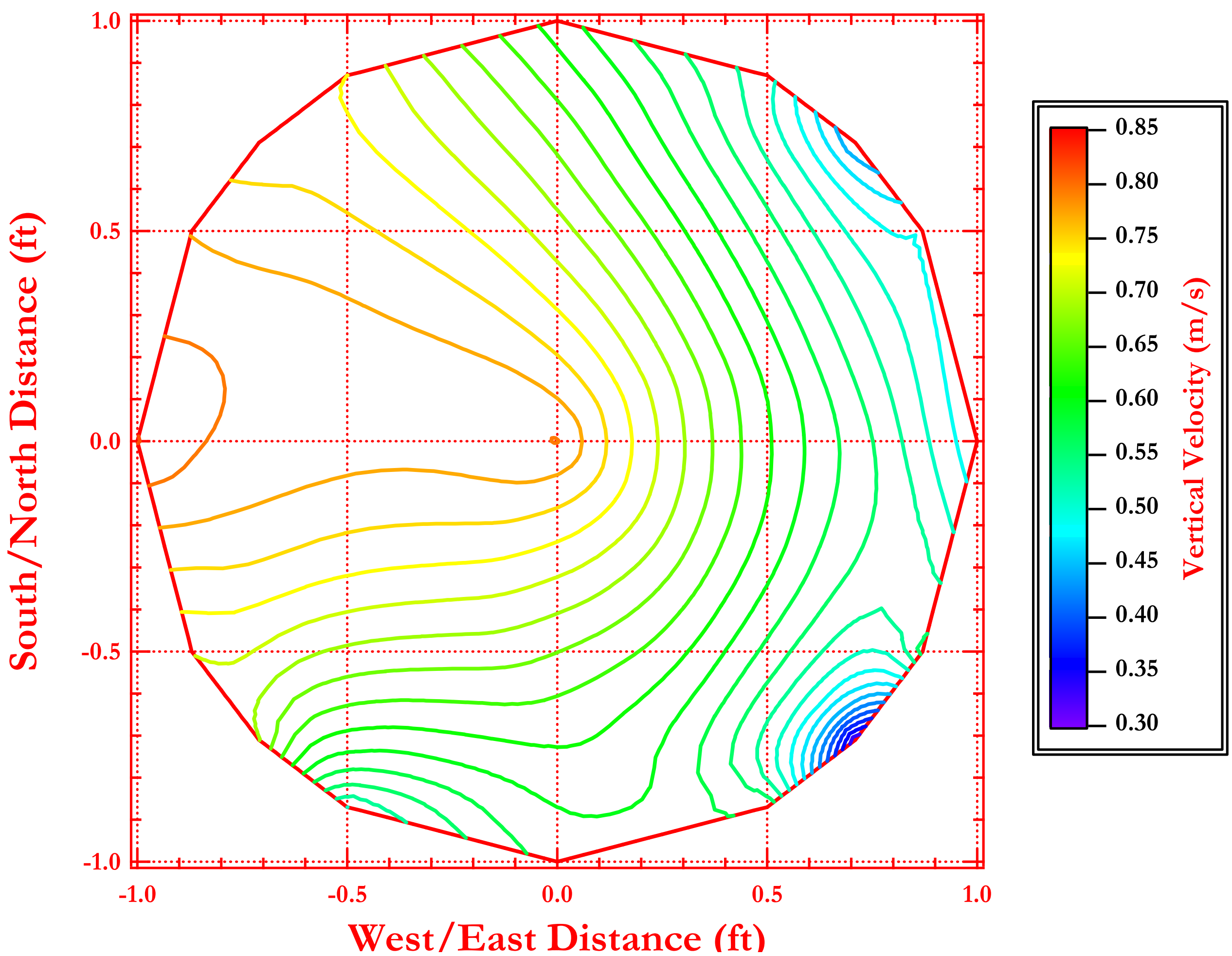


**Figure 4.5**. Contour Map Showing the Fluid Velocities in a 2-ft Diameter Core around the Center of the Tank and an Elevation of 102 inches (2.5908 m)

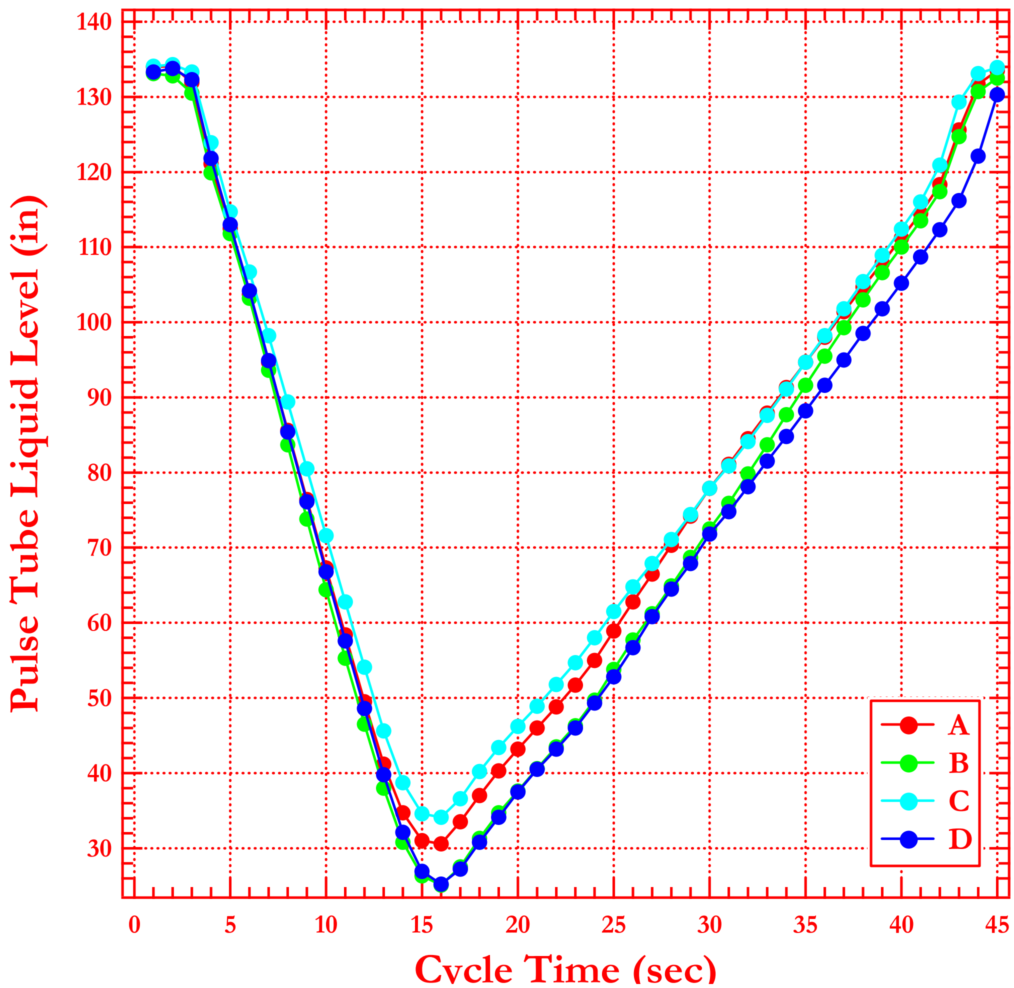


**Figure 4.6**. Cycle Averaged Liquid Level Changes in the Pulse Tubes

# 5.0 Results: Simulant Tests

The primary focus of the simulant tests was to determine the startup transients and steady state concentration profiles in the tank after the PJM realignment and fine tuning of the PRESCON™ controller programming of the PJM operation. These results are presented as Excel spreadsheets in the CD included along with this report.

In this section, the tests performed, simulants used, nomenclature used in the description of the files containing the data, and a brief discussion of the results is presented.

## 5.1 Simulant Used

The simulant used in the mixing tests was Spheriglass® glass-beads (specific gravity 2.49) of either 10 or 35 µm nominal volume mean particle size.[a, b] Spheriglass® is a registered trademark of Potters Industries Inc., Valley Forge, PA, is supplied under the trade names of A5000 and A3000 for the nominal volume mean particle sizes of 10 and 35 µm, respectively.

The choice of glass-beads of nominal volume mean particle sizes of 10 and 35 µm was driven by: 1) extremely poor mixing results obtained in FY01 with the larger (~75 µm volume mean) particle size glass-beads (Bontha et al 2003)[c] and 2) some preliminary settling tests performed with the A3000 and the A5000 grade materials. The latter indicated that the settling rates with the nominal 10 µm volume mean particle size material (A5000 grade)[d] were a factor of 3 greater than those of some typical Hanford type wastes (which are typically on the order of 10 cm/hr).

For the testing, 20,000 lbs each of the A3000 and A5000 grade materials were procured from Potters (packaged in 500 or 1000 lbs bags) to make up a simulant of a maximum solids loading of 20 wt%. Because of the sifting of the samples in the bags during shipping from the vendor, it was difficult to obtain representative samples to precisely determine the average particle size distribution (PSD). Also, since there was variability in the vendor supplied minimum, mean, and maximum values of the particle sizes between bag to bag of the same grade materials, homogenizing a single bag was deemed to not produce representative sample of the entire lot. Therefore, it is recommended that homogeneously[e] mixed slurry samples collected during the mixing tests be used to determine the representative particle size distribution of the simulant. This data for the different solid loading tests performed is listed in Appendix B.

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(a) The particle sizes presented here and through out this report are the volume based particle size distribution. The area (or Sauter's) based particle size distribution are included in Appendix A.
(b) The PSD distribution of the two simulants grade materials is presented in Appendix A.
(c) During these tests, no solids were observed above ~60 inches (1.524 m) from the bottom of the tank.
(d) It was difficult to determine the settling rate with the 35 µm nominal volume mean particle size (A3000 grade) material due to the lack of a clear solid/liquid interface during the settling tests.
(e) Here homogeneity is based on the density of the slurry in the tank at the top, middle and bottom regions of the tank being within ± 0.002 g/cm$^3$ of each other.

## 5.2 Tests Performed

A variety of PJM mixing tests were performed with the two different types of simulant at different solids loading and PJM operation conditions. The tests performed and their scope is summarized in Table 5.1.

**Table 5.1**. List of Simulant Mixing Test Performed and their Scope

| Test ID | Simulant | Wt% | Average SP GR[(a)] | PJMs Operating Mode | Test Scope |
|---|---|---|---|---|---|
| 1 | A5000 Grade - 10 μm Glass-beads | 5 | 1.029 | A, B, C, & D | Start Up Transient and Steady State Profiles |
| 2 | A5000 Grade - 10 μm Glass-beads | 20 | 1.113 | A, B, C, & D | Start Up Transient and Steady State Profiles |
| 3 | A5000 Grade - 10 μm Glass-beads | 20 | 1.113 | B & D | Settling Transient after Achieving Steady State |
| 4 | A5000 Grade - 10 μm Glass-beads | 20 | 1.113 | B & D | Start Up Transient and Steady State Profiles |
| 5 | A3000 Grade - 35 μm Glass-beads | 5 | 1.029 | A, B, C, & D | Start Up Transient and Steady State Profiles |
| 6 | A3000 Grade - 35 μm Glass-beads | 5 | 1.029 | B & D | Settling Transient after Achieving Steady State |
| 7 | A3000 Grade - 35 μm Glass-beads | 5 | 1.029 | B & D | Start Up Transient and Steady State Profiles |
| 8 | A3000 Grade - 35 μm Glass-beads | 20 | 1.134 | A, B, C, & D | Start Up Transient and Steady State Profiles |
| 9 | A3000 Grade - 35 μm Glass-beads | 20 | 1.134 | B & D | Settling Transient after Achieving Steady State |
| 10 | A3000 Grade - 35 μm Glass-beads | 20 | 1.134 | B & D | Start Up Transient and Steady State Profiles |
| (a) Determined from the actual mass of solid and liquid phases in the tank. | | | | | |

In all tests, the tank was filled up to 36 inches (0.9144 m) from the top rim and the PJM cycle time was maintained at 45 s. The difference in the PJM operation modes was with respect to the number of PJMs operated at a time, e.g., all four or two at a time. This was driven by the extent of mixing observed after steady state was achieved. For example, for Tests #1, #2, #5, and #8, it was observed that the tank contents, except for some slight variations, were nearly completely mixed. Although these slight variations are important from considerations of the PJMs ability to mix, they are not appreciable for code validation since it is generally very difficult to predict such small changes. By switching two of the PJMs off, the amount of mixing energy added to the system was reduced and this resulted in increased solids stratification in the tank. Such data is considered to be more relevant to code validation efforts.

## 5.3 Nomenclature Used

The Excel spreadsheets containing the results of Test # 1 (Table 5.1) are stored in the folder "021115 DATA" on the CD accompanying this report and the file list is summarized in Table 5.2.

**Table 5.2**. Summary of Files Containing the Startup Transient and Steady State Data for the Simulant Test #1 (5 wt%, 10 µm nominal volume mean glass-beads, 4 PJMs) Data

| File Name | Clock Time | | Vel. Probes (1 to 5) Pos. | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021115B.xls[(a)] | 12:57:44 | 13:50:00 | 0° | 0 | 54 | 54 | N/A |
| 021115C.xls[(b)] | 13:53:29 | 14:16:24 | 0° | 0 | 54 | 54 | N/A |
| 021115D.xls[(b)] | 15:23:00 | 15:41:56 | 180° | 24 | 126 | 36 | 24 |
| 021115E.xls[(b)] | 15:49:46 | 16:10:17 | 180° | 24 | 90 | 9 | 12 |
| 021115F.xls[(b)] | 16:22:39 | 16:43:58 | 135° | 24 | 24 | 90 | 54 |
| 021115G.xls[(b)] | 16:48:40 | 17:10:31 | 135° | 17 | 36 | 126 | 90 |
| 021115H.xls[(b)] | 17:13:50 | 17:35:57 | 135° | 17 | 72 | 12 | 36 |
| 021115I.xls[(b)] | 17:40:10 | 18:02:49 | 135° | 17 | 108 | 24 | 3 |
| 021115J.xls[(b)] | 18:14:36 | 18:36:27 | 0° | 0 | 54 | 54 | N/A |

(a) Contains the startup transient data.
(b) Files containing the velocity and concentration data after steady state or a periodic condition in concentration have been reached.

In all the data tables presented in this section, the radial position of the MicroMotion sensors sampling tubes and the vertical positions of the velocity probes (1 through 5) are listed in Tables 5.3 and 5.4.

**Table 5.3**. Radial Position of the MicroMotion Sensors During All Simulant Tests

| MicroMotion Sensor | Radial Position (in)[(a)] |
|---|---|
| Sensor 1 | 69 |
| Sensor 2 | 36 |
| Sensor 3 | 0 |

(a) As measured from the tank center

**Table 5.4**. Vertical Position of the Velocity Probes During All Simulant Tests

| Velocity Probe | Vertical Position (in)[(a)] |
|---|---|
| Probe #1 | 126 |
| Probe #2 | 102 |
| Probe #3 | 78 |
| Probe #4 | 54 |
| Probe #5 | 30 |

(a) As measured from the tank floor and the center of the drain pipe.

At the completion of Test #1, an additional amount of the nominal 10 μm volume mean particle size glass-beads was added to increase the solids loading up to 20 wt% and prepare for Test #2. The Excel spreadsheets containing the results of Test #2 (Table 5.1) are stored in the folder "021121 DATA" on the CD accompanying this report and the file list is summarized in Table 5.5.

**Table 5.5**. Summary of Files Containing the Startup Transient and Steady State Data for the Simulant Test #2 (20 wt%, 10 μm nominal volume mean glass-beads, 4 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021121A.xls[(a)] | 10:31:45 | 11:48:35 | 0° | 0 | 126 | 54 | N/A |
| 021121B.xls[(b)] | 12:00:45 | 12:56:25 | 0° | 0 | 126 | 54 | N/A |
| 021121C.xls[(b)] | 13:05:20 | 13:28:12 | 180° | 24 | 90 | 24 | 12 |
| 021121D.xls[(b)] | 13:33:45 | 13:00:08 | 180° | 24 | 54 | 18 | 3 |
| 021121E.xls[(b)] | 14:03:50 | 14:26:00 | 180° | 24 | 24 | 9 | 54 |
| 021121F.xls[(b)] | 14:31:30 | 14:33:00 | 135° | 17 | 36 | 108 | 90 |
| 021121G.xls[(b)] | 14:34:50 | 14:54:00 | 135° | 17 | 36 | 126 | 90 |
| 021121H.xls[(b)] | 15:01:30 | 15:20:50 | 135° | 17 | 72 | 90 | 24 |
| 021121I.xls[(b)] | 15:26:40 | 15:47:40 | 0° | 0 | 126 | 54 | N/A |

(a) Contains the startup transient data.
(b) Files containing the velocity and concentration data after steady state or a periodic condition in concentration have been reached.

At the completion of Test #2, the settling transient data with PJMs B and D running were determined. The Excel spreadsheets containing the results of the settling transient (Tests #3 of Table 5.1) are also stored in the folder "021121 DATA" on the CD accompanying this report. The file list is summarized in Table 5.6.

**Table 5.6**. Summary of Files Containing the Settling Transient Data for the Simulant Test #3 (20 wt%, 10 μm nominal volume mean glass-beads, 2 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021121K.xls[(a)] | 16:25:40 | 19:23:45 | 0° | 0 | 126 | 54 | N/A |
| 021121L.xls | 19:31:10 | 19:51:55 | 180° | 24 | 90 | 54 | 90 |
| 021121M.xls[(b)] | 19:58:30 | 20:21:09 | 180° | 24 | 138 | 54 | 90 |
| 021121O.xls | 20:37:15 | 21:15:22 | 180° | 24 | 134 | 54 | 126 |
| 021121P.xls | 21:22:30 | 21:37:55 | 180° | 24 | 126 | 9 | 36 |

(a) PJMs A & C running initially and at 16:47 PJMs A & C turned off and PJMs B & D turned on.
(b) At 20:04 MicroMotion sensor 1 sampling tube raised to 134 inches (3.4036 m).

After the completion of the simulant Test #3, the contents of the tank were allowed to settle overnight before the simulant Test #4 was started. The Excel spreadsheets containing the results of simulant Test #4 (Table 5.1) are stored in the folder "021122 DATA" on the CD accompanying this report. The file list is summarized in Table 5.7.

**Table 5.7.** Summary of Files Containing the Startup Transient Data for the Simulant Test #4 (20 wt%, 10 μm nominal volume mean glass-beads, 2 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021122A.xls | 14:07:00 | 15:15:00 | 0° | 0 | 136 | 54 | N/A |

After the completion of simulant Test #4, the tank contents were emptied and the nominal 35 μm volume mean glass-bead simulant at 5 wt% solids loading was prepared. The Excel spreadsheets containing the results of simulant Test #5 (Table 5.1) are stored in the folder "021204 DATA" on the CD accompanying this report. The file list is summarized in Table 5.8.

After completion of the Test #5, the PJMs A and B were turned off, and the settling transient with PJMs B and D operating (Test #6) were collected. The Excel spreadsheets containing the results of Test #6 (Table 5.1) are also stored in the folder "021204 DATA" of the CD accompanying this report. The file list is summarized in Table 5.9.

After the completion of Test #6, the simulant was allowed to settle for 6 days, and the startup transient with just PJMs B and D operating was determined. The Excel spreadsheets containing these results of Test #7 (Table 5.1) are stored in the folder "021210 DATA" on the CD accompanying this report. The file list is summarized in Table 5.10.

After the completion of Test #7, additional amount of the nominal 35 μm volume mean particle size glass-beads was added to increase the solids loading up to 20 wt%. The Excel spreadsheets containing the results of Tests #8 (Table 5.1) are stored in the folder "021212 DATA" on the CD accompanying this report. The file list is summarized in Table 5.11.

After the completion of Test #8, the PJMs A and C were turned off and the settling transient was determined with only PJMs B and D operating. The Excel spreadsheets containing the results of Test #9 (Table 5.1) are also stored in the folder "021212 DATA" on the CD accompanying this report. The file list is summarized in Table 5.12.

After the completion of Test #9, the simulant was allowed to settle for 3 days, and the startup and steady state data with only PJMs B and D operating was recorded. The Excel spreadsheets containing the results of Test #10 (Table 5.1) are stored in the folder "021216 DATA" on the CD accompanying this report. The file list is summarized in Table 5.13.

**Table 5.8**. Summary of Files Containing the Startup Transient and Steady State Data for the Simulant Test #5 (5 wt%, 35 μm nominal volume mean glass-beads, 4 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021204A.xls[(a)] | 11:14:00 | 11:38:00 | 0° | 0 | 126 | 54 | N/A |
| 021204B.xls[(b)] | 11:38:00 | 13:07:30 | 0° | 0 | 126 | 54 | N/A |
| 021204C.xls[(c)] | 13:09:40 | 13:46:05 | 0° | 0 | 126 | 54 | N/A |
| 021204D.xls[(c)] | 13:58:10 | 14:12:55 | 180° | 24 | 108 | 24 | 3 |
| 021204E.xls[(c)] | 14:20:50 | 14:39:55 | 135° | 17 | 90 | 36 | 6 |
| 021204F.xls[(c)] | 14:48:45 | 15:08:40 | 180° | 24 | 72 | 90 | 12 |
| 021204G.xls[(c)] | 15:15:10 | 15:36:40 | 225° | 17 | 54 | 9 | 24 |
| 021204H.xls[(c)] | 15:44:50 | 16:03:20 | 180° | 24 | 24 | 136 | 54 |
| 021204I.xls[(c)] | 16:07:00 | 16:28:50 | 180° | 24 | 36 | 126 | 90 |
| 021204J.xls | 16:36:20 | 17:09:15 | 0° | 0 | 126 | 54 | N/A |

(a) First log file of the startup transient data.
(b) Second log file of the startup transient data.
(c) Files containing the velocity and concentration data after steady state or a periodic condition in concentration have been reached.

**Table 5.9**. Summary of Files Containing the Settling Transient Data for the Simulant Test #6 (5 wt%, 35 μm nominal volume mean glass-beads, 2 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021204N.xls | 19:16:30 | 19:35:35 | 180° | 24 | 108 | 12 | 3 |
| 021204P.xls | 19:42:35 | 20:01:20 | 180° | 24 | 72 | 36 | 6 |
| 021204Q.xls | 20:17:35 | 20:38:40 | 180° | 24 | 126 | 90 | 24 |
| 021204R.xls | 20:48:15 | 21:07:05 | 0° | 0 | 24 | 54 | N/A |

**Table 5.10**. Summary of Files Containing the Startup Transient and Steady State Data for the Simulant Test #7 (5 wt%, 35 μm nominal volume mean glass-beads, 2 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021210A.xls | 09:59:37 | 11:49:12 | 180° | 24 | 126 | 54 | 30 |
| 021210B.xls | 11:54:15 | 12:29:25 | 180° | 24 | 126 | 54 | 3 |
| 021210C.xls | 12:38:00 | 13:33:00 | 0° | 0 | 126 | 54 | N/A |

**Table 5.11**. Summary of Files Containing the Startup Transient and Steady State Data for the Simulant Test #8 (20 wt%, 35 μm nominal volume mean glass-beads, 4 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | **Start** | **End** | **Angular (deg)** | **Radial (in)** | **Sensor 1 (in)** | **Sensor 2 (in)** | **Sensor 3 (in)** |
| 021212A.xls[a,b] | 11:57:40 | 12:19:00 | 0° | 0 | 126 | 54 | N/A |
| 021212B.xls[c] | 12:22:06 | 15:04:00 | 180° | 24 | 126 | 54 | 36 |
| 021212C.xls[d] | 15:10:46 | 15:29:15 | 0° | 0 | 126 | 54 | N/A |
| 021212D.xls[d] | 15:40:20 | 15:59:45 | 180° | 24 | 54 | 90 | 12 |
| 021212E.xls[d] | 16:10:15 | 16:30:45 | 180° | 24 | 24 | 108 | 3 |
| 021212F.xls[d] | 16:43:40 | 17:02:51 | 180° | 24 | 72 | 9 | 24 |
| 021212G.xls[d] | 17:09:55 | 17:29:05 | 180° | 24 | 90 | 24 | 54 |
| 021212H.xls[d] | 17:36:45 | 17:55:45 | 180° | 24 | 136 | 36 | 90 |
| 021212I.xls[d] | 18:18:15 | 18:37:45 | 0° | 0 | 126 | 54 | N/A |

(a) First log file of the startup transient data.
(b) PJMs started at 12:00:10.
(c) Second log file of the startup transient data.
(d) Files containing the velocity and concentration data after steady state or a periodic condition in concentration have been reached.

**Table 5.12**. Summary of Files Containing the Settling Transient Data for the Simulant Test #9 (20 wt%, 35 μm nominal volume mean glass-beads, 2 PJMs)

| File Name[a, b] | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | **Start** | **End** | **Angular (deg)** | **Radial (in)** | **Sensor 1 (in)** | **Sensor 2 (in)** | **Sensor 3 (in)** |
| 021212J.xls | 18:52:30 | 20:31:09 | 180° | 24 | 126 | 54 | 36 |
| 021212K.xls | 20:38:20 | 20:42:30 | 180° | 24 | 126 | 54 | 36 |
| 021212L.xls | 20:43:15 | 22:22:56 | 180° | 24 | 126 | 54 | 36 |
| 021212M.xls | 22:27:56 | 22:36:30 | 180° | 24 | 126 | 54 | 36 |
| 021212N.xls | 23:12:50 | 23:36:30 | 180° | 24 | 78 | 72 | 36 |

(a) Started w/4 PJMs running, @19:05:45 PJMs A & C shut down, leaving only B & D running.
(b) Files are consecutive log files containing the settling transient data

**Table 5.13**. Summary of Files Containing the Startup Transient and Steady State Data for the Simulant Test #5 (20 wt%, 35 μm nominal volume mean glass-beads, 2 PJMs)

| File Name | Clock Time | | Velocity Probe Position | | MicroMotion Sensor Elevation | | |
|---|---|---|---|---|---|---|---|
| | Start | End | Angular (deg) | Radial (in) | Sensor 1 (in) | Sensor 2 (in) | Sensor 3 (in) |
| 021216A.xls[a] | 07:41:45 | 09:18:10 | 180° | 24 | 72 | 54 | 36 |
| 021216B.xls[b] | 09:19:40 | 10:38:00 | 180° | 24 | 72 | 54 | 36 |
| 021216C.xls[c] | 10:39:35 | 12:14:28 | 180° | 24 | 72 | 78 | 36 |
| 021216D.xls[d] | 12:15:45 | 12:44:00 | 180° | 24 | 72 | 78 | 36 |
| 021216E.xls[d] | 12:50:10 | 13:54:00 | 180° | 24 | 126 | 90 | 24 |
| 021216H.xls[d] | 15:59:30 | 16:18:00 | 0° | 0 | 36 | 54 | N/A |
| 021216I.xls[d] | 16:29:20 | 16:49:20 | 135° | 17 | 72 | 78 | 36 |

(a) First log file of the startup transient data.
(b) Second log file of the startup transient data.
(c) Third log file of the startup transient data.
(d) Files containing the velocity and concentration data after steady state or a periodic condition in concentration have been reached.

## 5.4 Concentration Profiles and Mixing Effectiveness

The results of the simulant mixing tests were reviewed for consistency, and some of the data was partially analyzed to determine the average, maximum, and minimum values of the specific gravity, and the corresponding standard deviations[a]. These averages and standard deviations in the measured specific gravities at different elevations are summarized in Tables 5.14 through 5.17. In all of these tables, the elevation of the MicroMotion sampling line is measured from the tank floor at the center of the inlet to the drain pipe. It can be seen from the data in these tables that the repeat measurements made at several of the elevations confirm the reproducibility of the data and that a "near" steady state was achieved.

The effect of increasing the solids loading from 5 to 20 wt% is shown in Tables 5.14 and 5.15. In these two cases, the nominal volume mean particle size was 10 μm and all four PJMs were operated at a cycle time of 45 seconds. It can be seen from the data in theses tables, that with the nominal mean 10 μm volume mean particle size glass-beads, the tank is nearly homogenously mixed from top to bottom for both the 5 and 20 wt% solids loading cases.

The effect of all four PJMs versus only two PJMs operating is shown in Tables 5.16 and 5.17. In these two cases, the nominal volume mean particle size was ~35 μm, and the solids loading was 20 wt%. For the case of the four PJMs operating all the time, it can be seen from the data in Table 5.16, that except for the very top of the tank, the tank contents are nearly homogeneously mixed. For the two PJM case, it can be seen from the data in Table 5.17 that the majority of the solids are suspended at elevations below 72 inches (1.8288 m).

(a) Complete analysis of the data was beyond the scope of the testing activity.

**Table 5.14**. Average Specific Gravity Measurements for Test #1 (5 wt%, 10 µm nominal volume mean glass-beads, 4 PJMs)

| Elevation[(a)] (in) | Radial Position | | |
|---|---|---|---|
| | Tank Center | Radius = 3 ft | Radius = 5.75 ft |
| 3 | Average: 1.029<br>Std. Dev.: 0.001 | ___ | ___ |
| 9 | ___ | Average: 1.029<br>Std. Dev.: 0.000 | ___ |
| 12 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.000 | ___ |
| 24 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.001 |
| 36 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.001 |
| 54<br>Initial Measurement | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.028<br>Std. Dev.: 0.001 |
| 54<br>Final Measurement | ___ | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.0005 |
| 72 | ___ | ___ | Average: 1.028<br>Std. Dev.: 0.001 |
| 90 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.029<br>Std. Dev.: 0.000 | Average: 1.028<br>Std. Dev.: 0.000 |
| 108 | ___ | ___ | Average: 1.028<br>Std. Dev.: 0.000 |
| 126 | ___ | Average: 1.029<br>Std. Dev.: 0.004 | Average: 1.028<br>Std. Dev.: 0.000 |

(a) All elevations are measured from the floor of the tank at the centerline.

**Table 5.15**. Average Specific Gravity Measurements for Test #2 (20 wt%, 10µm nominal volume mean glass-beads, 4 PJMs)

| Elevation[a] (in) | Radial Position | | |
|---|---|---|---|
| | Tank Center | Radius = 3 ft | Radius = 5.75 ft |
| 3 | Average: 1.132<br>Std. Dev.: 0.001 | ____ | ____ |
| 9 | ____ | Average: 1.131<br>Std. Dev.: 0.000 | ____ |
| 12 | Average: 1.131<br>Std. Dev.: 0.001 | ____ | ____ |
| 18 | ____ | Average: 1.131<br>Std. Dev.: 0.000 | ____ |
| 24 | Average: 1.131<br>Std. Dev.: 0.000 | Average: 1.131<br>Std. Dev.: 0.000 | Average: 1.131<br>Std. Dev.: 0.001 |
| 36 | ____ | ____ | Average: 1.130<br>Std. Dev.: 0.001 |
| 54 | Average: 1.131<br>Std. Dev.: 0.000 | Average: 1.130<br>Std. Dev.: 0.001 | Average: 1.130<br>Std. Dev.: 0.001 |
| 54<br>2ndMeasurement | ____ | Average: 1.130<br>Std. Dev.: 0.001 | ____ |
| 54<br>Final Measurement | ____ | Average: 1.131<br>Std. Dev.: 0.001 | ____ |
| 72 | ____ | ____ | Average: 1.130<br>Std. Dev.: 0.000 |
| 90 | Average: 1.131<br>Std. Dev.: 0.000 | Average: 1.130<br>Std. Dev.: 0.001 | Average: 1.130<br>Std. Dev.: 0.000 |
| 126 | ____ | Average: 1.130<br>Std. Dev.: 0.000 | Average: 1.130<br>Std. Dev.: 0.000 |
| 126<br>2nd Measurement | ____ | ____ | Average: 1.130<br>Std. Dev.: 0.000 |
| 126<br>Final Measurement | ____ | ____ | Average: 1.130<br>Std. Dev.: 0.000 |

(a) All elevations are measured from the floor of the tank at the centerline.

**Table 5.16**. Average Specific Gravity Measurements for Test #8 (20 wt%, 35µm nominal volume mean glass-beads, 4 PJMs)

| Elevation[a] (in) | Radial Position | | |
|---|---|---|---|
| | **Tank Center** | **Radius = 3 ft** | **Radius = 5.75 ft** |
| 3 | Average: 1.152<br>Std. Dev.: 0.008 | ___ | ___ |
| 9 | ___ | Average: 1.146<br>Std. Dev.: 0.001 | ___ |
| 12 | Average: 1.148<br>Std. Dev.: 0.003 | ___ | ___ |
| 24 | Average: 1.147<br>Std. Dev.: 0.003 | Average: 1.145<br>Std. Dev.: 0.001 | Average: 1.144<br>Std. Dev.: 0.001 |
| 36 | ___ | Average: 1.143<br>Std. Dev.: 0.001 | ___ |
| 54 | Average: 1.146<br>Std. Dev.: 0.002 | Average: 1.140<br>Std. Dev.: 0.001 | Average: 1.142<br>Std. Dev.: 0.001 |
| 54 | ___ | Average: 1.144<br>Std. Dev.: 0.001 | ___ |
| 72 | ___ | ___ | Average: 1.141<br>Std. Dev.: 0.001 |
| 90 | Average: 1.142<br>Std. Dev.: 0.003 | Average: 1.140<br>Std. Dev.: 0.001 | Average: 1.138<br>Std. Dev.: 0.002 |
| 108 | ___ | Average: 1.137<br>Std. Dev.: 0.002 | ___ |
| 126<br>Initial Measurement | ___ | ___ | Average: 1.120<br>Std. Dev.: 0.009 |
| 126<br>Final Measurement | ___ | ___ | Average: 1.121<br>Std. Dev.: 0.007 |
| 136 | ___ | ___ | Average: 1.071<br>Std. Dev.: 0.029 |

(a) All elevations are measured from the floor of the tank at the centerline.

**Table 5.17**. Average Specific Gravity Measurements for Test #11 (20 wt%, 35µm nominal volume mean glass-beads, 2 PJMs)

| Elevation[a] (in) | Radial Position | | |
|---|---|---|---|
| | **Tank Center** | **Radius = 3 ft** | **Radius = 5.75 ft** |
| 24 | Average: 1.272<br>Std. Dev.: 0.005 | ___ | ___ |
| 36<br>Initial Measurement | Average: 1.278<br>Std. Dev.: 0.003 | ___ | Average: 1.280<br>Std. Dev.: 0.002 |
| 36<br>Final Measurement | Average: 1.279<br>Std. Dev.: 0.003 | ___ | ___ |
| 54 | ___ | Average: 1.274<br>Std. Dev.: 0.003 | ___ |
| 72<br>Initial Measurement | ___ | ___ | Average: 1.176<br>Std. Dev.: 0.051 |
| 72<br>Final Measurement | ___ | ___ | Average: 1.173<br>Std. Dev.: 0.054 |
| 78 | ___ | Average: 1.044<br>Std. Dev.: 0.021 | ___ |
| 90 | ___ | Average: 1.018<br>Std. Dev.: 0.008 | ___ |
| 126 | ___ | ___ | Average: 0.999<br>Std. Dev.: 0.000 |

(a) All elevations are measured from the floor of the tank at the centerline.

# 6.0 References

Bechtel National, Inc. (BNI). 2002. *Research and Technology Plan*. 24590-WTP-PL-RT-01-002, Rev 1, U.S. Department of Energy, Office of River Protection, Richland, WA.

Bontha, JR, GR Golcar, and N Hanigan. 2000. *Demonstration and Optimization of BNFL's Pulsed Jet Mixing and RFD Sampling Systems Using NCAW Simulants*. PNWD-3054, Pacific Northwest National Laboratory, Richland, WA.

Bontha, JR, TE Michener, DS Trent, JM Bates, and MD Johnson. 2002. *Development and Assessment of the TEMPEST CFD Model of the Pulsed Jet Mixing Systems*. WTP-RPT-061, Rev.0, Battelle Pacific Northwest Division, Richland, WA.

# Appendix A:  Vendor Specifications of Instruments Used

# Valeport Velocity Sensors

# Direct Reading Electromagnetic Current Meters

## *Model 802*

## FEATURES

- High Accuracy
- High Stability
- Low Noise
- Low Power Consumption
- Choice of Sensor Shapes
- Choice of Configurations
- Digital or Analogue Output
- Wide Measurement Range
- Corrosion resistant materials

## APPLICATIONS

- Sediment Transport Studies
- Hydraulic Modelling
- Open Channel Current Measurement
- Ship's Log
- ROV/AUV Speed
- Fixed Site Current Measurement

## INTRODUCTION

The Model 802 is the latest version of Valeport's successful 800 Series of electromagnetic current meters. Using state of the art electronics design techniques, we have produced a highly accurate, stable, solid state instrument that is greatly reduced in size and power consumption from earlier versions. These improvements, together with a selection of sensor shapes and a versatile range of electronics packages ensure that the Model 802 is the instrument of choice in a variety of applications, from sediment transport studies to modelling flow patterns or real time monitoring of current flow.

Output from the Model 802 is strictly in the format of X and Y velocity components only. If a compass or other additional parameters are required, please refer to the Model 808 data sheet.

VALEPORT

# Direct Reading Electromagnetic Current Meters

## Model 802

## DESCRIPTION

Electromagnetic Current Meters work on Faraday's principle that a conductor (water in this case) moving through a magnetic field (produced by the sensor) generates a voltage (measured by a pair of electrodes). By having 2 orthogonally positioned electrodes, 2 axis flow can be measured by a single sensor.

Each Model 802 system comprises a sensing head, and a set of electronics to produce the magnetic field and measure the resultant voltage. Valeport offers a range of different sensing heads and electronics assemblies to suit different applications. Any of the listed sensors may be fitted to any of the electronics packages to provide a Model 802 system. The standard output of all systems is RS232 of X and Y components of the flow speed, relative to the mounting position of the head.
2 channel analogue outputs are also available as an option.

**Heads**
*Annular Sensor:* The 17cm annular sensor measures flow in the open space inside the ring, and therefore has excellent response to off axis flow. It is therefore most suitable for use in applications where off axis flow is expected, or for use in pairs to measure 3 dimensional changes.

*Spherical Sensor:* Available in either 3.2cm or 5.5cm sizes, the spherical sensors have reasonable response to tilt and azimuth flow variations, but are hydrodynamically noisier than the other sensors. Spatial resolution requirements determine the choice of sensor size.

*Discus Sensor:* The discus sensor is available in 3 sizes; 3.2cm, 5.5cm and 11cm diameter. Since the flow is measured on one face of the discus, tilt response is as good as the other sensors ,but azimuth response is excellent, with low hydrodynamic noise. These sensors are therefore suited to any applications where two dimensional flow is expected. Again, choice of sensor size depends on spatial resolution required.

**Electronics**
*Control Display Unit:* This package consists of an IP67 (10secs at 0.3m) display unit, and 3m signal cable to the sensor of choice. The display has an integral battery compartment making it ideal for field use, or can be powered using external DC for laboratory applications. Features of the display include real time and averaged X & Y velocities and Standard Deviation of X & Y velocities. The user may choose the type of sampling required – fixed time, moving average, or free running, and the length of the average. In addition, the control unit has an optional internal memory, which can hold up to 999 records of the above information, together with date and time stamp. Recorded data can be viewed on screen or downloaded to PC in ASCII text format.

*Integral Underwater Housing:* Driving electronics and preamplifiers are contained in a stainless steel underwater housing, with the chosen sensor mounted on a stem protruding from one end. A single connector allows power in (12 to 24vDC) and RS232 signal out at 1Hz update rate. Output signal is in the format X=sn.nnn Y=sn.nnn<cr><lf>, where s indicates the flow direction + or -, and n.nnn signifies the flow speed in m/s. 0-5v analogue output option is available for X & Y channels

*Remote Underwater Housing:* Exactly as Integral Underwater System, but flow sensor is supplied on a 3m length of signal cable, rather than attached to the electronics housing.

*OEM Package:* Driving electronics are supplied as OEM parts, for interface to customers' existing systems. Electronics require power in (12 to 24vDC) and give RS232 digital signal out. Sensor is supplied on 3m signal cable, with free end. Again, analogue output is available as an option.

## ORDERING AND SPECIFICATIONS

| Sensor | Characteristics | | | | |
|---|---|---|---|---|---|
| | Accuracy | Depth Rating | Tilt Response | Azimuth Response | Hydrodynamic Noise |
| **17cm Annular** | ±1% + 5mm/s | 1000m | ✓✓✓✓✓ | ✓✓✓✓ | ✓✓✓✓ |
| **11cm Discus** | ±1% + 5mm/s | 5000m | ✓✓✓ | ✓✓✓✓✓ | ✓✓✓✓✓ |
| **5.5cm Discus** | ±1% + 5mm/s | 3000m | ✓✓✓ | ✓✓✓✓✓ | ✓✓✓✓✓ |
| **3.2cm Discus** | ±1% + 5mm/s | 3000m | ✓✓✓ | ✓✓✓✓✓ | ✓✓✓✓✓ |
| **5.5cm Spherical** | ±1% + 5mm/s | 3000m | ✓✓✓✓ | ✓✓✓ | ✓✓✓ |
| **3.2cm Spherical** | ±1% + 5mm/s | 3000m | ✓✓✓✓ | ✓✓✓ | ✓✓✓ |

| Package | Specification (may vary slightly according to sensor selection) | | |
|---|---|---|---|
| | Size | Power Consumption | Depth Rating |
| Sensor on spar with pre-amp housing and 3m cable to Control Display Unit | CDU: 250 x 170 x 100mm | 240mA | IP67 (10s at 0.3m) |
| Underwater housing with integral sensor on spar, and 3m power in/signal out cable | 525mm long x 76mm∅ (inc sensor) | 130mA | 3000m |
| Underwater housing with remote sensor on spar/pre-amp housing, 3m sensor cable, and 3m power in/signal out cable | 350mm long x 76mm∅ | 130mA | 3000m |
| Sensor on spar with pre-amp, 3m sensor cable to OEM board set with wiring loom. | 54mm x 205mm | 130mA | N/A |

**Also Available**
2 channel 0-5v analogue output option for any package.

Extra Sensor cable (maximum 50m)
Extra Power in/Signal out cable (maximum 100m)
Alternative Signal ranges (standard ±5m/s for each axis)

***For more detailed specification, please refer to additional sheet.***

Valeport manufactures a wide range of oceanographic and hydrometric instruments including self-recording and direct reading multi-parameter current meters, CTD probes, electromagnetic current meters, tide gauges, open channel flow meters, optical instruments, water and plankton samplers, winches, sinker weights, connectors and accessories.

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# MicroMotion Transmitter and Sensors

**Product Data Sheet**
PS-00024
March 2002

# Micro Motion Model RFT9739

## Mass Flow and Density Transmitter

PlantWeb CE

Micro Motion

www.micromotion.com

EMERSON
Process Management

## RFT9739 transmitter

The RFT9739 transmitter works with Micro Motion® sensors to provide precision fluid measurement in a wide variety of fluid applications. The RFT9739 has modular, microprocessor-based electronics, incorporating ASIC digital technology with a choice of digital communication protocols.

Combined with a Micro Motion sensor, the RFT9739 provides accurate mass flow, density, temperature, and volumetric measurements of process fluids. With a pressure transmitter properly installed in the flow loop, the transmitter also indicates pressure.

The RFT9739 simultaneously transmits four output signals. Two independently configured analog outputs can each indicate flow rate, density, temperature, or pressure. A frequency/pulse output indicates flow rate or total. A control output indicates flow direction, a fault, or flowmeter zero in progress.

The RFT9739 is available in field-mount and rack-mount versions. The field-mount transmitter is housed in a NEMA 4X (IP65) explosion-proof enclosure that provides easy access to the electronics module, and allows the transmitter and sensor to be installed in the same hazardous area. The rack-mount transmitter's compact housing is ideal for control room installations.

The RFT9739 features user-selected Bell 202 or RS-485 serial standard for HART® or Modbus® communication protocol. For configuration in the field, use Micro Motion ProLink® software, Fisher-Rosemount AMS software, or a Rosemount® Model 275 HART Communicator.

An integral liquid crystal display (LCD) is standard on the rack-mount model, optional with the field-mount version. Use the display to set communication parameters, read process variables, reset flow totalizers, and view diagnostic messages.

Choose from a wide range of sensors to suit your application. The RFT9739 is compatible with Micro Motion ELITE® sensors, the most accurate Coriolis meters available today. Or choose Micro Motion F-Series sensors, standard or high-pressure Model D sensors, Model DT high-temperature sensors, or Model DL sanitary sensors.

PlantWeb

*Model RFT9739 transmitters support PlantWeb® field-based architecture, a scalable way to use open and interoperable devices and systems to build process solutions of the future.*

# RFT9739 performance specifications

| Sensor model | | Flow accuracy* |
|---|---|---|
| ELITE® | liquid | ±0.10% ± [(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.50% ± [(zero stability/flow rate) x 100]% of rate |
| F-Series | liquid | ±0.20% ± [(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.70% ± [(zero stability/flow rate) x 100]% of rate |
| D (except DH38), DL and DT | liquid | ±0.15% ± [(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.65% ± [(zero stability/flow rate) x 100]% of rate |
| DH38 | liquid | ±0.15% ± [(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.50% ± [(zero stability/flow rate) x 100]% of rate |

| Sensor model | | Flow repeatability* |
|---|---|---|
| ELITE | liquid | ±0.05% ± [½(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.25% ± [(zero stability/flow rate) x 100]% of rate |
| F-Series | liquid | ±0.10% ± [½(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.35% ± [(zero stability/flow rate) x 100]% of rate |
| D (except DH38), DL and DT | liquid | ±0.05% ± [½(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.30% ± [(zero stability/flow rate) x 100]% of rate |
| DH38 | liquid | ±0.05% ± [½(zero stability/flow rate) x 100]% of rate |
| | gas | ±0.25% ± [½(zero stability/flow rate) x 100]% of rate |

| | | Density accuracy | | Density repeatability | |
|---|---|---|---|---|---|
| Sensor model | | *g/cc* | *kg/m³* | *g/cc* | *kg/m³* |
| ELITE (except high-pressure CMF010P) | liquid | ±0.0005 | ±0.5 | ±0.0002 | ±0.2 |
| | gas | ±0.002 | ±2.0 | ±0.001 | ±1.0 |
| ELITE high-pressure CMF010P | liquid | ±0.002 | ±2.0 | ±0.001 | ±1.0 |
| | gas | ±0.008 | ±8.0 | ±0.004 | ±4.0 |
| F-Series | liquid only | ±0.002 | ±2.0 | ±0.001 | ±1.0 |
| D6, D12, D25, D40, DH100, DH150 | liquid only | ±0.002 | ±2.0 | ±0.001 | ±1.0 |
| DH6, DH12, DH25, DH38 | liquid only | ±0.004 | ±4.0 | ±0.002 | ±2.0 |
| D65, DL65, DT65, D100, DT100, D150, DT150, DH300 | liquid only | ±0.001 | ±1.0 | ±0.0005 | ±0.5 |
| DL100, DL200, D300, D600 | liquid only | ±0.0005 | ±0.5 | ±0.0002 | ±0.2 |

| Sensor model | Temperature accuracy | Temperature repeatability |
|---|---|---|
| All models | ±1°C ± 0.5% of reading in °C | ±0.2°C |

**Flow accuracy includes the combined effects of repeatability, linearity, and hysteresis. All specifications are based on reference conditions of water at 68 to 77°F (20 to 25°C), and 15 to 30 psig (1 to 2 bar) unless otherwise noted. For gas measurement specifications, refer to product specifications for each sensor. For values of zero stability, refer to product specifications for each sensor.*

# RFT9739 functional specifications

## Output signals

### Analog

Two independently configured analog outputs, designated as primary and secondary, can represent mass or volumetric flow rate, density, temperature, event 1 or event 2. These outputs cannot be changed from active to passive. With a pressure transmitter, outputs can also provide indication for pressure. Internally powered, can be selected as 4-20 mA or 0-20 mA current outputs. Galvanically isolated to ±50 VDC, 1000 ohm load limit. Out-of-range capability: 0-22 mA on 0-20 mA output; 3.8-20.5 mA on 4-20 mA output.

***Milliamp (mA) output rangeability***

*Flow*

Maximum span determined by sensor specifications

Range limit determined by sensor maximum rate

Minimum recommended span (% of nominal flow range):

| | |
|---|---|
| ELITE sensors | 2.5% |
| F-Series sensors | 10% |
| D, DL, and DT sensors | 10% |
| D300 and D600 sensors | 5% |
| High-pressure (DH) sensors | 20% typical |

*Density*

| | |
|---|---|
| Range limit: | 0 to 5 g/cc (0 to 5000 kg/$m^3$) |
| Minimum span: | 0.1 g/cc (100 kg/$m^3$) |

*Temperature*

| | |
|---|---|
| Range limit: | –400 to 842°F (–240 to 450°C) |
| Minimum span: | 36°F (20°C) |

### Frequency

One frequency/pulse output can be configured to indicate mass flow rate, volumetric flow rate, mass total (inventory), or volume total (inventory), independent of analog outputs. Internally powered, 0-15 V square wave, unloaded; 2.2 kohm impedance at 15 V, galvanically isolated to ±50 VDC. In open collector configuration: sinking capability, 0.1 amps in “on” condition (0 volt level), 30 VDC compliance in “off” condition. Signal can be scaled up to 10,000 Hz. Out-of-range capability to 15,000 Hz. Programmable pulse width for low frequencies.

### Dual-channel frequency (rack-mount transmitter only)

Approved for custody transfer applications, a dual-channel frequency output, referred to as frequency A and frequency B. Phase shift between channels is 90 degrees. Output derived from the primary frequency, and represents the same process variable as the frequency/pulse output, but with half the frequency. All specifications match frequency/pulse output except: Signal can be scaled up to 5000 Hz; out-of-range capability to 7500 Hz. The output complies with VDE/VDI 2188.

### Optocoupler (rack-mount transmitter only)

The optocoupler is an externally powered output. Signal voltage: low level 0-2 VDC, high level 16-30 VDC. Maximum signal current 0.01 amp. Maximum capacitive load 150 nF at 10 kHz. Output is derived from the primary frequency, and represents the same process variable as the frequency/pulse output. The output complies with VDE/VDI 2188.

### Control

One control output can represent flow direction, fault alarm, zero in progress, event 1 or event 2. Internally powered, digital level, 0 or 15 V, 2.2 kohm pull-up, galvanically isolated to ±50 VDC. In open collector configuration: sinking capability, 0.1 amps in “on” condition (0 volt level), 30 VDC compliance in “off” condition.

### Digital

Switch allows selection of Bell 202 and/or RS-485 serial standard.

Bell 202 signal is superimposed on primary variable mA output, and available for host system interface. Frequency 1.2 and 2.2 kHz, amplitude 0.8 V peak-to-peak, 1200 baud. Requires 250 to 1000 ohms load resistance.

RS-485 signal is a ±5 V square wave referenced to transmitter ground. Baud rates between 1200 baud and 38.4 kilobaud can be selected.

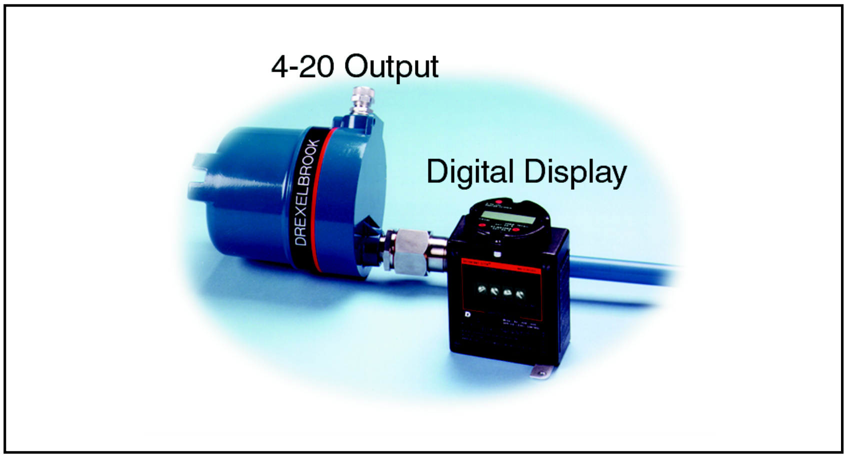
# Drexelbrook Level Sensors

AMETEK® DREXELBROOK

A Leader in Level Measurement

# Universal Lite™

## 509-15 Series RF Level Transmitter




### Easy Calibration Saves Time

Push button calibration is menu-driven through a full 4-digit LCD display that resides integral to the electronic unit. No hand-held calibration/ configuration terminals are required for a fast basic setup.

### Consistent Accuracy

Microprocessor-based circuitry means precise level indication along the entire sensing element. Internal circuitry provides ambient temperature compensation.

### Reliability

Drexelbrook's exclusive circuitry ensures dependable level indication in applications with light or moderate coatings.

### Eliminate Routine Maintenance

No moving parts to break or wear out. No need for routine maintenance or recalibration.

### Digital Display

An optional full 4-digit LCD display can be set up to read in percent or engineering units.

### The Drexelbrook Universal Lite RF Level indicating transmitter provides a low-cost solution to most level applications and is superior in reliability and performance.

AMETEK Drexelbrook's 509-15 Series two-wire RF Level transmitter provides dependable, low-cost level indication and control that is suitable for all liquid, and interface applications that do not leave a severe build-up on the sensing element. For applications where heavy build-up is expected, Drexelbrook offers the Universal Admittance transmitter.

A convenient integrally mounted package (or remote up to 50 feet) comes with optional local indication through a full 4-digit LCD display. Calibration and configuration is quick and easy through menu-driven push button selection.

Each system is available with:

- User definable display. (percent or engineering units).
- Easy 2-point calibration.
- Adjustable time delay provides signal damping.
- Meter trim to adjust the output signal to a known plant standard.
- Real-time View of input capacitance values.
- Optional display/keypad for quick and easy setup and local indication.

The Universal Lite can also be configured with the HART® Model 275 Communicator or optional AMETEK Drexelbrook PC software for more detailed setup and diagnostics.

## Specifications

| Application | Process Pressure and Temperature | Sensing Element Dimensions | Standard Mounting | Materials of Construction | System Model # (Sensing Element) |
|---|---|---|---|---|---|
| Water Based Liquids[1] | 100°F @ 1000 psi 38°C @ 69 BAR 300°F @ 500 psi 149°C @ 34 BAR | 3/8-inch (10 mm) OD TFE Rod Max. 20 feet (6 m) length | 3/4-inch NPT or Flange | 316 SS and TFE | 509-15-X09 (700-1-22) |
| Water Based Liquids in Tall Vessels[1] | 300°F @ 500 psi 149°C @ 34 BAR | 0.093-inch (2 mm) OD PFA Flex. Cable Max. 100 feet (30 m) length | 3/4-inch NPT or Flange | 316 SS and PFA | 509-15-X25 (700-5-54) |
| Conducting/ Insulating Interface | 100°F @ 1000 psi 38°C @ 69 BAR 300°F @ 500 psi 149°C @ 34 BAR | 0.56-inch (14 mm) OD TFE Rod Max. 19 feet (5.8 m) length | 3/4-inch NPT or Flange | 316 SS and FEP | 509-16-X02 (700-2-27) |
| Conducting/ Insulating Interface | 100°F @ 1000 psi 38°C @ 69 BAR 250°F @ 500 psi 121°C @ 34 BAR | 0.84-inch (21 mm) OD "X" Rod Max. 19 feet (5.8 m) length | 1-inch NPT or Flange | 316 SS and X[2] | 509-16-X06 (700-2-57) |
| Hydrocarbon & Organic Liquids | 100°F @ 1000 psi 38°C @ 69 BAR 300°F @ 500 psi 149°C @ 34 BAR | 1.66-inch (42 mm) OD Perforated Concentric Shield Max. 20 feet (6 m) length | 1 1/2-inch NPT or Flange | 316 SS and TFE | 509-17-X16 (700-1-26) |
| Water Based Liquids in Non-Metallic Vessels | 200°F @ 200 psi 93°C @ 14 BAR | 0.185-inch (5 mm) OD FEP Flex. Cable with Integral Ground Max. 100 feet (30 m) length | 3/4-inch NPT or Flange | 316 SS and TFE | 509-15-X85 (700-5-85) |

[1]Applications that produce significant coating build-up may require the Universal Admittance transmitter.
[2]X is a fluorocarbon-type insulation.

*Power Requirement:*
18 to 30 VDC, HART®
13 to 30 VDC, Analog

*Output:*
4-20mA Analog,
4-20mA HART Protocol,
Digital HART Protocol

*Maximum Load Resistance:*
550 ohms, HART® with modem/gateway
650 ohms @ 24 VDC, Analog

*Minimum Resistance:*
250 ohms for HART® protocol

*Supply Voltage Effect:*
0.05% / 10VDC

*Linearity:*
0.25% of span

Specifications subject to change.

*Electronic Housing:*
Meets Nema 1-5 & 12 including Nema 4X. Suitable for Class I, Groups A, B, C, D, Class II, Groups E, F, G, Div. 1 & 2, Class III Div. 2. Intrinsically Safe for Div. 1 when supplied from an approved power source

*Response Time:*
Less than 1 second with no damping time
1-90 seconds programmable damping time

*Spark Protection:*
10A standard (100A optional)

*Fail Safe:*
Direct Acting/Reverse Acting

*Ambient Temperature Limits:*
-40°F to 185°F (-40°C to 85°C)

*Maximum Cable Length:*
50 feet (15 m)

*Span Range (Typical):*
3" (76 mm) to 100' (30 m) on water-based materials. 3' (914 mm) to 100' (30 m) on organic materials

*Calibration:*
Three button keypad, PC-based software, or Model 275 calibrator

*Display:*
Integral 4-digit LCD

*Minimum Resistance Sensing Element to Ground:*
100,000 ohms (with less than a 1.0% effect on output signal)

*Temperature Stability:*
0.15% per 30°F (17°C)

*Approvals:*
CE Mark, KEMA (CENELEC), FM, CSA

AMETEK®
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# Digital Pressure Gauges

# Falcon Digi Pro⁴ NEMA 4X Digital Pressure Gauges



## F4DR 4-Wire Indicating Transmitter

## F4DRBL 4-Wire Indicating Transmitter with Backlit Display

- *±0.25% Test Gauge Accuracy*
- *316 Stainless Steel Wetted Parts*
- *Low-Voltage AC/DC-Powered*
- *4-20 mA or 0-2 V Analog Output*
- *4-20 mA Models Power Current Loop*
- *Output Test Function*
- *Polycarbonate Display Window*

## ELECTRICAL SPECIFICATIONS

**Ranges and Resolution**

**Bold** indicates standard ranges, price adder for all others
"abs" indicates absolute reference, gauge will read atmospheric pressure with no connection and zero under full vacuum.
"vac" indicates vacuum gauge

| | | | |
|---|---|---|---|
| Consult factory for other engineering units | 150.0 mmHg | ±1000 mbar | 14.00 MPa |
| | 250 mmHg | 1000 mbar | 19.99 MPa |
| | 760 mmHg abs | 1999 mbar abs | 35.0 MPa |
| | 760 mmHg vac | 1999 mbar | 1000 g/cm$^2$ abs |
| **3.00 psig** | 760 mmHg | 1.000 bar abs | 1000 g/cm$^2$ |
| **5.00 psig** | 1500 mmHg abs | 1.000 bar | 1999 g/cm$^2$ abs |
| 15.00 psi abs | 1500 mmHg | 1.999 bar abs | 1999 g/cm$^2$ |
| **15.00 psig vac** | 50.0 oz/in$^2$ | 1.999 bar | ±1.000 kg/cm$^2$ |
| ±15.00 psig | 80.0 oz/in$^2$ | 4.00 bar | 1.000 kg/cm$^2$ abs |
| **15.00 psig** | 240 oz/in$^2$ | 7.00 bar abs | 1.000 kg/cm$^2$ |
| 30.0 psia | 85.0 inH$_2$O | 7.00 bar | 1.999 kg/cm$^2$ abs |
| **30.0 psig** | 140.0 inH$_2$O | 14.00 bar | 1.999 kg/cm$^2$ |
| **60.0 psig** | 400 inH$_2$O abs | 19.99 bar | 4.00 kg/cm$^2$ |
| 100.0 psi abs | 400 inH$_2$O vac | 35.0 bar | 7.00 kg/cm$^2$ abs |
| **100.0 psig** | ±400 inH$_2$O | 70.0 bar | 7.00 kg/cm$^2$ |
| **199.9 psig** | 400 inH$_2$O | 140.0 bar | 14.00 kg/cm$^2$ |
| **300 psig** | 850 inH$_2$O | 199.9 bar | 19.99 kg/cm$^2$ |
| **500 psig** | 7.00 ftH$_2$O | 350 bar | 35.0 kg/cm$^2$ |
| **1000 psig** | 12.00 ftH$_2$O | 19.99 kPa | 70.0 kg/cm$^2$ |
| **1999 psig** | 35.0 ftH$_2$O | 35.0 kPa | 140.0 kg/cm$^2$ |
| **6.00 inHg** | 70.0 ftH$_2$O | 100.0 kPa abs | 199.9 kg/cm$^2$ |
| **10.00 inHg** | 140.0 ftH$_2$O | 100.0 kPa vac | 350 kg/cm$^2$ |
| 30.0 inHg abs | 230 ftH$_2$O | 100.0 kPa | 1.000 atm |
| **30.0 inHg vac** | 500 ftH$_2$O | 199.9 kPa abs | 4.00 atm |
| ±30.0 inHg | 1999 mmH$_2$O | 199.9 kPa | 7.00 atm |
| **30.0 inHg** | 199.9 cmH$_2$O | 400 kPa | 14.00 atm |
| 60.0 inHg abs | 350 cmH$_2$O | 700 kPa abs | 19.99 atm |
| **60.0 inHg** | 1000 cmH$_2$O | 700 kPa | 35.0 atm |
| **120.0 inHg** | 1999 cmH$_2$O | 1500 kPa | 70.0 atm |
| 199.9 inHg abs | 199.9 mbar | 1999 kPa | 135.0 atm |
| **199.9 inHg** | 350 mbar | 3.50 MPa | 199.9 atm |
| 760 torr abs | 1000 mbar abs | 7.00 MPa | 340 atm |

Resolution is fixed as indicated in table below

**Accuracy** (linearity, hysteresis, repeatability)
Standard: ±0.25% of full scale ±1 least significant digit
"-HA" option: ±0.1% FS ±1LSD (most ranges) or "-4A" option ±0.4% FS ±1LSD
NIST traceable test report and data optional

**Temperature Stability** (relative to 77°F or 25°C)
±1% FS for offset and span, 32 to 158°F (0 to 70°C) typical
±2% FS for offset and span, 32 to 158°F (0 to 70°C) typical for 3 and 5 psi ranges

**Display** (update rate, type, size)
3 readings per second nominal display update rate
DR in ranges up to 1999: 3½ digit LCD, ½" digit height
DRBL ranges up to 1999: 3½ digit LCD, ½" digit height, red LED backlighting

**Controls**
Non-interactive zero and span, ±10% range
Test calibration level: 0-100% range
Retransmission zero and span: internal potentiometers

**Retransmission Output**
True analog output, 50 milliseconds typical response time.
Current output: "-I" option, 4-20 mA DC, output drive (compliance) determined by power source. See graph.
Voltage output: "-V" option, 0-2 VDC into 5K Ohm or greater

**Test Function**
Front panel TEST button, when depressed sets display and retransmission output to "test calibration" level, independent of pressure input to allow testing of system operation. Test level is set by top-accessible multiturn potentiometer to any value from 0 to 100% of full scale.

**Power**
Any AC source of 8 to 24 VAC 50/60 Hz or any DC source of 9 to 32 VDC
30 mA maximum, 40 mA for DRBL model with backlighting
3 ft long, 4-conductor 22 AWG shielded cable
Order optional **WMPSK** 12 VDC wall mount power supply kit to operate on 115 VAC


*DPG1000DR200PSIG with 199.9 psig range*

## MECHANICAL SPECIFICATIONS

**Size**
3.5"W x 3.0"H x 2.0"D (not including pressure fitting)
Add approximately 0.75" to height for pressure fitting and 1" to depth for strain relief and wire clearance

**Weight** (approximate)
Gauge: 9 ounces
Shipping weight: 1 pound

**Housing**
NEMA 4X
UV stabilized polycarbonate/ABS case, light gray color
Clear polycarbonate window to protect display
Gasketed rear cover, six captive stainless steel screws

**Pressure/Vacuum Connection & Material**
¼" NPT male, 316 stainless steel

**Media Compatibility**
All wetted parts are 316 SS
Compatible with most liquids and gases

**Overpressure**
5000 psig for metric ranges equivalent to 3000 psig
7500 psig for metric ranges equivalent to 5000 psig
All others 2x rated pressure minimum

**Burst Pressure**
4x rated pressure minimum or 10,000 psi, whichever is less

## ENVIRONMENTAL SPECIFICATIONS

**Storage temperature** . . . . . . . . . . . . . . . . . . . –40 to 203°F (–40 to 95°C)
**Operating temperature** . . . . . . . . . . . . . . . . . . –4 to 185°F (–20 to 85°C)
**Compensated temperature** . . . . . . . . . . . . . . . . 32 to 158°F (0 to 70°C)

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## Installation and Precautions

Install or remove the gauge using wrench on hex fitting only. Do not attempt to tighten by turning housing or any other part of the gauge. Use fittings appropriate for the pressure range of the gauge. Do not apply vacuum to gauges not designed for vacuum operation. Due to the hardness of 316 stainless steel, it is recommended that a thread sealant be used to ensure leak-free operation. **NEVER** insert objects into the gauge port or blow out with compressed air. Permanent damage not covered by warranty will result to the sensor.

## Electrical Connection

***NEVER** connect the gauge wires directly to 115 VAC or permanent damage not covered by warranty will result.*

The **F4DR** and **F4DRBL** can be powered by any 9 to 32 VDC or 8 to 24 VAC 50/60 Hz power source. An inexpensive unregulated low voltage source can be used. The magnitude of the supply voltage has negligible effect on the gauge calibration as long as it is within the stated voltage ranges. Do not allow the gauge supply voltage fall below 9 VDC or 8 VAC RMS. Operation below these values may cause erratic or erroneous readings or output. Models with 4-20 mA output power the current loop. Use a power source with sufficient voltage to operate the current loop.

Connection is made with the 4-conductor cable at the gauge rear. This cable accommodates both the gauge power supply and retransmission output. This cable has one RED and one BLACK lead. If using a 9 to 32 VDC power source, connect the (+) supply to the RED lead and the (–) supply to the BLACK lead. If using a 8 to 24 VAC 50/60 Hz power source, connect to the RED and BLACK leads. When using low voltage AC power, there is of course, no polarity consideration.

The (+) retransmission output appears on the WHITE lead, and the (–) retransmission output appears on the GREEN lead. Use of the shield (drain) wire of the retransmission output is optional. It is not generally needed for 4-20 mA current loops unless very long cable lengths are used in electrically noisy environments.

The output is a continuous analog signal based on the transducer output rather than the display. This output is filtered to improve noise immunity and has a response time of about 50 milliseconds.

The power supply (–) lead is tied to the retransmission output ground. Therefore, if a DC supply is used, the power supply (–) lead should be considered common with regard to the retransmission output (–) connection.

## Using the Retransmission Output

**NEVER** connect retransmission output wires together or to an external power source or permanent damage not covered by warranty will result.

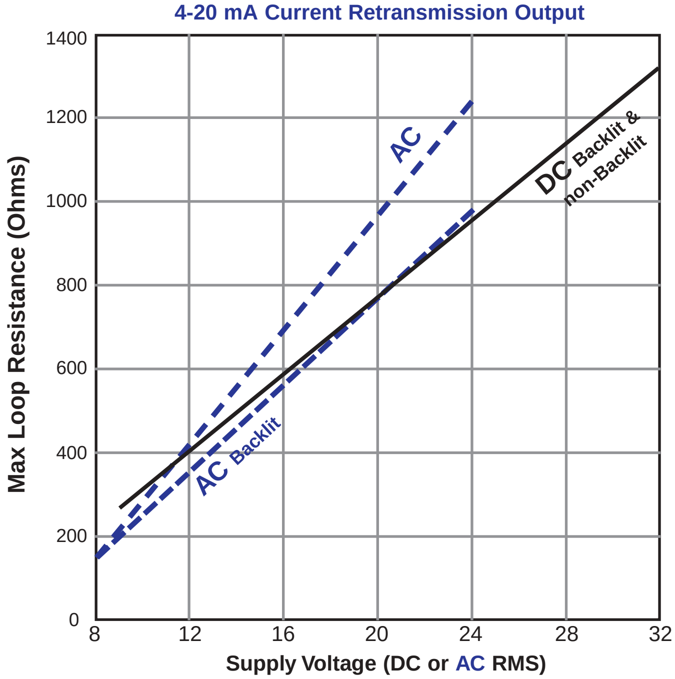
For 4-20 mA output models, be sure to observe the output compliance (voltage drive) capabilities of the gauge. The compliance, and therefore the maximum loop resistance the output can drive, is a function of the supply voltage to the gauge. Consult the graph below for maximum loop resistance vs. gauge supply voltage. Too large a loop resistance will cause the gauge output to "limit" or saturate before reaching its full 20 mA output.

When using the 0-2 volt retransmission output, do not allow the resistive load on the output to fall below 5K ohms. Also, avoid large capacitive loads (greater that 1000 pF) such as those caused by long runs of shielded cable. For long retransmission runs, use the 4-20 mA output model instead.

## Operation

The gauge is powered on whenever a supply voltage is applied. Warm-up time is negligible. In normal operation, the system pressure is displayed on the gauge LCD and an output signal will be present. **F4DRBL** model display backlighting will be on whenever power is applied.

**Voltage Compliance for**
**4-20 mA Current Retransmission Output**




## TEST Button

When the front-panel TEST button is held depressed, the display and retransmission output are switched, independent of the system pressure, to a test level determined by the setting of the Test potentiometer. This test mode will allow setup and testing of the output and any external device(s) connected to it by switching to this test level whenever desired without having to alter the system pressure.

To set the test output level, see gauge label for location of Test potentiometer. Press and hold the front-panel TEST button and adjust the Test potentiometer to set the display and retransmission output to the desired test level.

## Calibration

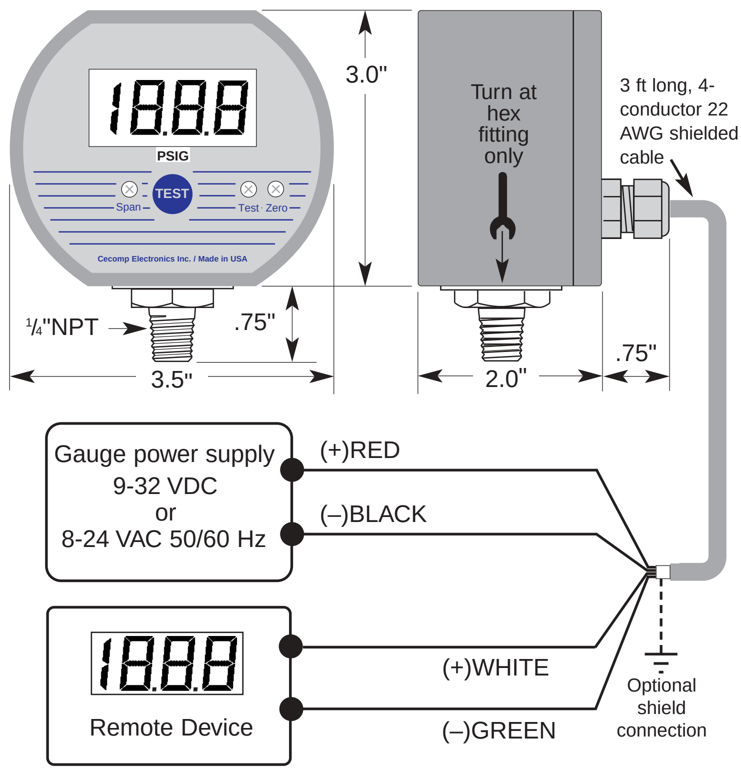
See gauge label for location of controls to adjust the zero and span of the display.

GAUGE reference units may be re-zeroed without affecting the span calibration. The gauge port must be open to the ambient with no pressure/vacuum applied. Adjust the Zero control until the gauge reads zero with the minus (–) sign occasionally flashing.

Span calibration should only be attempted if the user has access to a pressure reference of known accuracy. The quality of the calibration is only as good as the accuracy of the calibration equipment and ideally should be at least four times the gauge accuracy. Zero calibration must be done before span calibration. Record readings at three to five points over the range of gauge and adjust span control to minimize error and meet specifications.

ABSOLUTE reference gauges require vacuum generation and atmospheric pressure measurement equipment for accurate calibration and thus are more difficult to calibrate in the field. Gauges may be returned to Cecomp Electronics for factory certified recalibration. N.I.S.T. traceability is available.

Internal potentiometers adjust the agreement between the displayed value and the analog output. These are set at the factory and should not normally be adjusted. If adjustment is required, consult factory. Accurate pressure generation and measurement and current measurement equipment are required to successfully complete this calibration.




## MODEL DESIGNATION SYSTEM

**F4DR or F4DRBL range units ref**

Pressure/Vacuum Range (see table)

Units (see table)

**G**=Gauge, **A**=Absolute, **VAC**=Vacuum

Unit Abbreviations

| | | |
|---|---|---|
| psi = PSI | torr = TORR | mbar = MBAR |
| inHg = INHG | mmH$_2$O = MMH2O | bar = BAR |
| oz/in$^2$ = ZIN | kg/cm$^2$ = KGCM | cmH$_2$O = CMH2O |
| inH$_2$O = INH2O | g/cm$^2$ = GCM | atm = ATM |
| ftH$_2$O = FTH2O | kPa = KPA | |
| mmHg = MMHG | MPa = MPA | |

**Example:** F4DR100PSIG-I = F4DR, 100.0 psig, Current (4-20 mA) retransmission

Cecomp Electronics maintains a constant effort to upgrade and improve its products, therefore specifications are subject to change.

# Appendix B:  Particle Size Distribution Data

# Appendix B: Particle Size Distribution Data

During the simulant mixing tests discussed in this report, several grab samples were collected after a steady sate was observed in the slurry densities. A subset of the samples collected was analyzed using a MICROTRAC S3000 Particle Size Analyzer to determine the particle size distribution. The various samples analyzed are listed in Table B.1.

**Table B.1**. List of the Various Samples Analyzed for the Particle Size Distribution.

| **Simulant**[a] | **# of PJM Operating** | **Location of Sample Extraction** | | **Sample ID** |
|---|---|---|---|---|
| | | **Radial (in)** | **Vertical (in)** | |
| 10 µm, 5-wt% | 4 | 69 | 126 | Smp021119-2 |
| | 4 | 36 | 54 | Smp021119-4 |
| 10 µm, 20-wt% | 4 | 69 | 126 | Smp021121-1 |
| | 4 | 0 | 3 | Smp021121-3 |
| 35 µm, 5-wt% | 4 | 69 | 126 | Smp021204-1 |
| | 4 | 0 | 3 | Smp021204-3 |
| 35 µm, 20-wt% | 4 | 0 | 3 | Smp021212-4 |
| | 4 | 69 | 126 | Smp021212-5 |
| | 4 | 69 | 136 | Smp021212-7 |
| (a) Particle sizes listed here are the nominal volume mean diameters | | | | |

In this section, the approach used to determine the PSD data, and the measurements are included in terns of the volume based and area (Sauter's mean) based distribution data.

# Test Instructions for Measuring PSD

# RPP-WTP Support Project
# Test Instruction

Unique Numerical Designation: TI-RPP-WTP-228
Revision number: 0
Effective Date: Upon final signature
Controlling Procedure No: [TPR-RPP-WTP-222]

TITLE: Particle Size Distribution Analyses of B-55 Large Scale test Samples

Perform PSD analysis on the following 9 slurry samples:

Smp021119-2
Smp 021119-4
Smp 021121-1
Smp 021121-4
Smp 021204-1
Smp 021204-3
Smp021212-4
Smp021212-5
Smp021212-7

Reference the sample numbers when recording LRB entries and transmitting the results.

The samples were obtained from testing conducted according to TPR-RPP-WTP-214. For each 4-PJM test, single samples from the top and bottom of the tank are to be analyzed. Four 4-PJM tests were conducted. Three samples are supplied from the 4-PJM test conducted on 12/12/02. Refer to LRB BNW-14248 for a description of each sample. The corresponding logbook page is listed on each sample container.

Using Procedure TPR-RPP-WTP-222, "S3000 Microtrac Particle Size Analyzer", APEL 109:

1) Perform analysis on *Duke Scientific* 10 µm and 100 µm standards, lot numbers 24616 and 24343 respectively. Certificates of Calibration and Traceability are retained in Project files.
   a. Use 1 to 4 drops of dispersant for each standard
   b. Dilute with deionized water (DIW) as required to achieve measurable results
   c. Use the ultrasonic horn to de-agglomerate the standard slurry
   d. Agitate the standard slurry with a magnetic stirrer before drawing the aliquot for analysis
   e. Analyze each standard and printout the results. The mean standard particle size must fall between 9 µm and 11 µm for the 10 µm standard, and between 95 µm and 105 µm for the 100 µm standard. If the results do not fall within these

ranges, contact Carl Enderlin (375-2141) or Jim Bates (375-2539) before proceeding.

2) Agitate each slurry sample with a magnetic stirrer before drawing the aliquot for analysis.

3) Use 1 to 4 drops of dispersant for each aliquot.

4) Dilute with DIW as required to achieve measurable results.

5) Use the ultrasonic horn to de-agglomerate each aliquot.

6) Agitate the sample aliquot with a magnetic stirrer before transferring into the Microtrac S3000 for analysis.

7) Print out the results and record the appropriate LRB number and corresponding LRB page numbers on the printout.

8) Sign, and date each printout (to include the sample number reference), and attach the printouts to this test instruction along with the standards analysis results. Return all information to Jim Bates (5-2539).

**Approvals:**

Carl Enderlin 12/18/02

Author: Carl Enderlin

WCBuchmiller 12/17/02

Technical Reviewer: Bill Buchmiller

# Calibration Standard Certificates

Duke Scientific Corporation

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e-mail: info@dukesci.com

September 25, 2001

# PARTICLE SIZE STANDARDS
## NIST Traceable Mean Diameter

<u>1. DESCRIPTION</u>. These particle size standards provide accurate and traceable size calibration values for particle size analysis. They are part of a series of uniform glass microspheres with calibrated mean diameters traceable to the Standard Meter through the National Institute of Standards and Technology (NIST). Uniform glass microspheres are widely used as calibrants and controls for instruments requiring a higher density than polymer microspheres. Made of borosilicate or soda lime glass, diameters from 2 to 2000 micrometers (µm) are available as dry spheres, calibrated by optical microscopy. Other values are for information only and should not be used as calibration values.

| <u>2. PHYSICAL DATA</u>. | Catalog Number: 9010, Nominal 10µm |
|---|---|
| Certified Mean Diameter: | 10.0µm ± 1.0µm |
| Standard Deviation: | 1.0µm |
| Coefficient of Variation: | 10% |
| Microsphere Composition: | Borosilicate Glass |
| Microsphere Density: | 2.50g/cm$^3$ |
| Index of Refraction: | 1.56 @ 589nm |
| Dielectric Constant: | 5.8 @ 1MHz and 22°C |
| Approximate Number: | 7.6 x 10$^8$ per gram |

– Continued on page 2

# VALUABLE CERTIFICATE - KEEP ON FILE

## CERTIFICATE OF CALIBRATION AND TRACEABILITY

This certifies that the calibrated mean diameter dimension was transferred by optical microscopy from a stage micrometer calibrated by the National Institute of Standards and Technology (Calibration Report #5524). NIST Standard Reference Materials 1690, 1692, 1960, and 1961 were used to validate the accuracy and traceability of the calibration methods.

Catalog Number: 9010, Particle Size Standards - Borosilicate Glass

Certified Mean Diameter: 10.0µm — Material Batch: 9010-004

Uncertainty: ± 1.0µm — Certification Date: September 25, 2001

Philip L. Warren, President
Duke Scientific Corporation

*Void without seal*

Packaging Lot # 24616

Expiration Date: OCT '05

– Over for more data





cert009.04

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May 9, 2002

# PARTICLE SIZE STANDARDS
## NIST Traceable Mean Diameter

1. DESCRIPTION. These particle size standards provide accurate and traceable size calibration values for particle size analysis. They are part of a series of uniform glass microspheres with calibrated mean diameters traceable to the Standard Meter through the National Institute of Standards and Technology (NIST). Uniform glass microspheres are widely used as calibrants and controls for instruments requiring a higher density than polymer microspheres. Made of borosilicate or soda lime glass, diameters from 2 to 2000 micrometers (μm) are available as dry spheres, calibrated by optical microscopy. Other values are for information only and should not be used as calibration values.

| 2. PHYSICAL DATA. | Catalog Number: 9100, Nominal 100μm |
|---|---|
| Certified Mean Diameter: | 99.8μm ± 5.0μm |
| Standard Deviation: | 3.2μm |
| Coefficient of Variation: | 3.2% |
| Microsphere Composition: | Soda Lime Glass |
| Microsphere Density: | 2.45g/cm$^3$ |
| Index of Refraction: | 1.51 @ 589nm |
| Dielectric Constant: | 7.3 @ 1MHz and 22°C |
| Approximate Number: | 7.8 x $10^5$ per gram |

– Continued on page 2

## VALUABLE CERTIFICATE - KEEP ON FILE

### CERTIFICATE OF CALIBRATION AND TRACEABILITY

This certifies that the calibrated mean diameter dimension was transferred by optical microscopy from a stage micrometer calibrated by the National Institute of Standards and Technology (Calibration Report #5524). NIST Standard Reference Materials 1690, 1692, 1960, and 1961 were used to validate the accuracy and traceability of the calibration methods.

Catalog Number: 9100, Particle Size Standards - Soda Lime Glass

Certified Mean Diameter: 99.8μm — Material Batch: 9100-004

Uncertainty: ± 5.0μm — Certification Date: May 9, 2002

Philip L. Warren, President
Duke Scientific Corporation

*Void without seal*

SIZE STANDARDS

Packaging Lot # 24343

Expiration Date: JUL '05

– Over for more data





cert009.04

# Instrument Performance Checks

Serial Number: S3177
Range: 0.021 -1408 um

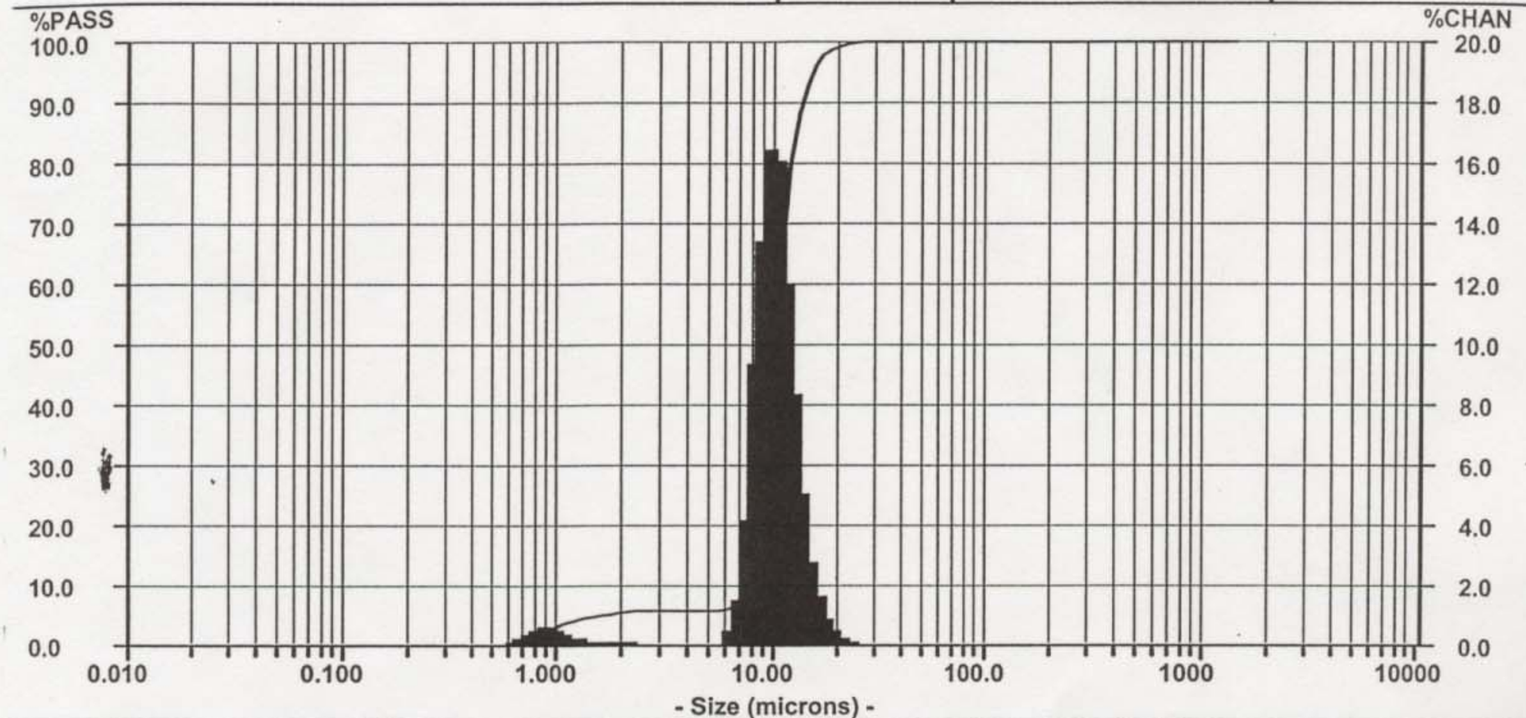
# MICROTRAC - S3000

Ver:8.0a

## 121802PJM

| | | |
|---|---|---|
| 10 Micron std | Date: 12/18/02 | Meas #: 12 |
| 1 hour | Time: 19:30 | Pres #: 1 |

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 10.02 | 5% = 1.568 | 60% = 10.53 | 10.16 | 94% | 4.171 |
| mn = 0.937 | 20% = 8.365 | 70% = 11.17 | 0.965 | 6% | 0.763 |
| ma = 6.529 | 30% = 8.967 | 80% = 12.02 | | | |
| cs = 0.919 | 40% = 9.497 | 90% = 13.42 | | | |
| sd = 2.196 | 50% = 10.00 | 95% = 14.91 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.00 | 3.889 | 5.83 | 0.00 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 100.00 | 0.00 | 3.566 | 5.83 | 0.00 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 100.00 | 0.00 | 3.270 | 5.83 | 0.00 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 100.00 | 0.00 | 2.999 | 5.83 | 0.00 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 100.00 | 0.00 | 2.750 | 5.83 | 0.00 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 100.00 | 0.00 | 2.522 | 5.83 | 0.00 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 100.00 | 0.00 | 2.312 | 5.83 | 0.16 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 100.00 | 0.00 | 2.121 | 5.67 | 0.21 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 100.00 | 0.00 | 1.945 | 5.46 | 0.19 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 100.00 | 0.00 | 1.783 | 5.27 | 0.18 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 100.00 | 0.00 | 1.635 | 5.09 | 0.19 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 100.00 | 0.00 | 1.499 | 4.90 | 0.22 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 100.00 | 0.12 | 1.375 | 4.68 | 0.28 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 99.88 | 0.22 | 1.261 | 4.40 | 0.36 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 99.66 | 0.33 | 1.156 | 4.04 | 0.48 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 99.33 | 0.53 | 1.060 | 3.56 | 0.59 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 98.80 | 0.92 | 0.972 | 2.97 | 0.67 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 97.88 | 1.65 | 0.892 | 2.30 | 0.66 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 96.23 | 2.87 | 0.818 | 1.64 | 0.58 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 93.36 | 5.07 | 0.750 | 1.06 | 0.48 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 88.29 | 8.47 | 0.688 | 0.58 | 0.37 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 79.82 | 12.05 | 0.630 | 0.21 | 0.21 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 67.77 | 16.09 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 51.68 | 16.53 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 35.15 | 13.43 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 21.72 | 9.40 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 12.32 | 4.20 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 8.12 | 1.60 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 6.52 | 0.57 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 5.95 | 0.12 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 5.83 | 0.00 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 5.83 | 0.00 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 5.83 | 0.00 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 5.83 | 0.00 | 0.223 | 0.00 | 0.00 | | | |

| | | | |
|---|---|---|---|
| Distribution: Volume | RunTime: 30 seconds | Fluid: Water | Analysis Mode: S3000 |
| Progression: Geometric Root8 | Run Number Avg of 3 runs | Fluid Refractive Index: 1.33 | Sample Cell Id: 0084 |
| Upper Edge: 1408 | Particle: active anode powder | Loading Factor: 0.0311 | |
| Lower Edge: 0.021 | Particle Transparency: Absorb | Transmission: 0.94 | |
| Residuals: Disabled | Particle Refractive Index: N/A | Above Residual: 0.00 | |
| Number Of Channels: 128 | Particle Shape: N/A | Below Residual: 0.00 | |

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

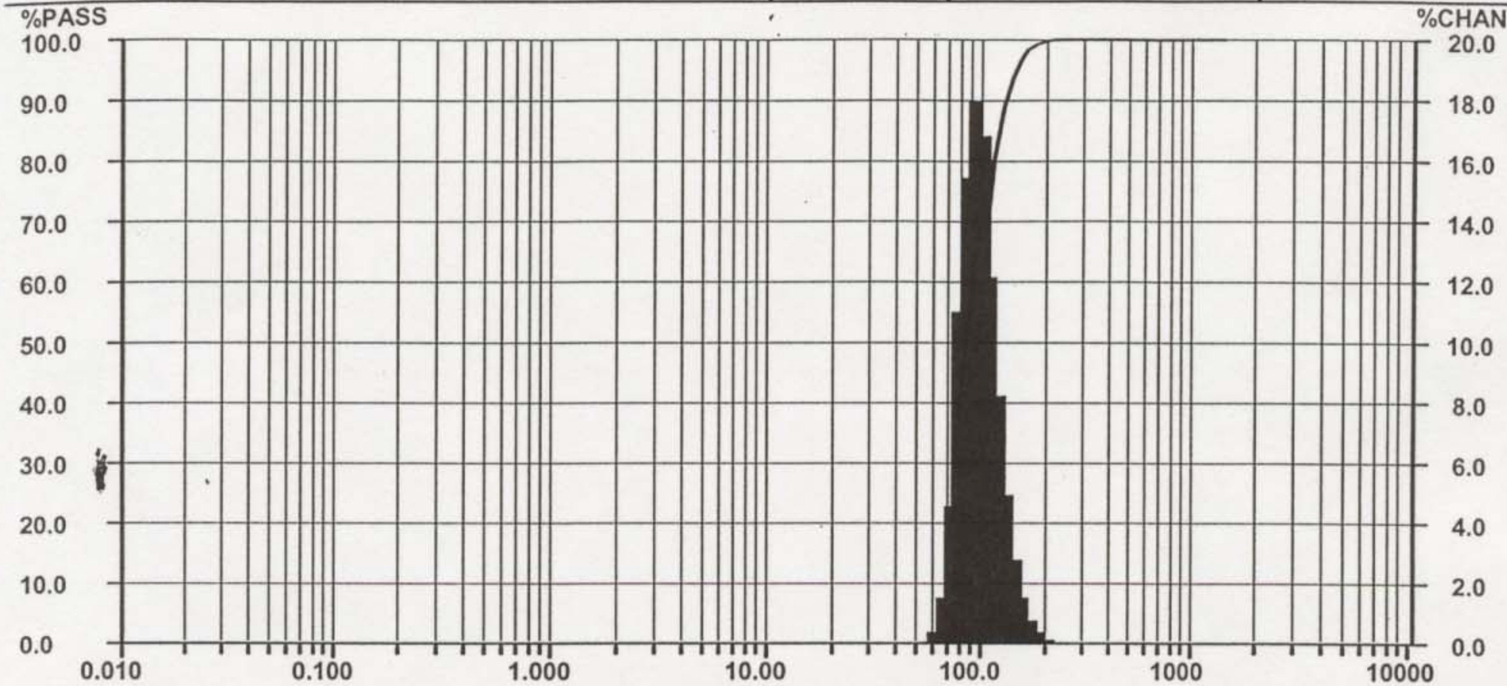
Ver:8.0a

## 121802PJM

100 Micron std 24343
1 hour

Date: 12/18/02 Meas #: 2
Time: 16:50 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 98.96 | 5% = 71.98 | 60% = 100.0 | 95.32 | 100% | 38.25 |
| mn = 54.68 | 20% = 81.71 | 70% = 105.8 | | | |
| ma = 94.30 | 30% = 86.43 | 80% = 113.6 | | | |
| cs = 0.064 | 40% = 90.90 | 90% = 126.6 | | | |
| sd = 19.13 | 50% = 95.32 | 95% = 139.7 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 6.84 | 4.64 | 3.889 | 0.00 | 0.00 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 2.20 | 1.61 | 3.566 | 0.00 | 0.00 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 0.59 | 0.43 | 3.270 | 0.00 | 0.00 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 0.16 | 0.06 | 2.999 | 0.00 | 0.00 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 0.10 | 0.00 | 2.750 | 0.00 | 0.00 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 0.10 | 0.00 | 2.522 | 0.00 | 0.00 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 0.10 | 0.00 | 2.312 | 0.00 | 0.00 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 0.10 | 0.00 | 2.121 | 0.00 | 0.00 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 0.10 | 0.00 | 1.945 | 0.00 | 0.00 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 0.10 | 0.00 | 1.783 | 0.00 | 0.00 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 0.10 | 0.00 | 1.635 | 0.00 | 0.00 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 0.10 | 0.00 | 1.499 | 0.00 | 0.00 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 0.10 | 0.00 | 1.375 | 0.00 | 0.00 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 0.10 | 0.00 | 1.261 | 0.00 | 0.00 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 0.10 | 0.00 | 1.156 | 0.00 | 0.00 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 0.10 | 0.00 | 1.060 | 0.00 | 0.00 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 0.10 | 0.00 | 0.972 | 0.00 | 0.00 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 0.10 | 0.00 | 0.892 | 0.00 | 0.00 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 0.10 | 0.00 | 0.818 | 0.00 | 0.00 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 0.10 | 0.00 | 0.750 | 0.00 | 0.00 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 0.10 | 0.00 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 0.10 | 0.00 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.25 | 11.00 | 0.10 | 0.05 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 99.75 | 0.50 | 10.09 | 0.05 | 0.05 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 99.25 | 0.88 | 9.250 | 0.00 | 0.00 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 98.37 | 1.61 | 8.482 | 0.00 | 0.00 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 96.76 | 2.84 | 7.778 | 0.00 | 0.00 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 93.92 | 5.00 | 7.133 | 0.00 | 0.00 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 88.92 | 8.32 | 6.541 | 0.00 | 0.00 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 80.60 | 12.20 | 5.998 | 0.00 | 0.00 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 68.40 | 16.96 | 5.500 | 0.00 | 0.00 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 51.44 | 18.02 | 5.044 | 0.00 | 0.00 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 33.42 | 15.49 | 4.625 | 0.00 | 0.00 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 17.93 | 11.09 | 4.241 | 0.00 | 0.00 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0839
Transmission: 0.96
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

# 10 μm, 5 wt% PSD Data

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

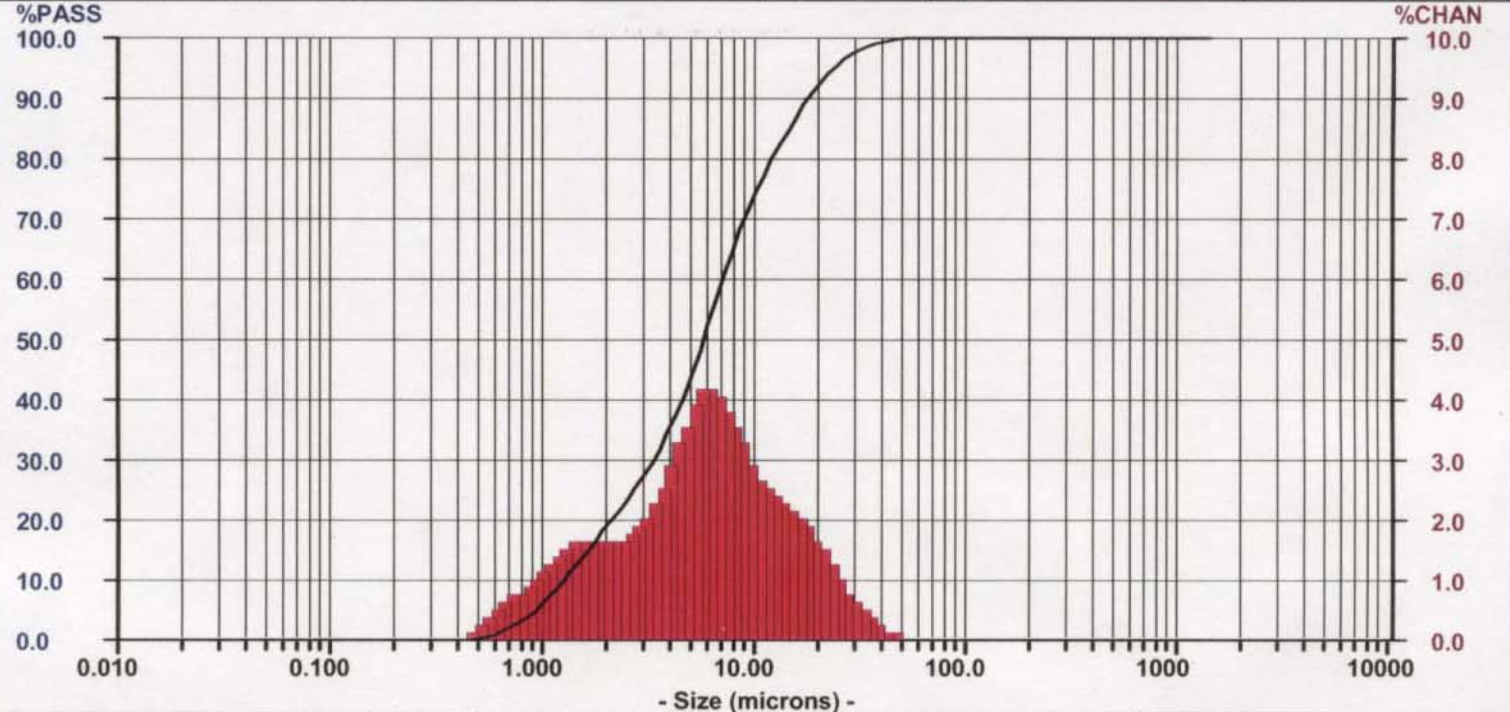
Ver:8.0af

**121802PJM**

SMP021119-2

Date: 12/18/02 Meas #: 11
Time: 21:20 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 7.866 | 5% = 0.906 | 60% = 7.009 | 5.697 | 100% | 12.14 |
| mn = 0.878 | 20% = 2.113 | 70% = 8.857 | | | |
| ma = 3.178 | 30% = 3.332 | 80% = 12.00 | | | |
| cs = 1.888 | 40% = 4.543 | 90% = 17.70 | | | |
| sd = 6.070 | 50% = 5.697 | 95% = 23.10 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.00 | 3.889 | 34.46 | 2.61 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 100.00 | 0.00 | 3.566 | 31.85 | 2.34 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 100.00 | 0.00 | 3.270 | 29.51 | 2.12 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 100.00 | 0.00 | 2.999 | 27.39 | 1.96 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 100.00 | 0.12 | 2.750 | 25.43 | 1.85 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 99.88 | 0.19 | 2.522 | 23.58 | 1.77 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 99.69 | 0.23 | 2.312 | 21.81 | 1.74 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 99.46 | 0.31 | 2.121 | 20.07 | 1.71 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 99.15 | 0.41 | 1.945 | 18.36 | 1.71 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 98.74 | 0.53 | 1.783 | 16.65 | 1.70 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 98.21 | 0.69 | 1.635 | 14.95 | 1.68 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 97.52 | 0.88 | 1.499 | 13.27 | 1.65 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 96.64 | 1.09 | 1.375 | 11.62 | 1.59 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 95.55 | 1.31 | 1.261 | 10.03 | 1.49 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 94.24 | 1.54 | 1.156 | 8.54 | 1.37 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 92.70 | 1.74 | 1.060 | 7.17 | 1.25 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 90.96 | 1.92 | 0.972 | 5.92 | 1.12 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 89.04 | 2.08 | 0.892 | 4.80 | 0.99 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 86.96 | 2.20 | 0.818 | 3.81 | 0.87 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 84.76 | 2.32 | 0.750 | 2.94 | 0.76 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 82.44 | 2.44 | 0.688 | 2.18 | 0.64 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 80.00 | 2.59 | 0.630 | 1.54 | 0.53 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 77.41 | 2.78 | 0.578 | 1.01 | 0.40 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 74.63 | 3.01 | 0.530 | 0.61 | 0.30 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 71.62 | 3.30 | 0.486 | 0.31 | 0.20 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 68.32 | 3.60 | 0.446 | 0.11 | 0.11 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 64.72 | 3.89 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 60.83 | 4.10 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 56.73 | 4.22 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 52.51 | 4.18 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 48.33 | 3.96 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 44.37 | 3.66 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 40.71 | 3.30 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 37.41 | 2.95 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0297
Transmission: 0.91
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

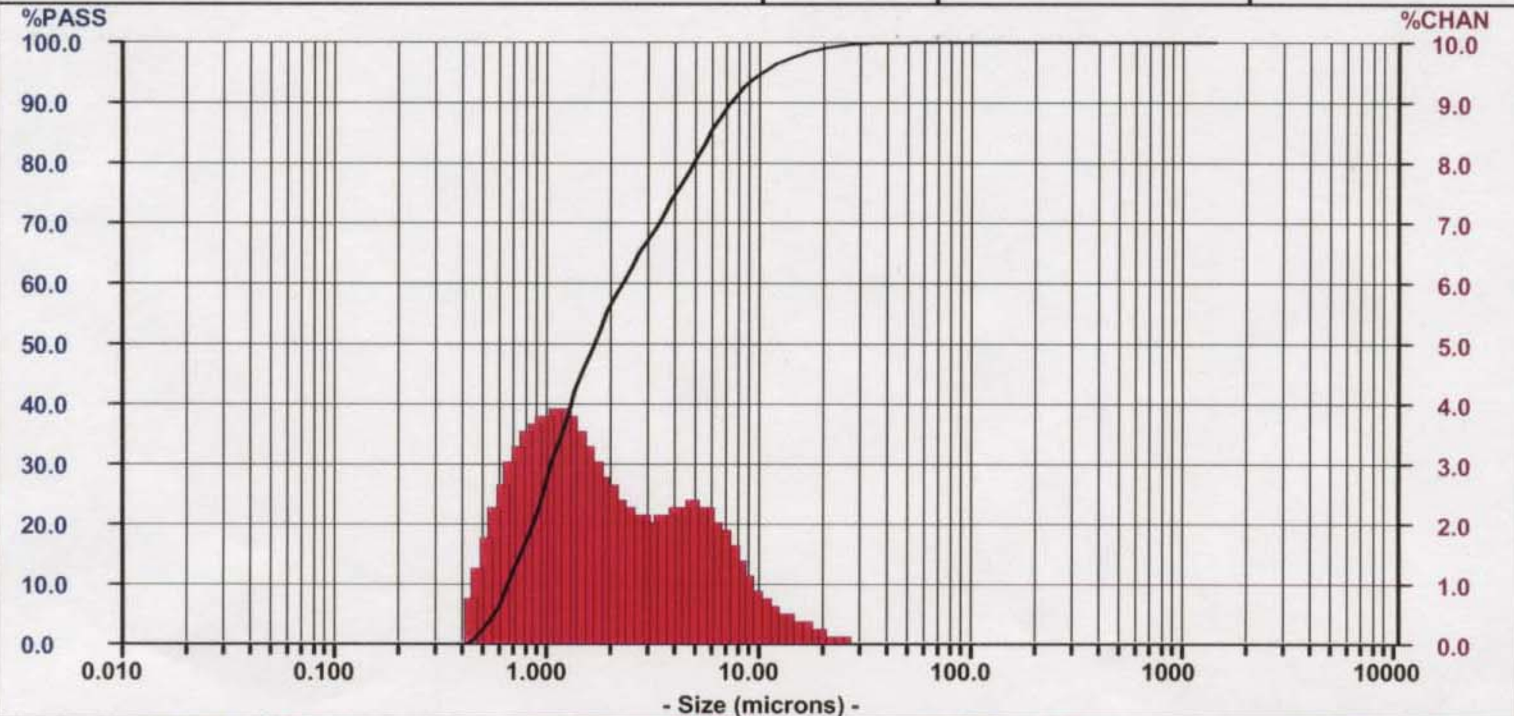
Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

Ver:8.0a

| 121802PJM | SMP021119-2 | Date: 12/18/02 Meas #: 11<br>Time: 21:20 Pres #: 1 |
|---|---|---|

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 7.866 | 5% = 0.550 | 60% = 2.264 | 4.710 | 42% | 6.100 |
| mn = 0.878 | 20% = 0.834 | 70% = 3.341 | 1.024 | 58% | 0.980 |
| ma = 3.178 | 30% = 1.046 | 80% = 4.873 | | | |
| cs = 1.888 | 40% = 1.305 | 90% = 7.244 | | | |
| sd = 2.440 | 50% = 1.664 | 95% = 10.17 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.00 | 3.889 | 73.88 | 2.23 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 100.00 | 0.00 | 3.566 | 71.65 | 2.18 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 100.00 | 0.00 | 3.270 | 69.47 | 2.15 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 100.00 | 0.00 | 2.999 | 67.32 | 2.17 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 100.00 | 0.01 | 2.750 | 65.15 | 2.23 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 99.99 | 0.01 | 2.522 | 62.92 | 2.33 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 99.98 | 0.02 | 2.312 | 60.59 | 2.48 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 99.96 | 0.03 | 2.121 | 58.11 | 2.68 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 99.93 | 0.04 | 1.945 | 55.43 | 2.91 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 99.89 | 0.05 | 1.783 | 52.52 | 3.16 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 99.84 | 0.07 | 1.635 | 49.36 | 3.41 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 99.77 | 0.10 | 1.499 | 45.95 | 3.64 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 99.67 | 0.14 | 1.375 | 42.31 | 3.83 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 99.53 | 0.18 | 1.261 | 38.48 | 3.93 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 99.35 | 0.23 | 1.156 | 34.55 | 3.95 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 99.12 | 0.29 | 1.060 | 30.60 | 3.90 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 98.83 | 0.34 | 0.972 | 26.70 | 3.81 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 98.49 | 0.40 | 0.892 | 22.89 | 3.70 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 98.09 | 0.47 | 0.818 | 19.19 | 3.55 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 97.62 | 0.54 | 0.750 | 15.64 | 3.35 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 97.08 | 0.62 | 0.688 | 12.29 | 3.12 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 96.46 | 0.71 | 0.630 | 9.17 | 2.78 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 95.75 | 0.83 | 0.578 | 6.39 | 2.33 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 94.92 | 0.99 | 0.530 | 4.06 | 1.86 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 93.93 | 1.18 | 0.486 | 2.20 | 1.39 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 92.75 | 1.40 | 0.446 | 0.81 | 0.81 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 91.35 | 1.65 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 89.70 | 1.90 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 87.80 | 2.14 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 85.66 | 2.30 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 83.36 | 2.39 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 80.97 | 2.41 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 78.56 | 2.37 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 76.19 | 2.31 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0297
Transmission: 0.91
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

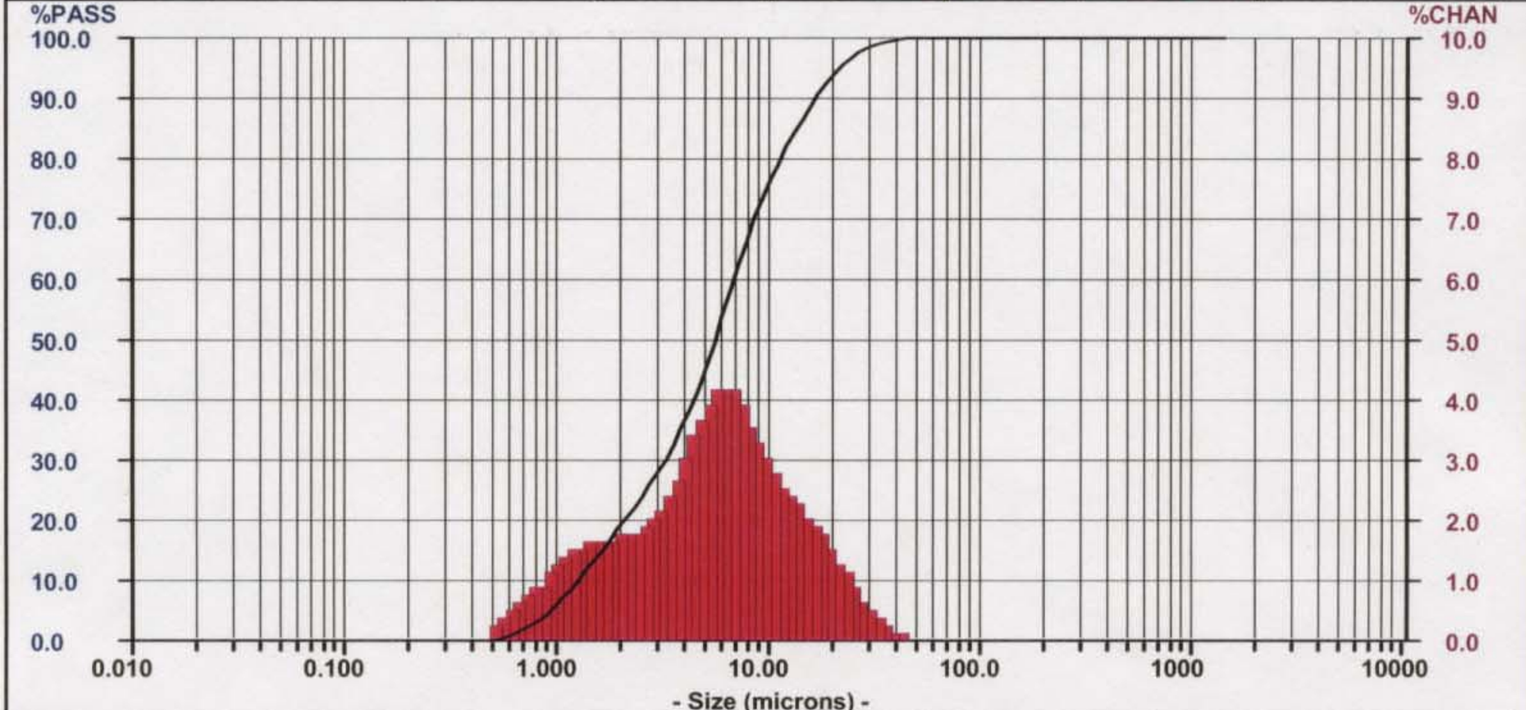
Ver:8.0af

**121802PJM**

SMP021119-4

Date: 12/18/02 Meas #: 10
Time: 21:11 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 7.393 | 5% = 0.918 | 60% = 6.779 | 5.532 | 100% | 11.22 |
| mn = 0.928 | 20% = 2.088 | 70% = 8.466 | | | |
| ma = 3.158 | 30% = 3.242 | 80% = 11.26 | | | |
| cs = 1.900 | 40% = 4.413 | 90% = 16.42 | | | |
| sd = 5.608 | 50% = 5.532 | 95% = 21.19 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.00 | 3.889 | 35.41 | 2.73 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 100.00 | 0.00 | 3.566 | 32.68 | 2.45 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 100.00 | 0.00 | 3.270 | 30.23 | 2.23 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 100.00 | 0.00 | 2.999 | 28.00 | 2.06 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 100.00 | 0.00 | 2.750 | 25.94 | 1.94 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 100.00 | 0.00 | 2.522 | 24.00 | 1.86 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 100.00 | 0.14 | 2.312 | 22.14 | 1.81 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 99.86 | 0.24 | 2.121 | 20.33 | 1.78 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 99.62 | 0.30 | 1.945 | 18.55 | 1.77 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 99.32 | 0.40 | 1.783 | 16.78 | 1.75 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 98.92 | 0.54 | 1.635 | 15.03 | 1.73 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 98.38 | 0.72 | 1.499 | 13.30 | 1.69 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 97.66 | 0.93 | 1.375 | 11.61 | 1.62 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 96.73 | 1.15 | 1.261 | 9.99 | 1.53 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 95.58 | 1.39 | 1.156 | 8.46 | 1.41 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 94.19 | 1.62 | 1.060 | 7.05 | 1.28 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 92.57 | 1.82 | 0.972 | 5.77 | 1.14 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 90.75 | 2.00 | 0.892 | 4.63 | 1.01 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 88.75 | 2.14 | 0.818 | 3.62 | 0.89 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 86.61 | 2.29 | 0.750 | 2.73 | 0.76 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 84.32 | 2.42 | 0.688 | 1.97 | 0.65 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 81.90 | 2.60 | 0.630 | 1.32 | 0.53 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 79.30 | 2.80 | 0.578 | 0.79 | 0.42 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 76.50 | 3.06 | 0.530 | 0.37 | 0.27 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 73.44 | 3.36 | 0.486 | 0.10 | 0.08 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 70.08 | 3.67 | 0.446 | 0.02 | 0.02 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 66.41 | 3.97 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 62.44 | 4.18 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 58.26 | 4.29 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 53.97 | 4.25 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 49.72 | 4.05 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 45.67 | 3.78 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 41.89 | 3.42 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 38.47 | 3.06 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0270
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

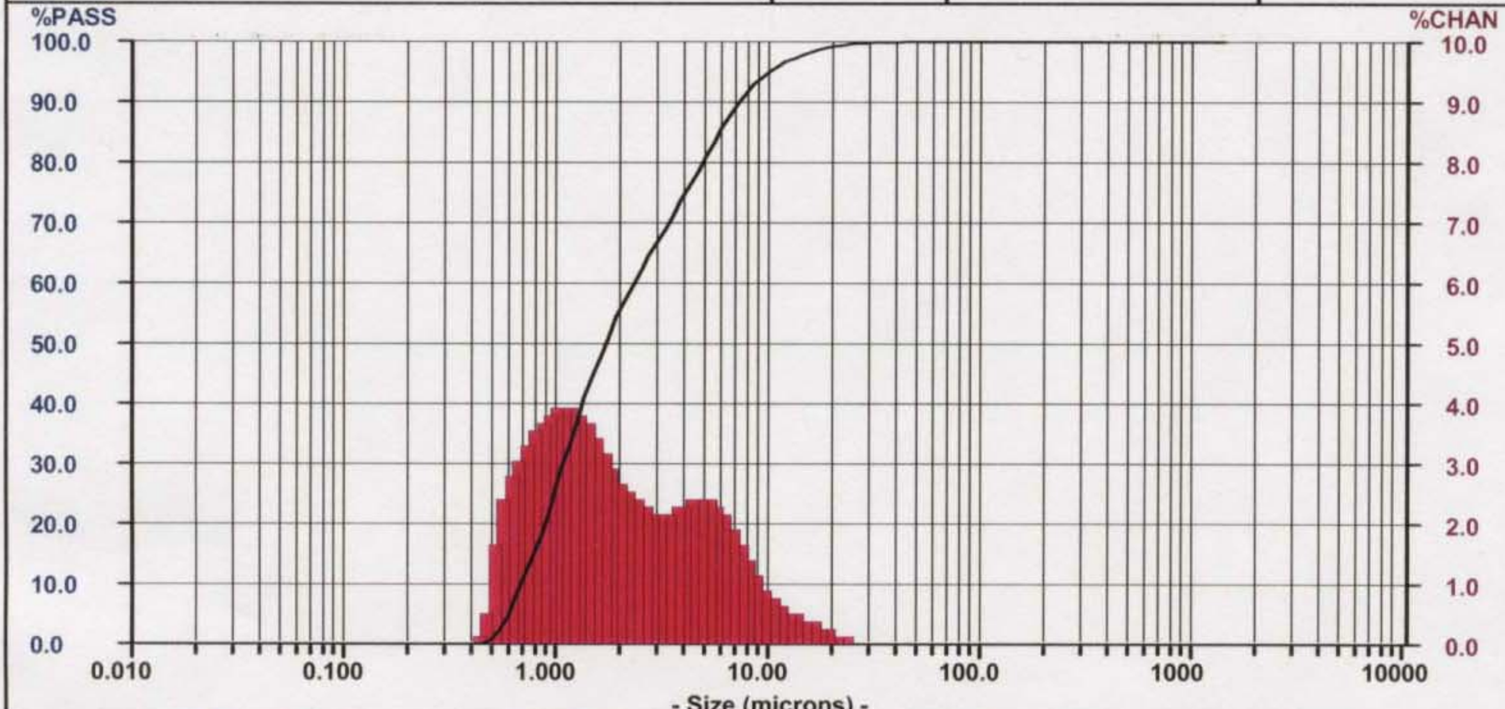
Ver:8.0af

**121802PJM**

SMP021119-4

Date: 12/18/02 Meas #: 10
Time: 21:11 Pres #: 1

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 7.393 | 5% = 0.582 | 60% = 2.320 | 1.708 | 100% | 4.823 |
| mn = 0.928 | 20% = 0.864 | 70% = 3.376 | | | |
| ma = 3.158 | 30% = 1.078 | 80% = 4.863 | | | |
| cs = 1.900 | 40% = 1.340 | 90% = 7.173 | | | |
| sd = 2.412 | 50% = 1.708 | 95% = 9.930 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.00 | 3.889 | 73.73 | 2.31 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 100.00 | 0.00 | 3.566 | 71.42 | 2.27 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 100.00 | 0.00 | 3.270 | 69.15 | 2.25 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 100.00 | 0.00 | 2.999 | 66.90 | 2.27 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 100.00 | 0.00 | 2.750 | 64.63 | 2.32 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 100.00 | 0.00 | 2.522 | 62.31 | 2.43 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 100.00 | 0.01 | 2.312 | 59.88 | 2.58 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 99.99 | 0.02 | 2.121 | 57.30 | 2.76 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 99.97 | 0.03 | 1.945 | 54.54 | 2.99 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 99.94 | 0.04 | 1.783 | 51.55 | 3.23 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 99.90 | 0.06 | 1.635 | 48.32 | 3.49 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 99.84 | 0.08 | 1.499 | 44.83 | 3.71 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 99.76 | 0.12 | 1.375 | 41.12 | 3.89 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 99.64 | 0.16 | 1.261 | 37.23 | 3.99 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 99.48 | 0.21 | 1.156 | 33.24 | 4.00 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 99.27 | 0.26 | 1.060 | 29.24 | 3.98 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 99.01 | 0.32 | 0.972 | 25.26 | 3.87 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 98.69 | 0.39 | 0.892 | 21.39 | 3.73 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 98.30 | 0.45 | 0.818 | 17.66 | 3.57 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 97.85 | 0.53 | 0.750 | 14.09 | 3.37 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 97.32 | 0.61 | 0.688 | 10.72 | 3.12 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 96.71 | 0.71 | 0.630 | 7.60 | 2.79 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 96.00 | 0.84 | 0.578 | 4.81 | 2.42 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 95.16 | 1.00 | 0.530 | 2.39 | 1.68 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 94.16 | 1.19 | 0.486 | 0.71 | 0.57 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 92.97 | 1.42 | 0.446 | 0.14 | 0.14 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 91.55 | 1.68 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 89.87 | 1.93 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 87.94 | 2.16 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 85.78 | 2.33 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 83.45 | 2.43 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 81.02 | 2.47 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 78.55 | 2.44 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 76.11 | 2.38 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0270
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

**10 $\mu$m, 20 wt% PSD Data**

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

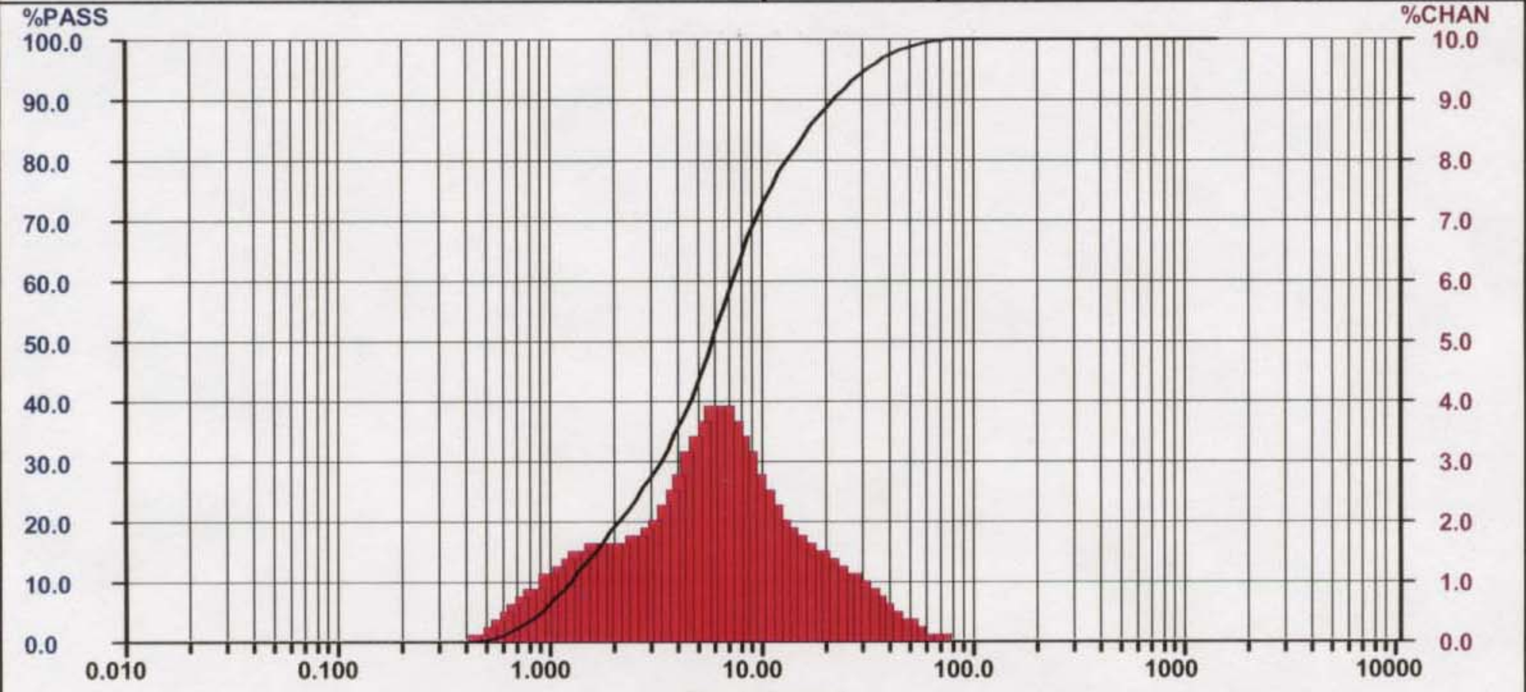
Ver:8.0af

**121802PJM**

SMP021121-1

Date: 12/18/02 Meas #: 8
Time: 20:51 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 9.012 | 5% = 0.886 | 60% = 7.160 | 5.760 | 100% | 13.77 |
| mn = 0.857 | 20% = 2.096 | 70% = 9.177 | | | |
| ma = 3.170 | 30% = 3.308 | 80% = 12.94 | | | |
| cs = 1.893 | 40% = 4.549 | 90% = 21.34 | | | |
| sd = 6.887 | 50% = 5.760 | 95% = 30.34 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.15 | 3.889 | 34.59 | 2.57 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 99.85 | 0.22 | 3.566 | 32.02 | 2.32 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 99.63 | 0.25 | 3.270 | 29.70 | 2.12 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 99.38 | 0.31 | 2.999 | 27.58 | 1.97 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 99.07 | 0.38 | 2.750 | 25.61 | 1.86 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 98.69 | 0.46 | 2.522 | 23.75 | 1.78 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 98.23 | 0.57 | 2.312 | 21.97 | 1.73 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 97.66 | 0.67 | 2.121 | 20.24 | 1.70 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 96.99 | 0.79 | 1.945 | 18.54 | 1.69 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 96.20 | 0.91 | 1.783 | 16.85 | 1.67 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 95.29 | 1.03 | 1.635 | 15.18 | 1.65 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 94.26 | 1.14 | 1.499 | 13.53 | 1.62 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 93.12 | 1.25 | 1.375 | 11.91 | 1.56 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 91.87 | 1.36 | 1.261 | 10.35 | 1.49 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 90.51 | 1.46 | 1.156 | 8.86 | 1.38 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 89.05 | 1.55 | 1.060 | 7.48 | 1.26 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 87.50 | 1.64 | 0.972 | 6.22 | 1.14 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 85.86 | 1.75 | 0.892 | 5.08 | 1.01 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 84.11 | 1.86 | 0.818 | 4.07 | 0.90 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 82.25 | 1.99 | 0.750 | 3.17 | 0.79 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 80.26 | 2.15 | 0.688 | 2.38 | 0.68 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 78.11 | 2.35 | 0.630 | 1.70 | 0.57 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 75.76 | 2.59 | 0.578 | 1.13 | 0.44 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 73.17 | 2.88 | 0.530 | 0.69 | 0.33 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 70.29 | 3.19 | 0.486 | 0.36 | 0.23 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 67.10 | 3.49 | 0.446 | 0.13 | 0.13 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 63.61 | 3.78 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 59.83 | 3.95 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 55.88 | 4.02 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 51.86 | 3.95 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 47.91 | 3.77 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 44.14 | 3.51 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 40.63 | 3.18 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 37.45 | 2.86 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

Filter: On

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Database Path: C:\MTWIN\1217PJM.DB

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0272
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

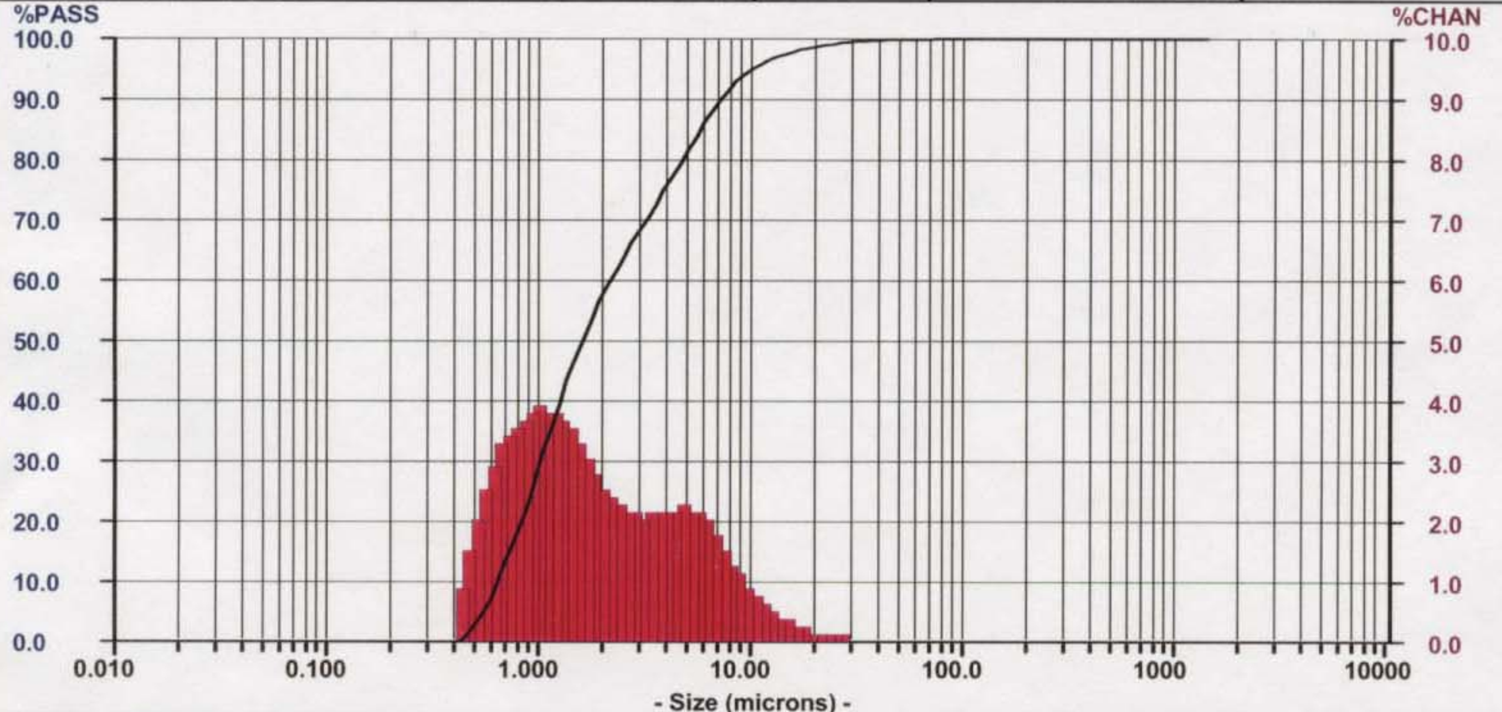
Ver:8.0a

**121802PJM**

SMP021121-1

Date: 12/18/02 Meas #: 8
Time: 20:51 Pres #: 1

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 9.012 | 5% = 0.538 | 60% = 2.175 | 1.607 | 100% | 4.755 |
| mn = 0.857 | 20% = 0.807 | 70% = 3.188 | | | |
| ma = 3.170 | 30% = 1.011 | 80% = 4.716 | | | |
| cs = 1.893 | 40% = 1.261 | 90% = 7.101 | | | |
| sd = 2.377 | 50% = 1.607 | 95% = 9.964 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.01 | 3.889 | 74.97 | 2.19 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 99.99 | 0.01 | 3.566 | 72.78 | 2.16 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 99.98 | 0.01 | 3.270 | 70.62 | 2.15 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 99.97 | 0.02 | 2.999 | 68.47 | 2.17 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 99.95 | 0.02 | 2.750 | 66.30 | 2.24 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 99.93 | 0.03 | 2.522 | 64.06 | 2.33 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 99.90 | 0.04 | 2.312 | 61.73 | 2.47 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 99.86 | 0.06 | 2.121 | 59.26 | 2.65 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 99.80 | 0.07 | 1.945 | 56.61 | 2.87 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 99.73 | 0.09 | 1.783 | 53.74 | 3.10 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 99.64 | 0.11 | 1.635 | 50.64 | 3.34 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 99.53 | 0.13 | 1.499 | 47.30 | 3.57 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 99.40 | 0.16 | 1.375 | 43.73 | 3.77 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 99.24 | 0.19 | 1.261 | 39.96 | 3.89 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 99.05 | 0.22 | 1.156 | 36.07 | 3.92 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 98.83 | 0.25 | 1.060 | 32.15 | 3.94 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 98.58 | 0.29 | 0.972 | 28.21 | 3.86 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 98.29 | 0.34 | 0.892 | 24.35 | 3.77 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 97.95 | 0.39 | 0.818 | 20.58 | 3.65 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 97.56 | 0.46 | 0.750 | 16.93 | 3.49 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 97.10 | 0.54 | 0.688 | 13.44 | 3.30 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 96.56 | 0.65 | 0.630 | 10.14 | 2.98 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 95.91 | 0.78 | 0.578 | 7.16 | 2.54 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 95.13 | 0.94 | 0.530 | 4.62 | 2.06 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 94.19 | 1.14 | 0.486 | 2.56 | 1.60 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 93.05 | 1.36 | 0.446 | 0.96 | 0.96 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 91.69 | 1.60 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 90.09 | 1.83 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 88.26 | 2.03 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 86.23 | 2.18 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 84.05 | 2.27 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 81.78 | 2.30 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 79.48 | 2.27 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 77.21 | 2.24 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0272
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

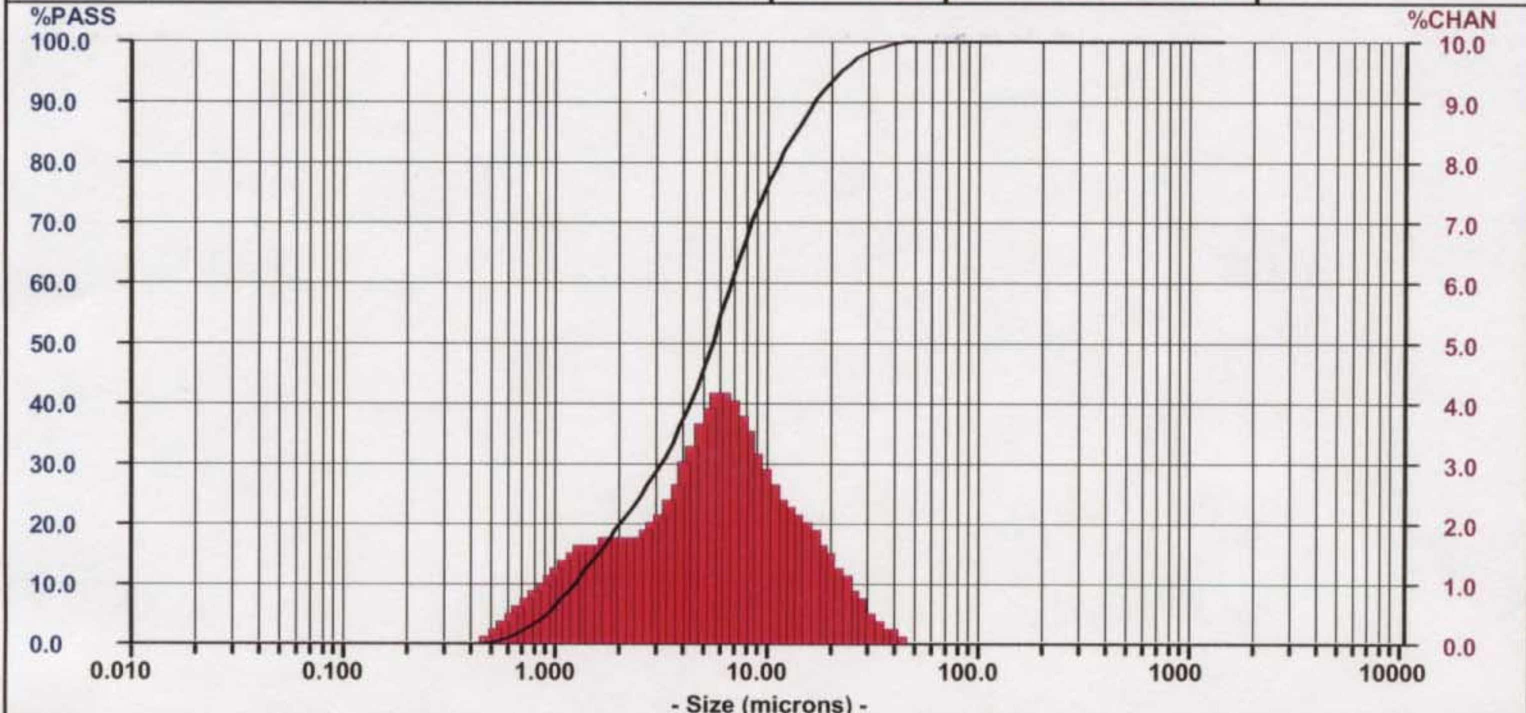
Ver:8.0af

**121802PJM**

SMP021121-4

Date: 12/18/02 Meas #: 9
Time: 20:59 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 7.375 | 5% = 0.892 | 60% = 6.685 | 5.443 | 100% | 11.21 |
| mn = 0.878 | 20% = 2.021 | 70% = 8.354 | | | |
| ma = 3.070 | 30% = 3.146 | 80% = 11.15 | | | |
| cs = 1.954 | 40% = 4.320 | 90% = 16.55 | | | |
| sd = 5.605 | 50% = 5.443 | 95% = 21.66 | | | |




| SIZE | %PASS | %CHAN |
|---|---|---|
| 1408 | 100.00 | 0.00 |
| 1291 | 100.00 | 0.00 |
| 1184 | 100.00 | 0.00 |
| 1086 | 100.00 | 0.00 |
| 995.6 | 100.00 | 0.00 |
| 913.0 | 100.00 | 0.00 |
| 837.2 | 100.00 | 0.00 |
| 767.7 | 100.00 | 0.00 |
| 704.0 | 100.00 | 0.00 |
| 645.6 | 100.00 | 0.00 |
| 592.0 | 100.00 | 0.00 |
| 542.9 | 100.00 | 0.00 |
| 497.8 | 100.00 | 0.00 |
| 456.5 | 100.00 | 0.00 |
| 418.6 | 100.00 | 0.00 |
| 383.9 | 100.00 | 0.00 |
| 352.0 | 100.00 | 0.00 |
| 322.8 | 100.00 | 0.00 |
| 296.0 | 100.00 | 0.00 |
| 271.4 | 100.00 | 0.00 |
| 248.9 | 100.00 | 0.00 |
| 228.2 | 100.00 | 0.00 |
| 209.3 | 100.00 | 0.00 |
| 191.9 | 100.00 | 0.00 |
| 176.0 | 100.00 | 0.00 |
| 161.4 | 100.00 | 0.00 |
| 148.0 | 100.00 | 0.00 |
| 135.7 | 100.00 | 0.00 |
| 124.5 | 100.00 | 0.00 |
| 114.1 | 100.00 | 0.00 |
| 104.7 | 100.00 | 0.00 |
| 95.96 | 100.00 | 0.00 |
| 88.00 | 100.00 | 0.00 |
| 80.70 | 100.00 | 0.00 |

| SIZE | %PASS | %CHAN |
|---|---|---|
| 74.00 | 100.00 | 0.00 |
| 67.86 | 100.00 | 0.00 |
| 62.23 | 100.00 | 0.00 |
| 57.06 | 100.00 | 0.00 |
| 52.33 | 100.00 | 0.00 |
| 47.98 | 100.00 | 0.00 |
| 44.00 | 100.00 | 0.18 |
| 40.35 | 99.82 | 0.28 |
| 37.00 | 99.54 | 0.35 |
| 33.93 | 99.19 | 0.45 |
| 31.11 | 98.74 | 0.60 |
| 28.53 | 98.14 | 0.77 |
| 26.16 | 97.37 | 0.96 |
| 23.99 | 96.41 | 1.17 |
| 22.00 | 95.24 | 1.38 |
| 20.17 | 93.86 | 1.57 |
| 18.50 | 92.29 | 1.75 |
| 16.96 | 90.54 | 1.91 |
| 15.56 | 88.63 | 2.04 |
| 14.27 | 86.59 | 2.17 |
| 13.08 | 84.42 | 2.32 |
| 12.00 | 82.10 | 2.49 |
| 11.00 | 79.61 | 2.71 |
| 10.09 | 76.90 | 2.98 |
| 9.250 | 73.92 | 3.29 |
| 8.482 | 70.63 | 3.61 |
| 7.778 | 67.02 | 3.92 |
| 7.133 | 63.10 | 4.14 |
| 6.541 | 58.96 | 4.25 |
| 5.998 | 54.71 | 4.21 |
| 5.500 | 50.50 | 4.03 |
| 5.044 | 46.47 | 3.76 |
| 4.625 | 42.71 | 3.41 |
| 4.241 | 39.30 | 3.06 |

| SIZE | %PASS | %CHAN |
|---|---|---|
| 3.889 | 36.24 | 2.74 |
| 3.566 | 33.50 | 2.47 |
| 3.270 | 31.03 | 2.25 |
| 2.999 | 28.78 | 2.08 |
| 2.750 | 26.70 | 1.96 |
| 2.522 | 24.74 | 1.89 |
| 2.312 | 22.85 | 1.84 |
| 2.121 | 21.01 | 1.81 |
| 1.945 | 19.20 | 1.80 |
| 1.783 | 17.40 | 1.79 |
| 1.635 | 15.61 | 1.77 |
| 1.499 | 13.84 | 1.72 |
| 1.375 | 12.12 | 1.65 |
| 1.261 | 10.47 | 1.56 |
| 1.156 | 8.91 | 1.44 |
| 1.060 | 7.47 | 1.30 |
| 0.972 | 6.17 | 1.17 |
| 0.892 | 5.00 | 1.03 |
| 0.818 | 3.97 | 0.91 |
| 0.750 | 3.06 | 0.79 |
| 0.688 | 2.27 | 0.67 |
| 0.630 | 1.60 | 0.55 |
| 0.578 | 1.05 | 0.42 |
| 0.530 | 0.63 | 0.31 |
| 0.486 | 0.32 | 0.21 |
| 0.446 | 0.11 | 0.11 |
| 0.409 | 0.00 | 0.00 |
| 0.375 | 0.00 | 0.00 |
| 0.344 | 0.00 | 0.00 |
| 0.315 | 0.00 | 0.00 |
| 0.289 | 0.00 | 0.00 |
| 0.265 | 0.00 | 0.00 |
| 0.243 | 0.00 | 0.00 |
| 0.223 | 0.00 | 0.00 |

| SIZE | %PASS | %CHAN |
|---|---|---|
| 0.204 | 0.00 | 0.00 |
| 0.187 | 0.00 | 0.00 |
| 0.172 | 0.00 | 0.00 |
| 0.158 | 0.00 | 0.00 |
| 0.145 | 0.00 | 0.00 |
| 0.133 | 0.00 | 0.00 |
| 0.122 | 0.00 | 0.00 |
| 0.111 | 0.00 | 0.00 |
| 0.102 | 0.00 | 0.00 |
| 0.094 | 0.00 | 0.00 |
| 0.086 | 0.00 | 0.00 |
| 0.079 | 0.00 | 0.00 |
| 0.072 | 0.00 | 0.00 |
| 0.066 | 0.00 | 0.00 |
| 0.061 | 0.00 | 0.00 |
| 0.056 | 0.00 | 0.00 |
| 0.051 | 0.00 | 0.00 |
| 0.047 | 0.00 | 0.00 |
| 0.043 | 0.00 | 0.00 |
| 0.039 | 0.00 | 0.00 |
| 0.036 | 0.00 | 0.00 |
| 0.033 | 0.00 | 0.00 |
| 0.030 | 0.00 | 0.00 |
| 0.028 | 0.00 | 0.00 |
| 0.026 | 0.00 | 0.00 |
| 0.023 | 0.00 | 0.00 |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0259
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

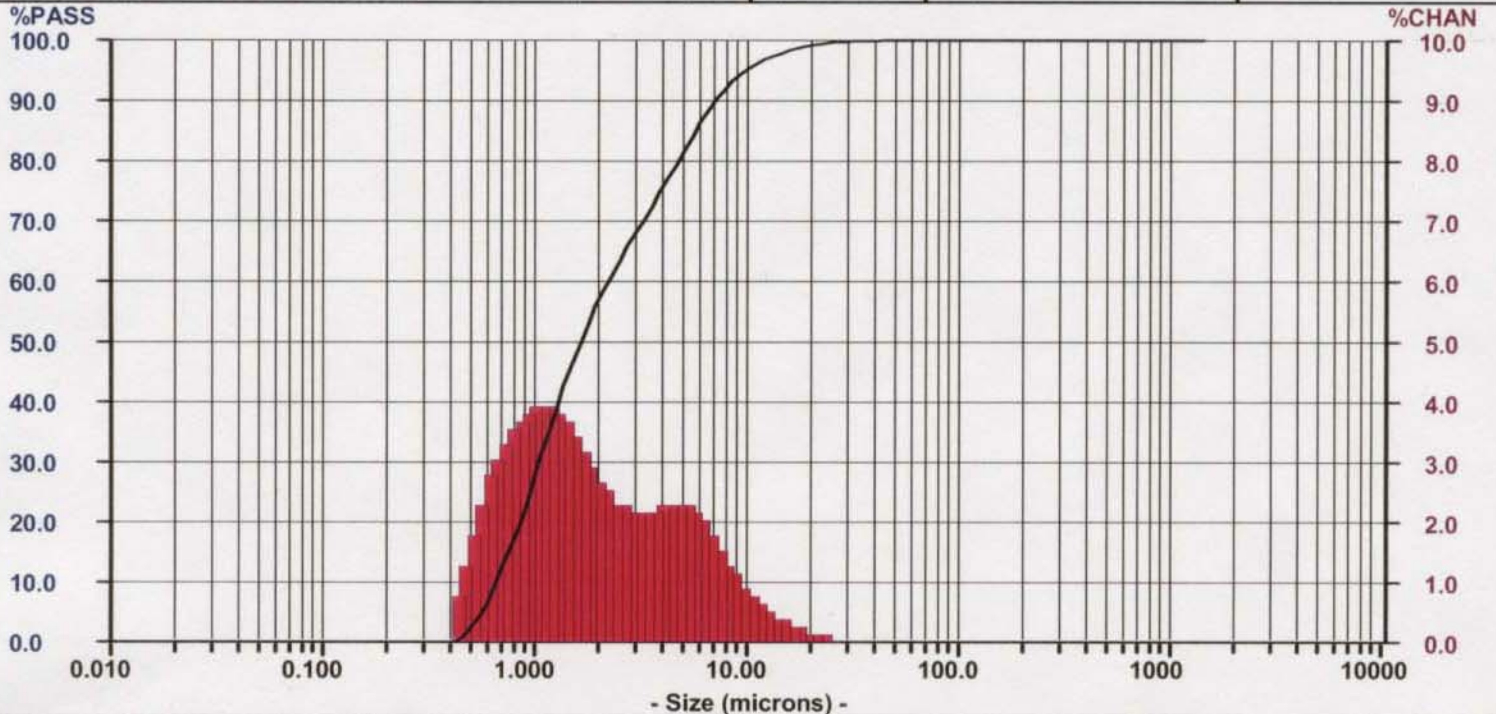
Ver:8.0at

**121802PJM**

SMP021121-4

Date: 12/18/02 Meas #: 9
Time: 20:59 Pres #: 1

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 7.375 | 5% = 0.550 | 60% = 2.217 | 1.646 | 100% | 4.703 |
| mn = 0.878 | 20% = 0.831 | 70% = 3.230 | | | |
| ma = 3.070 | 30% = 1.041 | 80% = 4.715 | | | |
| cs = 1.954 | 40% = 1.297 | 90% = 7.001 | | | |
| sd = 2.351 | 50% = 1.646 | 95% = 9.666 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 100.00 | 0.00 | 3.889 | 74.79 | 2.26 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 100.00 | 0.00 | 3.566 | 72.53 | 2.22 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 100.00 | 0.00 | 3.270 | 70.31 | 2.20 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 100.00 | 0.00 | 2.999 | 68.11 | 2.22 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 100.00 | 0.00 | 2.750 | 65.89 | 2.29 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 100.00 | 0.00 | 2.522 | 63.60 | 2.39 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 100.00 | 0.01 | 2.312 | 61.21 | 2.54 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 99.99 | 0.02 | 2.121 | 58.67 | 2.73 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 99.97 | 0.03 | 1.945 | 55.94 | 2.97 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 99.94 | 0.04 | 1.783 | 52.97 | 3.21 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 99.90 | 0.06 | 1.635 | 49.76 | 3.46 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 99.84 | 0.09 | 1.499 | 46.30 | 3.68 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 99.75 | 0.12 | 1.375 | 42.62 | 3.85 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 99.63 | 0.15 | 1.261 | 38.77 | 3.95 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 99.48 | 0.20 | 1.156 | 34.82 | 4.00 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 99.28 | 0.25 | 1.060 | 30.82 | 3.95 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 99.03 | 0.30 | 0.972 | 26.87 | 3.84 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 98.73 | 0.36 | 0.892 | 23.03 | 3.72 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 98.37 | 0.42 | 0.818 | 19.31 | 3.57 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 97.95 | 0.49 | 0.750 | 15.74 | 3.38 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 97.46 | 0.57 | 0.688 | 12.36 | 3.14 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 96.89 | 0.66 | 0.630 | 9.22 | 2.80 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 96.23 | 0.79 | 0.578 | 6.42 | 2.35 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 95.44 | 0.94 | 0.530 | 4.07 | 1.87 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 94.50 | 1.14 | 0.486 | 2.20 | 1.39 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 93.36 | 1.36 | 0.446 | 0.81 | 0.81 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.00 | 7.778 | 92.00 | 1.61 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 100.00 | 0.00 | 7.133 | 90.39 | 1.85 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 100.00 | 0.00 | 6.541 | 88.54 | 2.08 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 100.00 | 0.00 | 5.998 | 86.46 | 2.25 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 100.00 | 0.00 | 5.500 | 84.21 | 2.35 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 100.00 | 0.00 | 5.044 | 81.86 | 2.39 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 100.00 | 0.00 | 4.625 | 79.47 | 2.36 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 100.00 | 0.00 | 4.241 | 77.11 | 2.32 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0259
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

# 35 $\mu$m, 5 wt% PSD Data

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

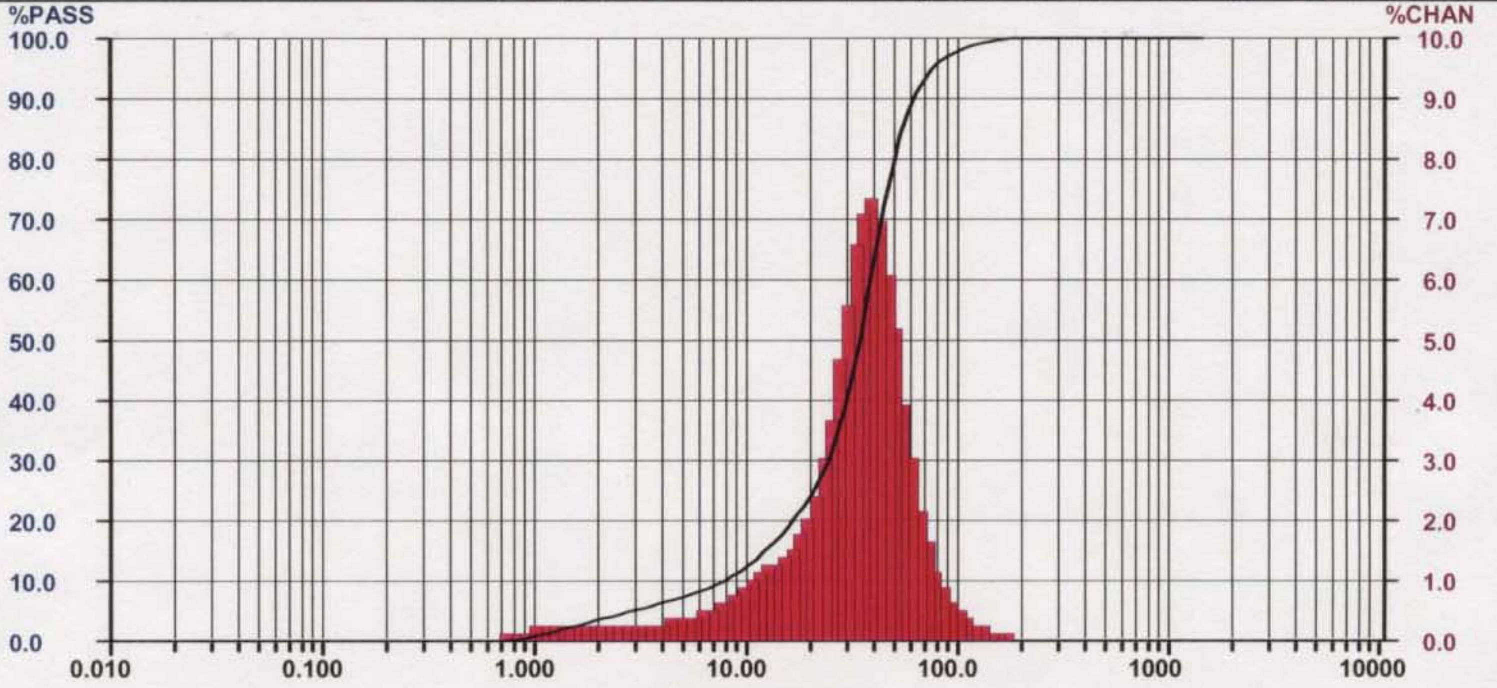
Ver:8.0a

**121802PJM**

SMP021204-1

Date: 12/18/02 Meas #: 6
Time: 18:01 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 35.28 | 5% = 2.855 | 60% = 37.86 | 33.57 | 100% | 39.50 |
| mn = 1.194 | 20% = 16.39 | 70% = 42.65 | | | |
| ma = 12.94 | 30% = 23.90 | 80% = 49.01 | | | |
| cs = 0.464 | 40% = 29.18 | 90% = 60.39 | | | |
| sd = 19.75 | 50% = 33.57 | 95% = 74.35 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 94.93 | 1.66 | 3.889 | 6.27 | 0.36 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 93.27 | 2.27 | 3.566 | 5.91 | 0.36 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 91.00 | 3.08 | 3.270 | 5.55 | 0.35 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 87.92 | 4.05 | 2.999 | 5.20 | 0.35 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 83.87 | 5.19 | 2.750 | 4.85 | 0.34 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 78.68 | 6.19 | 2.522 | 4.51 | 0.35 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 72.49 | 7.05 | 2.312 | 4.16 | 0.35 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 65.44 | 7.39 | 2.121 | 3.81 | 0.35 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 58.05 | 7.19 | 1.945 | 3.46 | 0.35 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 50.86 | 6.61 | 1.783 | 3.11 | 0.36 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 44.25 | 5.64 | 1.635 | 2.75 | 0.36 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 38.61 | 4.70 | 1.499 | 2.39 | 0.35 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 33.91 | 3.78 | 1.375 | 2.04 | 0.34 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 30.13 | 3.04 | 1.261 | 1.70 | 0.33 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 27.09 | 2.50 | 1.156 | 1.37 | 0.30 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 24.59 | 2.09 | 1.060 | 1.07 | 0.28 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 22.50 | 1.83 | 0.972 | 0.79 | 0.24 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 20.67 | 1.64 | 0.892 | 0.55 | 0.22 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 19.03 | 1.51 | 0.818 | 0.33 | 0.20 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 17.52 | 1.39 | 0.750 | 0.13 | 0.13 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 16.13 | 1.29 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 14.84 | 1.19 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 13.65 | 1.07 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 12.58 | 0.95 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.14 | 9.250 | 11.63 | 0.84 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 99.86 | 0.21 | 8.482 | 10.79 | 0.73 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 99.65 | 0.24 | 7.778 | 10.06 | 0.64 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.41 | 0.29 | 7.133 | 9.42 | 0.57 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.12 | 0.36 | 6.541 | 8.85 | 0.51 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 98.76 | 0.44 | 5.998 | 8.34 | 0.47 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 98.32 | 0.55 | 5.500 | 7.87 | 0.43 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 97.77 | 0.70 | 5.044 | 7.44 | 0.41 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 97.07 | 0.91 | 4.625 | 7.03 | 0.39 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 96.16 | 1.23 | 4.241 | 6.64 | 0.37 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0732
Transmission: 0.93
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

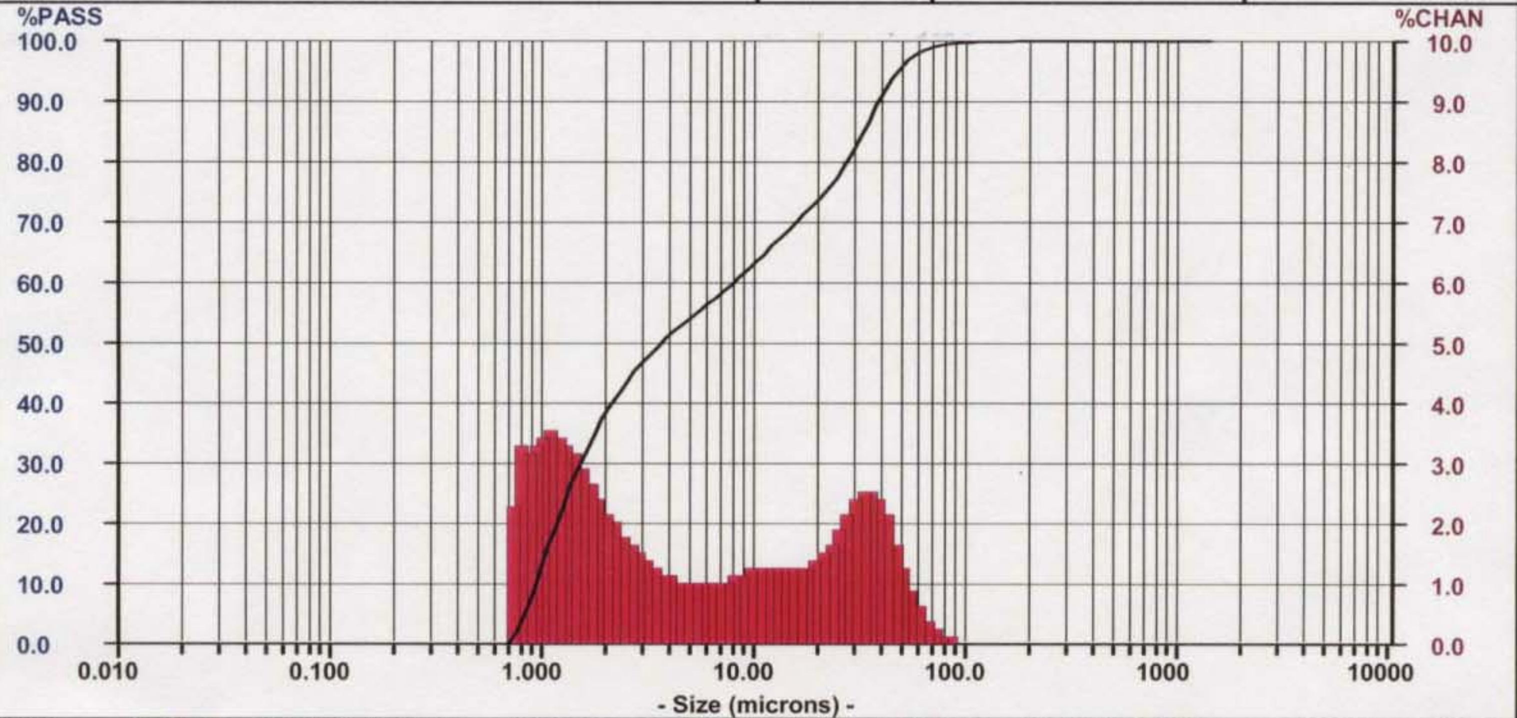
Ver:8.0af

**121802PJM**

SMP021204-1

Date: 12/18/02 Meas #: 6
Time: 18:01 Pres #: 1

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 35.28 | 5% = 0.804 | 60% = 7.911 | 20.27 | 52% | 34.32 |
| mn = 1.194 | 20% = 1.173 | 70% = 15.50 | 1.303 | 48% | 1.333 |
| ma = 12.94 | 30% = 1.522 | 80% = 26.89 | | | |
| cs = 0.464 | 40% = 2.138 | 90% = 37.96 | | | |
| sd = 15.02 | 50% = 3.630 | 95% = 46.43 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 99.32 | 0.30 | 3.889 | 51.00 | 1.26 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 99.02 | 0.45 | 3.566 | 49.74 | 1.35 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 98.57 | 0.66 | 3.270 | 48.39 | 1.45 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 97.91 | 0.95 | 2.999 | 46.94 | 1.57 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 96.96 | 1.33 | 2.750 | 45.37 | 1.69 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 95.63 | 1.73 | 2.522 | 43.68 | 1.85 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 93.90 | 2.16 | 2.312 | 41.83 | 2.03 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 91.74 | 2.46 | 2.121 | 39.80 | 2.23 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 89.28 | 2.63 | 1.945 | 37.57 | 2.45 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 86.65 | 2.63 | 1.783 | 35.12 | 2.69 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 84.02 | 2.46 | 1.635 | 32.43 | 2.95 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 81.56 | 2.23 | 1.499 | 29.48 | 3.18 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 79.33 | 1.95 | 1.375 | 26.30 | 3.37 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 77.38 | 1.72 | 1.261 | 22.93 | 3.50 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 75.66 | 1.53 | 1.156 | 19.43 | 3.57 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 74.13 | 1.41 | 1.060 | 15.86 | 3.52 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 72.72 | 1.34 | 0.972 | 12.34 | 3.38 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 71.38 | 1.31 | 0.892 | 8.96 | 3.28 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 70.07 | 1.31 | 0.818 | 5.68 | 3.35 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 68.76 | 1.32 | 0.750 | 2.33 | 2.33 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 67.44 | 1.34 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 66.10 | 1.34 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 64.76 | 1.31 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 63.45 | 1.28 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.01 | 9.250 | 62.17 | 1.22 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 99.99 | 0.02 | 8.482 | 60.95 | 1.17 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 99.97 | 0.02 | 7.778 | 59.78 | 1.12 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.95 | 0.03 | 7.133 | 58.66 | 1.08 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.92 | 0.04 | 6.541 | 57.58 | 1.06 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 99.88 | 0.05 | 5.998 | 56.52 | 1.05 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 99.83 | 0.07 | 5.500 | 55.47 | 1.06 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 99.76 | 0.10 | 5.044 | 54.41 | 1.09 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 99.66 | 0.14 | 4.625 | 53.32 | 1.13 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 99.52 | 0.20 | 4.241 | 52.19 | 1.19 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0732
Transmission: 0.93
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

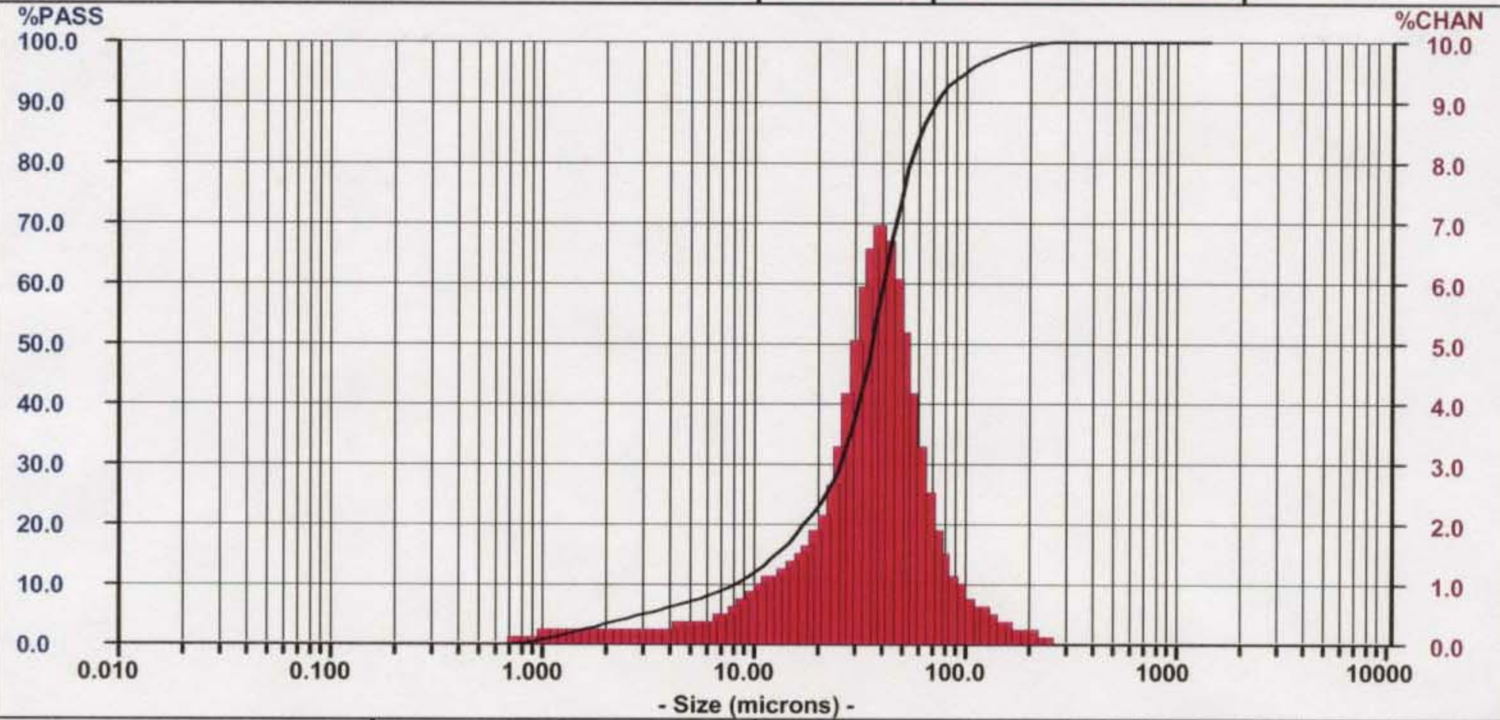
Ver:8.0a

**121802PJM**

SMP021204-3

Date: 12/18/02 Meas #: 7
Time: 18:16 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 39.86 | 5% = 2.932 | 60% = 39.90 | 35.17 | 100% | 44.76 |
| mn = 1.190 | 20% = 17.05 | 70% = 45.44 | | | |
| ma = 13.36 | 30% = 25.00 | 80% = 53.37 | | | |
| cs = 0.449 | 40% = 30.51 | 90% = 70.35 | | | |
| sd = 22.38 | 50% = 35.17 | 95% = 96.61 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 91.11 | 1.99 | 3.889 | 6.13 | 0.35 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 89.12 | 2.57 | 3.566 | 5.78 | 0.35 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 86.55 | 3.33 | 3.270 | 5.43 | 0.34 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 83.22 | 4.22 | 2.999 | 5.09 | 0.34 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 79.00 | 5.23 | 2.750 | 4.75 | 0.34 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 73.77 | 6.08 | 2.522 | 4.41 | 0.34 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 67.69 | 6.76 | 2.312 | 4.07 | 0.34 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 60.93 | 6.97 | 2.121 | 3.73 | 0.35 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 53.96 | 6.69 | 1.945 | 3.38 | 0.35 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 47.27 | 6.06 | 1.783 | 3.03 | 0.35 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 41.21 | 5.12 | 1.635 | 2.68 | 0.35 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 36.09 | 4.22 | 1.499 | 2.33 | 0.34 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 31.87 | 3.39 | 1.375 | 1.99 | 0.33 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 28.48 | 2.73 | 1.261 | 1.66 | 0.32 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 25.75 | 2.25 | 1.156 | 1.34 | 0.29 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 23.50 | 1.91 | 1.060 | 1.05 | 0.27 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 21.59 | 1.69 | 0.972 | 0.78 | 0.24 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 19.90 | 1.53 | 0.892 | 0.54 | 0.21 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 18.37 | 1.43 | 0.818 | 0.33 | 0.20 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 16.94 | 1.33 | 0.750 | 0.13 | 0.13 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.14 | 13.08 | 15.61 | 1.24 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 99.86 | 0.23 | 12.00 | 14.37 | 1.14 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 99.63 | 0.26 | 11.00 | 13.23 | 1.03 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 99.37 | 0.31 | 10.09 | 12.20 | 0.92 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 99.06 | 0.37 | 9.250 | 11.28 | 0.80 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 98.69 | 0.44 | 8.482 | 10.48 | 0.70 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 98.25 | 0.50 | 7.778 | 9.78 | 0.61 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 97.75 | 0.57 | 7.133 | 9.17 | 0.55 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 97.18 | 0.65 | 6.541 | 8.62 | 0.49 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 96.53 | 0.74 | 5.998 | 8.13 | 0.45 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 95.79 | 0.86 | 5.500 | 7.68 | 0.42 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 94.93 | 1.02 | 5.044 | 7.26 | 0.39 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 93.91 | 1.24 | 4.625 | 6.87 | 0.38 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 92.67 | 1.56 | 4.241 | 6.49 | 0.36 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0859
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

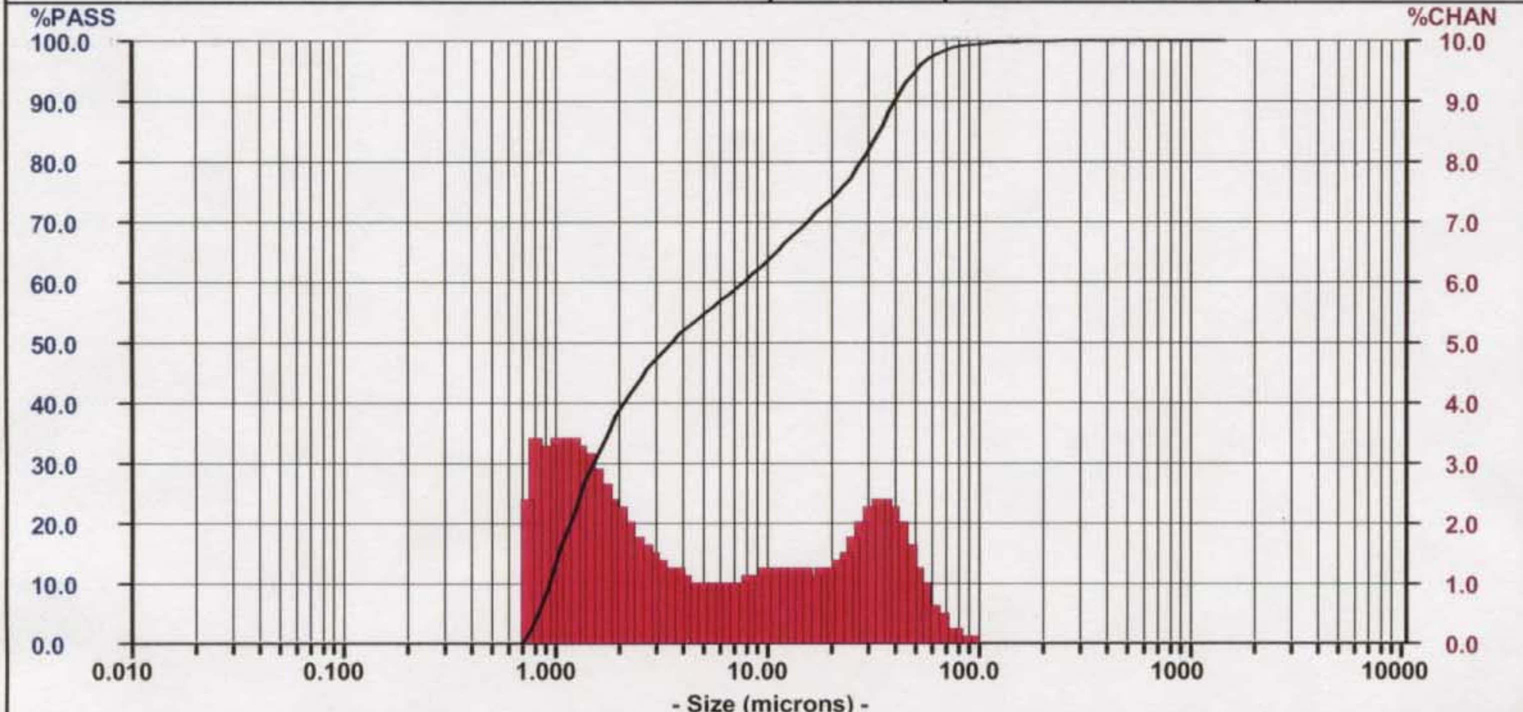
Ver:8.0a

**121802PJM**

SMP021204-3

Date: 12/18/02 Meas #: 7
Time: 18:16 Pres #: 1

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 39.86 | 5% = 0.801 | 60% = 7.620 | 20.37 | 51% | 35.78 |
| mn = 1.190 | 20% = 1.166 | 70% = 15.10 | 1.303 | 49% | 1.337 |
| ma = 13.36 | 30% = 1.511 | 80% = 27.16 | | | |
| cs = 0.449 | 40% = 2.104 | 90% = 39.01 | | | |
| sd = 15.30 | 50% = 3.507 | 95% = 48.48 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 98.87 | 0.37 | 3.889 | 51.53 | 1.27 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 98.50 | 0.53 | 3.566 | 50.26 | 1.35 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 97.97 | 0.74 | 3.270 | 48.91 | 1.45 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 97.23 | 1.03 | 2.999 | 47.46 | 1.57 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 96.20 | 1.39 | 2.750 | 45.89 | 1.72 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 94.81 | 1.76 | 2.522 | 44.17 | 1.88 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 93.05 | 2.14 | 2.312 | 42.29 | 2.07 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 90.91 | 2.40 | 2.121 | 40.22 | 2.28 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 88.51 | 2.53 | 1.945 | 37.94 | 2.51 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 85.98 | 2.49 | 1.783 | 35.43 | 2.74 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 83.49 | 2.30 | 1.635 | 32.69 | 2.97 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 81.19 | 2.07 | 1.499 | 29.72 | 3.18 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 79.12 | 1.81 | 1.375 | 26.54 | 3.38 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 77.31 | 1.60 | 1.261 | 23.16 | 3.50 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 75.71 | 1.43 | 1.156 | 19.66 | 3.53 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 74.28 | 1.32 | 1.060 | 16.13 | 3.52 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 72.96 | 1.27 | 0.972 | 12.61 | 3.40 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 71.69 | 1.26 | 0.892 | 9.21 | 3.34 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 70.43 | 1.28 | 0.818 | 5.87 | 3.45 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 69.15 | 1.30 | 0.750 | 2.42 | 2.42 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.01 | 13.08 | 67.85 | 1.32 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 99.99 | 0.01 | 12.00 | 66.53 | 1.33 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 99.98 | 0.02 | 11.00 | 65.20 | 1.31 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 99.96 | 0.02 | 10.09 | 63.89 | 1.27 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 99.94 | 0.03 | 9.250 | 62.62 | 1.21 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 99.91 | 0.04 | 8.482 | 61.41 | 1.15 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 99.87 | 0.05 | 7.778 | 60.26 | 1.10 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.82 | 0.06 | 7.133 | 59.16 | 1.07 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.76 | 0.07 | 6.541 | 58.09 | 1.05 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 99.69 | 0.09 | 5.998 | 57.04 | 1.04 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 99.60 | 0.11 | 5.500 | 56.00 | 1.06 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 99.49 | 0.15 | 5.044 | 54.94 | 1.09 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 99.34 | 0.20 | 4.625 | 53.85 | 1.13 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 99.14 | 0.27 | 4.241 | 52.72 | 1.19 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0859
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

# 35 $\mu$m, 20 wt% PSD Data

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

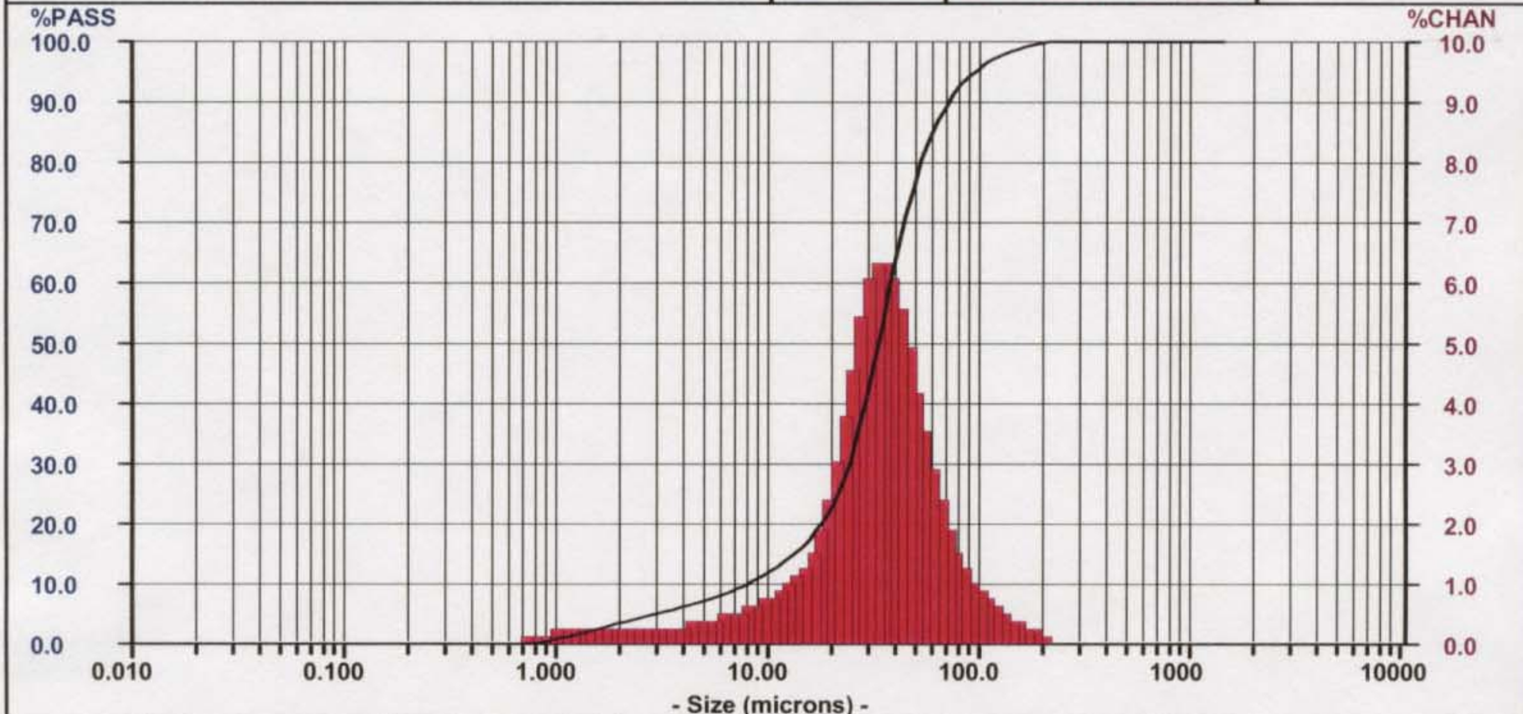
Ver:8.0af

**121802PJM**

SMP021212-4
1 hour

Date: 12/18/02 Meas #: 3
Time: 17:18 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 37.89 | 5% = 2.902 | 60% = 37.28 | 32.59 | 100% | 42.94 |
| mn = 1.191 | 20% = 17.74 | 70% = 43.18 | | | |
| ma = 13.18 | 30% = 23.81 | 80% = 51.90 | | | |
| cs = 0.455 | 40% = 28.32 | 90% = 69.72 | | | |
| sd = 21.47 | 50% = 32.59 | 95% = 92.72 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 91.34 | 1.98 | 3.889 | 6.16 | 0.35 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 89.36 | 2.43 | 3.566 | 5.81 | 0.34 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 86.93 | 2.96 | 3.270 | 5.47 | 0.34 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 83.97 | 3.57 | 2.999 | 5.13 | 0.34 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 80.40 | 4.26 | 2.750 | 4.79 | 0.34 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 76.14 | 4.94 | 2.522 | 4.45 | 0.34 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 71.20 | 5.62 | 2.312 | 4.11 | 0.34 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 65.58 | 6.12 | 2.121 | 3.77 | 0.35 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 59.46 | 6.45 | 1.945 | 3.42 | 0.35 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 53.01 | 6.43 | 1.783 | 3.07 | 0.36 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 46.58 | 6.08 | 1.635 | 2.71 | 0.35 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 40.50 | 5.48 | 1.499 | 2.36 | 0.35 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 35.02 | 4.66 | 1.375 | 2.01 | 0.34 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 30.36 | 3.85 | 1.261 | 1.67 | 0.32 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 26.51 | 3.07 | 1.156 | 1.35 | 0.30 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 23.44 | 2.44 | 1.060 | 1.05 | 0.27 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 21.00 | 1.96 | 0.972 | 0.78 | 0.24 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 19.04 | 1.59 | 0.892 | 0.54 | 0.21 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 17.45 | 1.35 | 0.818 | 0.33 | 0.20 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 16.10 | 1.16 | 0.750 | 0.13 | 0.13 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 14.94 | 1.04 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 13.90 | 0.95 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.17 | 11.00 | 12.95 | 0.87 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 99.83 | 0.27 | 10.09 | 12.08 | 0.80 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 99.56 | 0.32 | 9.250 | 11.28 | 0.74 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 99.24 | 0.38 | 8.482 | 10.54 | 0.67 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 98.86 | 0.47 | 7.778 | 9.87 | 0.61 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 98.39 | 0.57 | 7.133 | 9.26 | 0.56 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 97.82 | 0.67 | 6.541 | 8.70 | 0.51 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 97.15 | 0.79 | 5.998 | 8.19 | 0.46 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 96.36 | 0.93 | 5.500 | 7.73 | 0.43 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 95.43 | 1.12 | 5.044 | 7.30 | 0.40 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 94.31 | 1.34 | 4.625 | 6.90 | 0.38 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 92.97 | 1.63 | 4.241 | 6.52 | 0.36 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0725
Transmission: 0.93
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

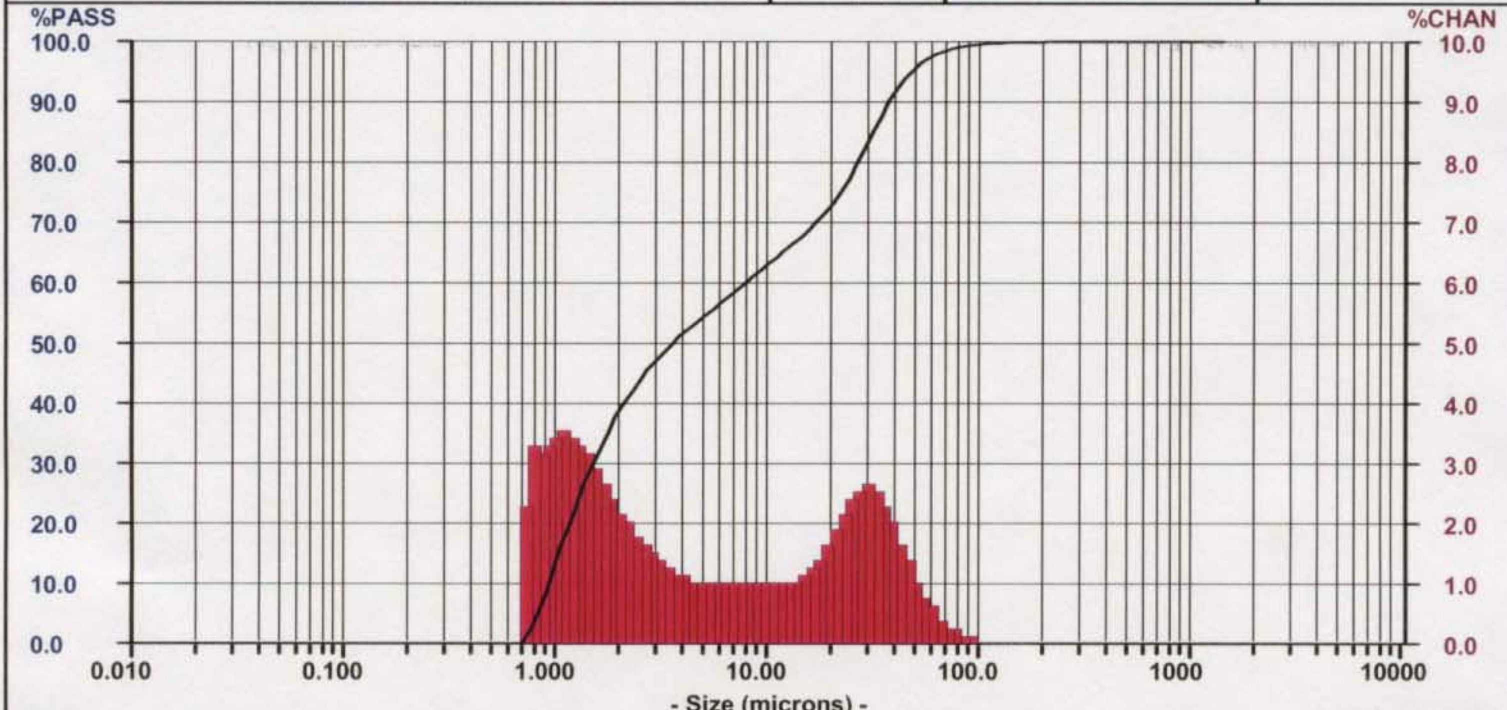
Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

Ver:8.0af

| 121802PJM | SMP021212-4<br>1 hour | Date: 12/18/02 Meas #: 3<br>Time: 17:18 Pres #: 1 |
|---|---|---|

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 37.89 | 5% = 0.802 | 60% = 7.823 | 21.22 | 51% | 33.50 |
| mn = 1.191 | 20% = 1.170 | 70% = 16.86 | 1.303 | 49% | 1.330 |
| ma = 13.18 | 30% = 1.517 | 80% = 26.32 | | | |
| cs = 0.455 | 40% = 2.116 | 90% = 36.79 | | | |
| sd = 14.45 | 50% = 3.580 | 95% = 46.76 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 98.89 | 0.37 | 3.889 | 51.17 | 1.23 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 98.52 | 0.49 | 3.566 | 49.94 | 1.32 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 98.03 | 0.65 | 3.270 | 48.62 | 1.43 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 97.38 | 0.86 | 2.999 | 47.19 | 1.56 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 96.52 | 1.11 | 2.750 | 45.63 | 1.70 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 95.41 | 1.41 | 2.522 | 43.93 | 1.86 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 94.00 | 1.75 | 2.312 | 42.07 | 2.03 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 92.25 | 2.08 | 2.121 | 40.04 | 2.25 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 90.17 | 2.40 | 1.945 | 37.79 | 2.50 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 87.77 | 2.60 | 1.783 | 35.29 | 2.74 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 85.17 | 2.69 | 1.635 | 32.55 | 2.97 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 82.48 | 2.64 | 1.499 | 29.58 | 3.18 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 79.84 | 2.46 | 1.375 | 26.40 | 3.38 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 77.38 | 2.22 | 1.261 | 23.02 | 3.51 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 75.16 | 1.93 | 1.156 | 19.51 | 3.55 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 73.23 | 1.67 | 1.060 | 15.96 | 3.52 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 71.56 | 1.46 | 0.972 | 12.44 | 3.36 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 70.10 | 1.30 | 0.892 | 9.08 | 3.28 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 68.80 | 1.19 | 0.818 | 5.80 | 3.41 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 67.61 | 1.13 | 0.750 | 2.39 | 2.39 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 66.48 | 1.10 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 65.38 | 1.09 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.01 | 11.00 | 64.29 | 1.09 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 99.99 | 0.02 | 10.09 | 63.20 | 1.09 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 99.97 | 0.02 | 9.250 | 62.11 | 1.10 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 99.95 | 0.03 | 8.482 | 61.01 | 1.09 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 99.92 | 0.04 | 7.778 | 59.92 | 1.08 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.88 | 0.06 | 7.133 | 58.84 | 1.08 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.82 | 0.07 | 6.541 | 57.76 | 1.07 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 99.75 | 0.09 | 5.998 | 56.69 | 1.06 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 99.66 | 0.12 | 5.500 | 55.63 | 1.07 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 99.54 | 0.16 | 5.044 | 54.56 | 1.09 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 99.38 | 0.21 | 4.625 | 53.47 | 1.13 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 99.17 | 0.28 | 4.241 | 52.34 | 1.17 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0725
Transmission: 0.93
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

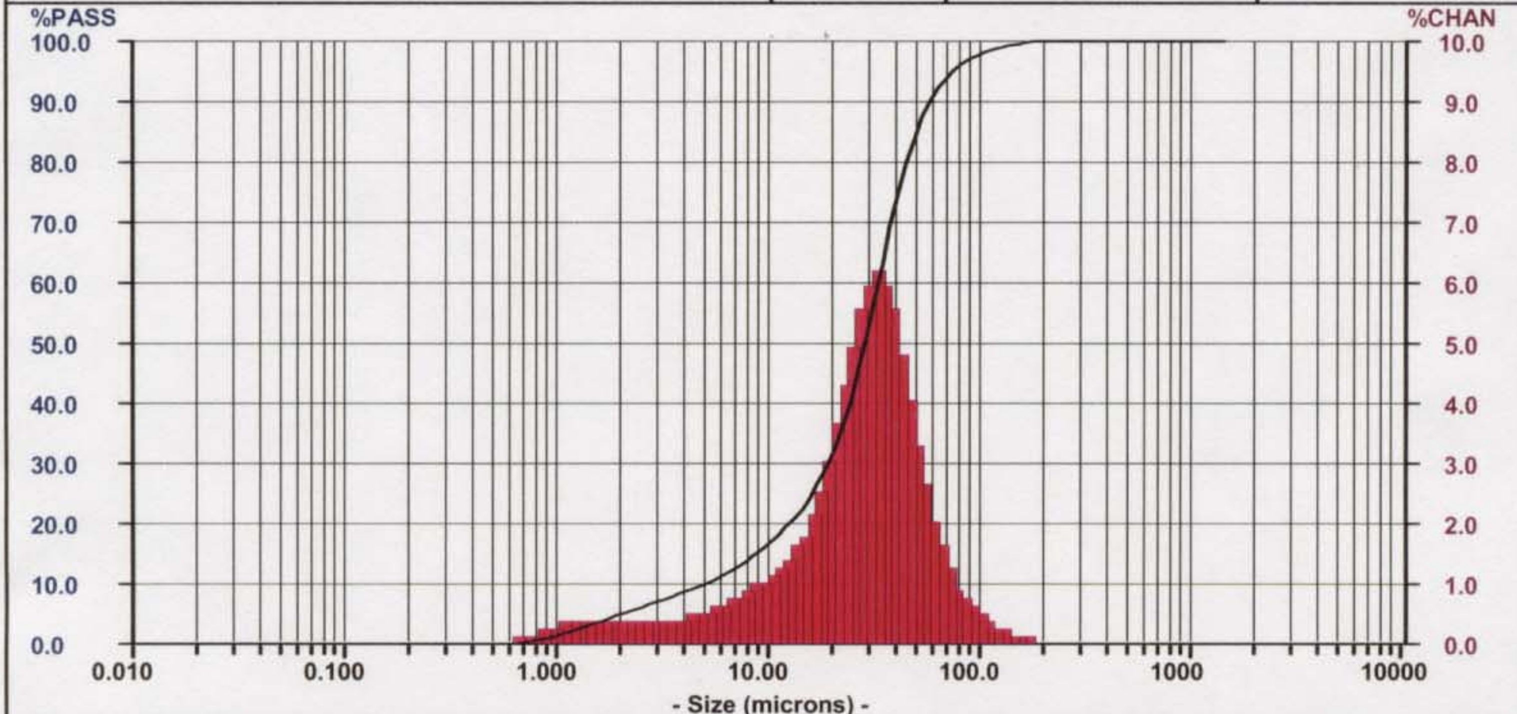
Ver:8.0a

**121802PJM**

SMP021212-5

Date: 12/18/02 Meas #: 4
Time: 17:31 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 31.12 | 5% = 2.005 | 60% = 32.36 | 28.06 | 100% | 38.41 |
| mn = 1.045 | 20% = 12.44 | 70% = 37.31 | | | |
| ma = 10.07 | 30% = 18.94 | 80% = 44.04 | | | |
| cs = 0.596 | 40% = 23.82 | 90% = 56.63 | | | |
| sd = 19.21 | 50% = 28.06 | 95% = 72.54 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 95.28 | 1.28 | 3.889 | 8.52 | 0.48 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 94.00 | 1.65 | 3.566 | 8.04 | 0.47 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 92.35 | 2.12 | 3.270 | 7.57 | 0.46 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 90.23 | 2.71 | 2.999 | 7.11 | 0.46 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 87.52 | 3.41 | 2.750 | 6.65 | 0.45 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 84.11 | 4.15 | 2.522 | 6.20 | 0.45 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 79.96 | 4.93 | 2.312 | 5.75 | 0.45 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 75.03 | 5.57 | 2.121 | 5.30 | 0.46 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 69.46 | 6.05 | 1.945 | 4.84 | 0.46 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 63.41 | 6.22 | 1.783 | 4.38 | 0.46 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 57.19 | 6.07 | 1.635 | 3.92 | 0.46 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 51.12 | 5.68 | 1.499 | 3.46 | 0.46 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 45.44 | 5.05 | 1.375 | 3.00 | 0.45 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 40.39 | 4.39 | 1.261 | 2.55 | 0.42 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 36.00 | 3.69 | 1.156 | 2.13 | 0.40 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 32.31 | 3.10 | 1.060 | 1.73 | 0.36 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 29.21 | 2.60 | 0.972 | 1.37 | 0.32 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 26.61 | 2.19 | 0.892 | 1.05 | 0.29 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 24.42 | 1.89 | 0.818 | 0.76 | 0.24 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 22.53 | 1.65 | 0.750 | 0.52 | 0.21 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 20.88 | 1.48 | 0.688 | 0.31 | 0.19 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 19.40 | 1.33 | 0.630 | 0.12 | 0.12 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 18.07 | 1.22 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 16.85 | 1.12 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.15 | 9.250 | 15.73 | 1.03 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 99.85 | 0.23 | 8.482 | 14.70 | 0.94 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 99.62 | 0.25 | 7.778 | 13.76 | 0.87 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.37 | 0.30 | 7.133 | 12.89 | 0.79 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.07 | 0.36 | 6.541 | 12.10 | 0.72 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 98.71 | 0.44 | 5.998 | 11.38 | 0.66 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 98.27 | 0.53 | 5.500 | 10.72 | 0.61 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 97.74 | 0.65 | 5.044 | 10.11 | 0.56 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 97.09 | 0.80 | 4.625 | 9.55 | 0.53 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 96.29 | 1.01 | 4.241 | 9.02 | 0.50 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0827
Transmission: 0.91
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

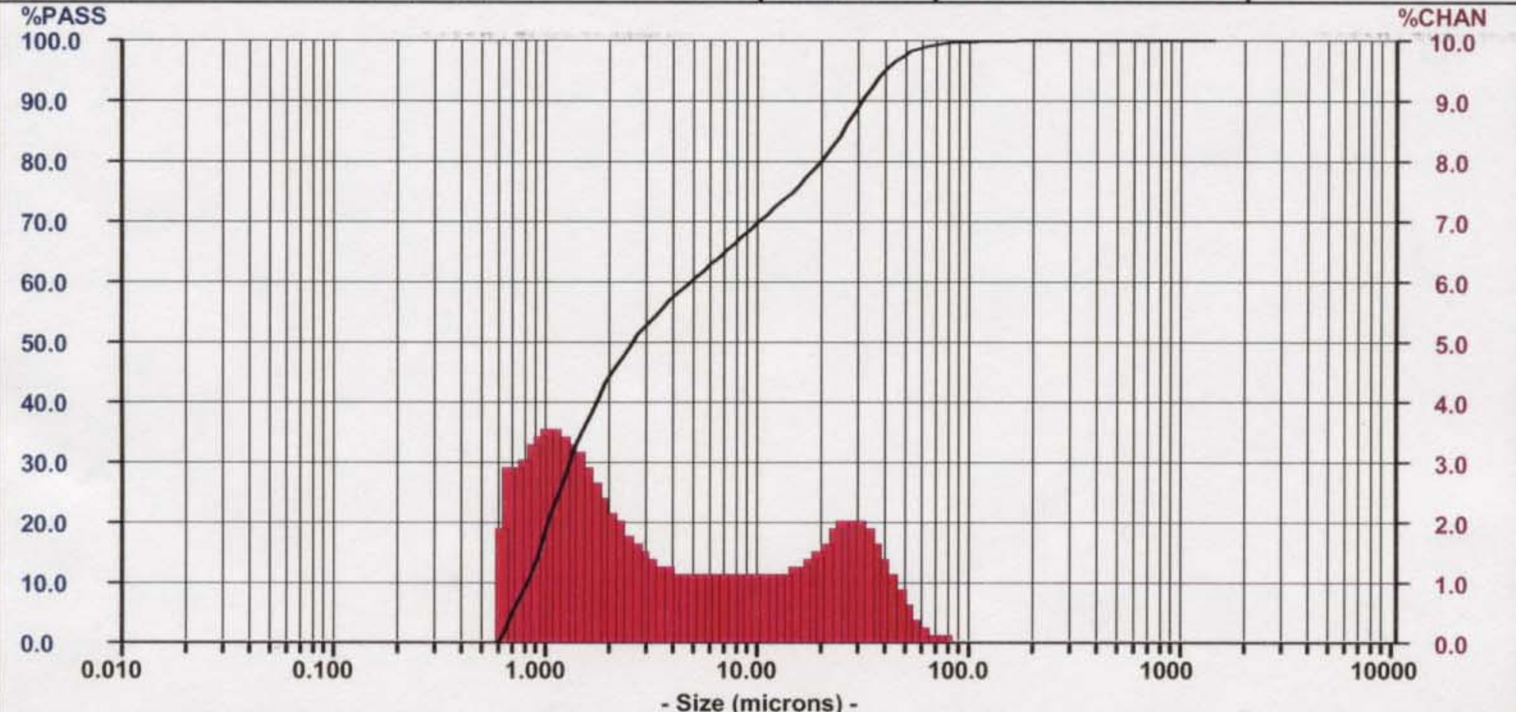
Ver:8.0at

**121802PJM**

SMP021212-5

Date: 12/18/02 Meas #: 4
Time: 17:31 Pres #: 1

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 31.12 | 5% = 0.689 | 60% = 4.789 | 15.98 | 47% | 29.25 |
| mn = 1.045 | 20% = 1.023 | 70% = 10.07 | 1.195 | 53% | 1.260 |
| ma = 10.07 | 30% = 1.305 | 80% = 19.65 | | | |
| cs = 0.596 | 40% = 1.731 | 90% = 30.61 | | | |
| sd = 11.42 | 50% = 2.573 | 95% = 39.18 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 99.52 | 0.18 | 3.889 | 57.08 | 1.30 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 99.34 | 0.25 | 3.566 | 55.78 | 1.38 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 99.09 | 0.36 | 3.270 | 54.40 | 1.49 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 98.73 | 0.50 | 2.999 | 52.91 | 1.60 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 98.23 | 0.68 | 2.750 | 51.31 | 1.72 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 97.55 | 0.91 | 2.522 | 49.59 | 1.87 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 96.64 | 1.17 | 2.312 | 47.72 | 2.06 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 95.47 | 1.45 | 2.121 | 45.66 | 2.26 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 94.02 | 1.72 | 1.945 | 43.40 | 2.48 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 92.30 | 1.92 | 1.783 | 40.92 | 2.72 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 90.38 | 2.05 | 1.635 | 38.20 | 2.97 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 88.33 | 2.09 | 1.499 | 35.23 | 3.20 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 86.24 | 2.03 | 1.375 | 32.03 | 3.40 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 84.21 | 1.93 | 1.261 | 28.63 | 3.54 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 82.28 | 1.77 | 1.156 | 25.09 | 3.62 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 80.51 | 1.62 | 1.060 | 21.47 | 3.60 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 78.89 | 1.48 | 0.972 | 17.87 | 3.52 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 77.41 | 1.36 | 0.892 | 14.35 | 3.36 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 76.05 | 1.28 | 0.818 | 10.99 | 3.11 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 74.77 | 1.22 | 0.750 | 7.88 | 2.93 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 73.55 | 1.19 | 0.688 | 4.95 | 2.93 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 72.36 | 1.17 | 0.630 | 2.02 | 2.02 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 71.19 | 1.17 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 70.02 | 1.17 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.01 | 9.250 | 68.85 | 1.17 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 99.99 | 0.01 | 8.482 | 67.68 | 1.17 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 99.98 | 0.02 | 7.778 | 66.51 | 1.17 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.96 | 0.02 | 7.133 | 65.34 | 1.17 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.94 | 0.03 | 6.541 | 64.17 | 1.16 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 99.91 | 0.04 | 5.998 | 63.01 | 1.16 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 99.87 | 0.05 | 5.500 | 61.85 | 1.16 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 99.82 | 0.07 | 5.044 | 60.69 | 1.17 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 99.75 | 0.10 | 4.625 | 59.52 | 1.20 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 99.65 | 0.13 | 4.241 | 58.32 | 1.24 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0827
Transmission: 0.91
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

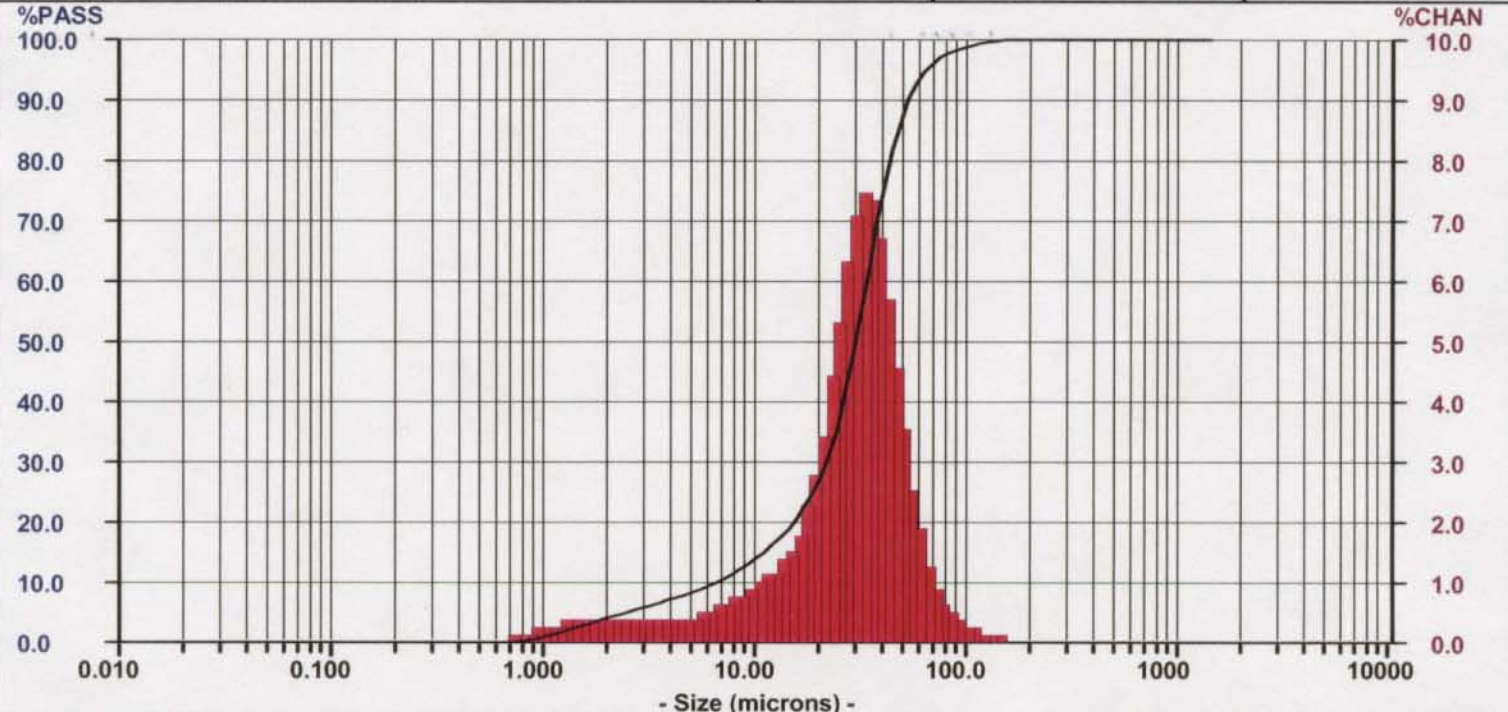
Ver:8.0a

**121802PJM**

SMP021212-7

Date: 12/18/02 Meas #: 5
Time: 17:43 Pres #: 1

| Summary | Percentiles | | Dia | Vol% | Width |
|---|---|---|---|---|---|
| mv = 30.74 | 5% = 2.439 | 60% = 33.16 | 29.48 | 100% | 33.83 |
| mn = 1.185 | 20% = 15.12 | 70% = 37.27 | | | |
| ma = 11.63 | 30% = 21.45 | 80% = 42.65 | | | |
| cs = 0.516 | 40% = 25.79 | 90% = 52.02 | | | |
| sd = 16.91 | 50% = 29.48 | 95% = 63.13 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 97.09 | 0.97 | 3.889 | 7.10 | 0.40 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 96.12 | 1.36 | 3.566 | 6.70 | 0.39 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 94.76 | 1.90 | 3.270 | 6.31 | 0.39 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 92.86 | 2.63 | 2.999 | 5.92 | 0.38 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 90.23 | 3.58 | 2.750 | 5.54 | 0.39 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 86.65 | 4.65 | 2.522 | 5.15 | 0.39 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 82.00 | 5.82 | 2.312 | 4.76 | 0.39 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 76.18 | 6.75 | 2.121 | 4.37 | 0.40 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 69.43 | 7.40 | 1.945 | 3.97 | 0.40 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 62.03 | 7.54 | 1.783 | 3.57 | 0.41 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 54.49 | 7.13 | 1.635 | 3.16 | 0.41 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 47.36 | 6.42 | 1.499 | 2.75 | 0.40 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 40.94 | 5.40 | 1.375 | 2.35 | 0.39 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 35.54 | 4.44 | 1.261 | 1.96 | 0.37 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 31.10 | 3.54 | 1.156 | 1.59 | 0.35 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 27.56 | 2.83 | 1.060 | 1.24 | 0.32 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 24.73 | 2.29 | 0.972 | 0.92 | 0.28 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 22.44 | 1.89 | 0.892 | 0.64 | 0.25 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 20.55 | 1.61 | 0.818 | 0.39 | 0.23 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 18.94 | 1.40 | 0.750 | 0.16 | 0.16 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 17.54 | 1.26 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 16.28 | 1.14 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 15.14 | 1.05 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 14.09 | 0.97 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 13.12 | 0.88 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 12.24 | 0.81 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.15 | 7.778 | 11.43 | 0.73 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.85 | 0.22 | 7.133 | 10.70 | 0.66 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.63 | 0.24 | 6.541 | 10.04 | 0.59 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 99.39 | 0.28 | 5.998 | 9.45 | 0.54 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 99.11 | 0.34 | 5.500 | 8.91 | 0.50 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 98.77 | 0.42 | 5.044 | 8.41 | 0.46 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 98.35 | 0.54 | 4.625 | 7.95 | 0.44 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 97.81 | 0.72 | 4.241 | 7.51 | 0.41 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Volume
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0734
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

Serial Number: S3177
Range: 0.021 -1408 um

# MICROTRAC - S3000

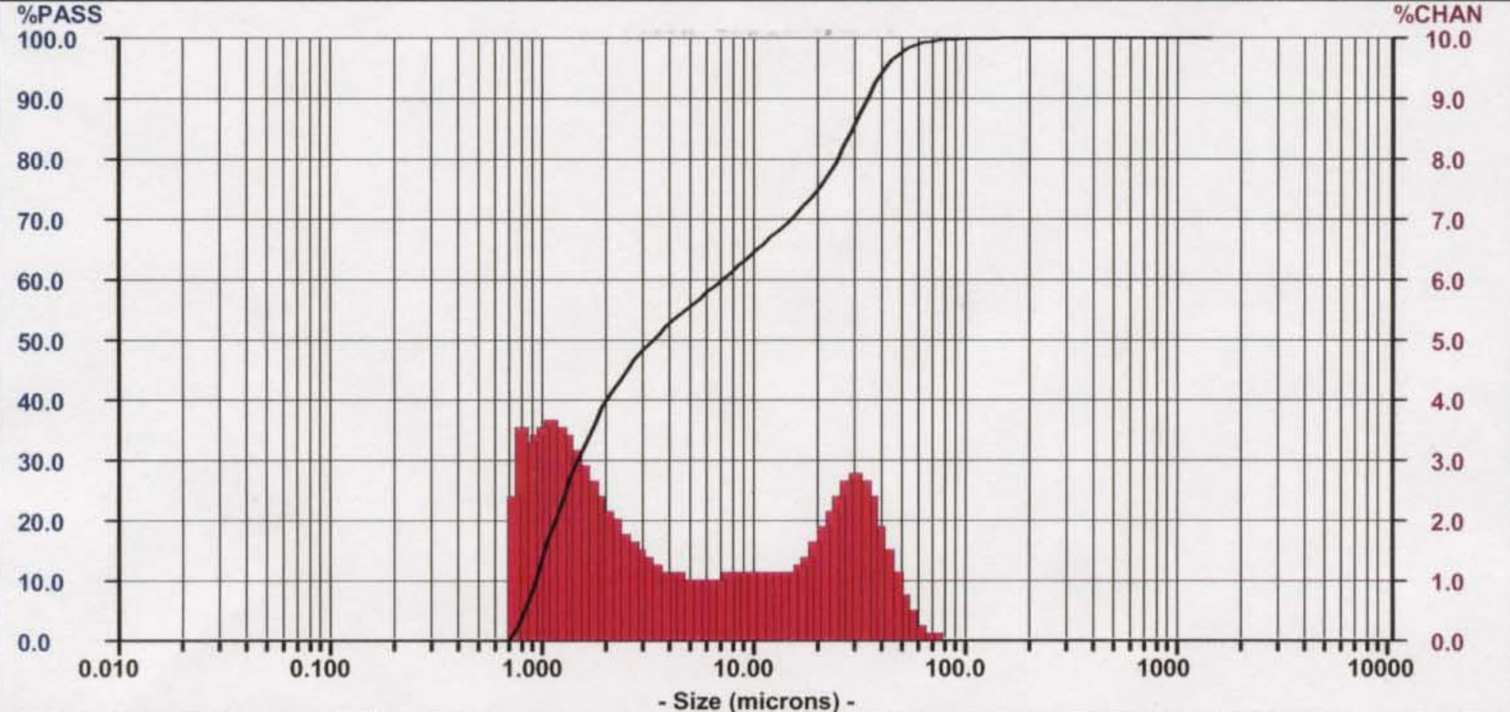
Ver:8.0a

**121802PJM**

SMP021212-7

Date: 12/18/02 Meas #: 5
Time: 17:43 Pres #: 1

| Summary | Percentiles | | Dia | Area% | Width |
|---|---|---|---|---|---|
| mv = 30.74 | 5% = 0.798 | 60% = 7.024 | 19.04 | 52% | 30.32 |
| mn = 1.185 | 20% = 1.148 | 70% = 14.77 | 1.271 | 48% | 1.225 |
| ma = 11.63 | 30% = 1.477 | 80% = 24.38 | | | |
| cs = 0.516 | 40% = 2.029 | 90% = 33.63 | | | |
| sd = 13.39 | 50% = 3.319 | 95% = 40.92 | | | |




| SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN | SIZE | %PASS | %CHAN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1408 | 100.00 | 0.00 | 74.00 | 99.65 | 0.16 | 3.889 | 52.37 | 1.25 | 0.204 | 0.00 | 0.00 |
| 1291 | 100.00 | 0.00 | 67.86 | 99.49 | 0.24 | 3.566 | 51.12 | 1.33 | 0.187 | 0.00 | 0.00 |
| 1184 | 100.00 | 0.00 | 62.23 | 99.25 | 0.37 | 3.270 | 49.79 | 1.43 | 0.172 | 0.00 | 0.00 |
| 1086 | 100.00 | 0.00 | 57.06 | 98.88 | 0.56 | 2.999 | 48.36 | 1.56 | 0.158 | 0.00 | 0.00 |
| 995.6 | 100.00 | 0.00 | 52.33 | 98.32 | 0.82 | 2.750 | 46.80 | 1.71 | 0.145 | 0.00 | 0.00 |
| 913.0 | 100.00 | 0.00 | 47.98 | 97.50 | 1.17 | 2.522 | 45.09 | 1.88 | 0.133 | 0.00 | 0.00 |
| 837.2 | 100.00 | 0.00 | 44.00 | 96.33 | 1.60 | 2.312 | 43.21 | 2.06 | 0.122 | 0.00 | 0.00 |
| 767.7 | 100.00 | 0.00 | 40.35 | 94.73 | 2.02 | 2.121 | 41.15 | 2.27 | 0.111 | 0.00 | 0.00 |
| 704.0 | 100.00 | 0.00 | 37.00 | 92.71 | 2.43 | 1.945 | 38.88 | 2.51 | 0.102 | 0.00 | 0.00 |
| 645.6 | 100.00 | 0.00 | 33.93 | 90.28 | 2.69 | 1.783 | 36.37 | 2.77 | 0.094 | 0.00 | 0.00 |
| 592.0 | 100.00 | 0.00 | 31.11 | 87.59 | 2.79 | 1.635 | 33.60 | 3.03 | 0.086 | 0.00 | 0.00 |
| 542.9 | 100.00 | 0.00 | 28.53 | 84.80 | 2.73 | 1.499 | 30.57 | 3.25 | 0.079 | 0.00 | 0.00 |
| 497.8 | 100.00 | 0.00 | 26.16 | 82.07 | 2.51 | 1.375 | 27.32 | 3.43 | 0.072 | 0.00 | 0.00 |
| 456.5 | 100.00 | 0.00 | 23.99 | 79.56 | 2.25 | 1.261 | 23.89 | 3.57 | 0.066 | 0.00 | 0.00 |
| 418.6 | 100.00 | 0.00 | 22.00 | 77.31 | 1.96 | 1.156 | 20.32 | 3.71 | 0.061 | 0.00 | 0.00 |
| 383.9 | 100.00 | 0.00 | 20.17 | 75.35 | 1.71 | 1.060 | 16.61 | 3.67 | 0.056 | 0.00 | 0.00 |
| 352.0 | 100.00 | 0.00 | 18.50 | 73.64 | 1.51 | 0.972 | 12.94 | 3.49 | 0.051 | 0.00 | 0.00 |
| 322.8 | 100.00 | 0.00 | 16.96 | 72.13 | 1.36 | 0.892 | 9.45 | 3.41 | 0.047 | 0.00 | 0.00 |
| 296.0 | 100.00 | 0.00 | 15.56 | 70.77 | 1.26 | 0.818 | 6.04 | 3.55 | 0.043 | 0.00 | 0.00 |
| 271.4 | 100.00 | 0.00 | 14.27 | 69.51 | 1.19 | 0.750 | 2.49 | 2.49 | 0.039 | 0.00 | 0.00 |
| 248.9 | 100.00 | 0.00 | 13.08 | 68.32 | 1.17 | 0.688 | 0.00 | 0.00 | 0.036 | 0.00 | 0.00 |
| 228.2 | 100.00 | 0.00 | 12.00 | 67.15 | 1.16 | 0.630 | 0.00 | 0.00 | 0.033 | 0.00 | 0.00 |
| 209.3 | 100.00 | 0.00 | 11.00 | 65.99 | 1.16 | 0.578 | 0.00 | 0.00 | 0.030 | 0.00 | 0.00 |
| 191.9 | 100.00 | 0.00 | 10.09 | 64.83 | 1.16 | 0.530 | 0.00 | 0.00 | 0.028 | 0.00 | 0.00 |
| 176.0 | 100.00 | 0.00 | 9.250 | 63.67 | 1.16 | 0.486 | 0.00 | 0.00 | 0.026 | 0.00 | 0.00 |
| 161.4 | 100.00 | 0.00 | 8.482 | 62.51 | 1.15 | 0.446 | 0.00 | 0.00 | 0.023 | 0.00 | 0.00 |
| 148.0 | 100.00 | 0.01 | 7.778 | 61.36 | 1.14 | 0.409 | 0.00 | 0.00 | | | |
| 135.7 | 99.99 | 0.02 | 7.133 | 60.22 | 1.12 | 0.375 | 0.00 | 0.00 | | | |
| 124.5 | 99.97 | 0.02 | 6.541 | 59.10 | 1.10 | 0.344 | 0.00 | 0.00 | | | |
| 114.1 | 99.95 | 0.03 | 5.998 | 58.00 | 1.09 | 0.315 | 0.00 | 0.00 | | | |
| 104.7 | 99.92 | 0.04 | 5.500 | 56.91 | 1.10 | 0.289 | 0.00 | 0.00 | | | |
| 95.96 | 99.88 | 0.05 | 5.044 | 55.81 | 1.11 | 0.265 | 0.00 | 0.00 | | | |
| 88.00 | 99.83 | 0.07 | 4.625 | 54.70 | 1.14 | 0.243 | 0.00 | 0.00 | | | |
| 80.70 | 99.76 | 0.11 | 4.241 | 53.56 | 1.19 | 0.223 | 0.00 | 0.00 | | | |

Distribution: Area
Progression: Geometric Root8
Upper Edge: 1408
Lower Edge: 0.021
Residuals: Disabled
Number Of Channels: 128

RunTime: 30 seconds
Run Number Avg of 3 runs
Particle: active anode powder
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: 1.33
Loading Factor: 0.0734
Transmission: 0.92
Above Residual: 0.00
Below Residual: 0.00

Analysis Mode: S3000
Sample Cell Id: 0084

Filter: On

Database Path: C:\MTWIN\1217PJM.DB

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