UNDERGROUND FLOW MEASUREMENT AND PARTICLE RELEASE TEST

Revision 0

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SUMMARY

The following report summarizes the results and analyses of data taken during flow testing and particle release testing performed in the WIPP underground in March 1998. Engineering proposed the test to further quantify performance of the radiation monitoring equipment located at the exit of the active waste emplacement room (currently Room 7), and to gather empirical data to evaluate the removal of Station A effluent monitors. Filters placed on the walls and floors of the waste emplacement room and further downstream along the exhaust path were analyzed to quantify possible contamination concentration levels following an unlikely accidental release.

For the flow measurement portion of the test, the underground ventilation system was operated to ensure a minimum of 35,000 cfm through the waste emplacement room. Flow measurements were taken using an array of hot wire anemometers. The array was sized to match the waste emplacement room exit louver. The flow measurements were taken at different distances upstream and downstream of the waste emplacement room exit louvers and at different louver positions.

For the particle release portion of the test, the underground ventilation system was placed in three different modes of operation: Single 700 fan operation or Alternative Mode; two 700 fan operation or Normal Ventilation; and finally a shift to filtration from Alternative Mode and subsequent Filtration Mode. The actual waste emplacement room flow for the particle release portion of the test was approximately 40,000 to 42,000 CFM with one fan operating and 48,300 CFM with two fans operating. Flow at Station A flow varied from 268,000 CFM for single 700 fan operation to 411,000 CFM with two 700 fans in operation. Following the shift to filtration, exhaust flow was reduced to approximately 60,000 CFM.

The particle release involved dispersing particles of 9 different metals with known diameters and desirable neutronic characteristics into the airstream at the entrance of Room 7. The released material was collected on filters placed at specified locations in the waste emplacement room; filters placed along the exhaust pathway; and on filters integral to permanent and portable radiation monitoring equipment. The filter samples were then activated in a reactor and measurements subsequently taken to quantify the portion of the released metals captured on the filters.

Both flow and particle release results support the current positioning of the room exit radiation monitoring equipment.

Air filters placed upon the walls and the floors of the underground drifts downstream of the waste emplacement room indicate that surface contamination levels (SCLs) at all points along the exhaust drift are as expected. Test results show that particles with relatively small Activity Median Aerodynamic Diameters (AMAD) of approximately 5 micron would deposit on surfaces at a concentration of one part per million (ppm) per 100 cm^2 of drift surface per unit of material released. Conversely, the majority of particles with relatively large (25 micron) AMADs would be deposited on surfaces within the WR and expected SCLs beyond the WR would be on the order of parts per billion (ppb).

FLOW PROFILE TESTING AT THE WASTE ROOM EXIT

The flow instrumentation used for the test was comprised of twenty-four sensors, each including a hot-wire anemometer and a temperature sensor, uniformly spaced on a metal grid approximately the size of the waste emplacement room exit louver. The sensor array was connected to a personal computer (PC) to sample and record the airflow. The PC was set up to take a snapshot every 15 seconds for approximately 2 minutes.

The array was installed and data taken on both the inlet and exhaust sides of the north and south waste emplacement room exit louvers (see Attachments 3 through 13). The array was positioned several times to obtain data close to the louvers and up to 60 inches away from the louvers. Additional flow profile measurements were obtained 40 feet downstream of the room exit louver where the overall velocity is approximately 2 meters per second. Flow graphics were generated to obtain a visual of the velocity profile. Sensor 24 was inoperable for the duration of the test and sensor 18 failed prior to obtaining flow measurements at the exhaust side of the south louver. The failed sensors measured off-scale, high-flow, but are depicted in the array chart printouts as zero for clarity (see Attachments 11 through 13).

The measurements show that the flow at the intake of the louvers is uniform and has few peaks (see Attachments 3, 4, 9, and 10). The exhaust side has many peaks and is strongly affected by the louver positioning (see Attachments 5, 6, 11 and 12). Positioning the louvers to less than 100% open affects the flow and direction of flow because of the shape of the louver bars. At 40 feet downstream of the room exit bulkhead, the flow profile measurement again has areas of uniform flow.

With the louvers positioned to 100% open, the air travels towards the mid-section of the louver opening. The flow, while at a high velocity, is uniform. The current positioning of the room exit Continuous Air Monitors (CAMs) is near the mid-section at approximately 18 inches from the louvers.

PARTICLE RELEASE Test and Analysis

The particle test procedure used here differs from conventional aerosol testing methods because it uses physically similar aerosols to estimate the behavior of plutonium dust whereas conventional aerosol testing would use oil droplets of calculated aerodynamic diameters. Although conventional testing methods are valid for estimating particle behavior, the range of detectable particle concentrations is not as great as can be achieved using neutron activation analysis techniques. Because of the high dilution factors associated with underground air flows and because of the desire to estimate deposition factors, the higher detectability of the NAA approach resulted in it's selection as the preferred experimental method

The materials released included 2 gram quantities of Aluminum Oxide (Al2O3), Palladium (Pd), Tungsten (W), Rhenium (Re), Titanium Dioxide (TiO2), Tantalum Pentoxide (Ta2O5), Scandium Oxide (Sc2O3), Gold (Au), and Rhodium (Rh). The elemental particles were chosen for their physical and neutron activation characteristics. Density and size were considered and included in the metals selected as analogs for airborne plutonium. The low density particles represent plutonium attached to a salt dust particle, the medium density particles represents a plutonium oxide particle, and the high density particles represent a pure plutonium particle that might exist in the waste if it were prevented from oxidizing. Neutron activation characteristics including absorption cross section, isotopic abundance fractions, the half-life of the activated atom, and the frequency of emitted radiation were considered in the material selection to optimize the minimum detectable concentration of the element chosen. Ultimately the selected materials also had to be commercially available in the desired sizes and environmentally acceptable.

Sampling locations are shown in Attachments 14 and 15. Filters were placed on the walls and floors of the waste emplacement room and further downstream along the exhaust path to quantify possible contamination concentration levels following an unlikely accidental release. The filters used are a cellulose acetate based membrane filter that had been recommended in discussion with neutron activation laboratories. The filters are the same as used by WID's Operational Health Physics group for sampling workplace air. The room exit radiation monitoring equipment was placed in service as well as the samplers and effluent monitors at Station A. Portable radiation monitoring and sampling equipment was placed at specified locations between the room exit and Station A and in the waste emplacement room itself.

CAMs 119 and 129 samplers located at the Room 7 exit use Eberline Radial Head Samplers. These samplers are mounted facing the exhaust side of the louvers (see Attachment 15). One radial head sampler is placed at each louver (north and south). The sampler used on CAM 130 is a Alpha Radiation Particulate Samplers (ARPS) used for monitoring beta particulates, which is an upgraded Texas A&M sampler design. It has a stainless steel piece of tubing connected to the sampler. The tubing entrance is facing the exhaust side of the south louver. FAS 122 uses a sampler head designed by Hi-Q Environmental Products Co. This sampler is positioned so that the air entrance (covered by a filter) is facing the north louver. All the room exit CAMs and FAS were set to sample at a rate of 1 (one) scfm, which is the normal sampling flow rate for this location.

Station A uses three different types of samplers. They are Eberline inline samplers, ARPS and inline FAS samplers. They obtain samples from the air passing through the exhaust shaft at Station A by the use of a shrouded probe. Each shrouded probe is connected to a three way splitter at each skid to supply effluent samples to three different samplers. Each set of three samplers are located at Stations A-1, 2, and 3. CAMs 153 (A2) and 157 (A1) use Eberline Inline samplers. Samplers for CAMs 154 (A2) and 158 (A1) are ARPS, which are the same used by CAM 130. And all the inline FAS samplers at Station A are designed by Westinghouse which include FASs 001 (A1), 002 (A2), and 005 thru 007 (A3). All the Station A effluent monitors and samplers were set to sample at a rate of 2 (two) scfm, which is the normal sampling flow rate for this location.

For the particle release , the underground ventilation system was placed in three different modes of operation: Single 700 fan operation or Alternative Ventilation; two 700 fan operation or Normal Ventilation; and finally a shift to filtration and subsequent Filtration Mode. The actual waste emplacement room flow for the particle release portion of the test was 42,136 CFM with one fan operating and 48,300 CFM with two fans operating. Exhaust flow at Station A changed from 268,000 CFM to 411,000 CFM with alternative and normal ventilation, respectively. Following the shift to filtration the exhaust flow was approximately 60,000 CFM.

For each initial flow configuration, the particles were released in 5 sequential batches due to safety concerns about mixing metals. Batch 1 included TiO2, Ta2O5, Au, Sc2O3 and Al2O3. Batch 2 was comprised of Pd; Batch 3 was comprised of Rh; Batch 4 was comprised of Re; and Batch 5 was comprised of W.

Combining five powders into a single release as Batch 1 was done to shorten the time required to release the aerosols. This combining was not expected to adversely affect the dispersion of the powders because all the aerosols were dry, fine, and chemically inert powders. There was no indication during the release or in the resulting data that combining the powders had an adverse affect. Because tantalum oxide is hygroscopic, care was taken to limit it's exposure to the atmosphere. It was only exposed to the atmosphere during weighing and during loading into the air nozzle tube used for dispersion.

Once the required minimum waste room flow was established and relevant underground flow measurements recorded, the particles were released. A minimum of 30 minutes elapsed after the particle release to ensure adequate time for the particles entrained in the air to reach Station A. Personnel access in the exhaust drift of the underground was restricted following the release as a safety precaution. Filters in the permanent and portable radiation monitoring equipment were then changed following the minimum 30 minute waiting period. Filters placed on the walls and floors and the surface environmental monitoring filters were left in place for the duration of the test.

Following all releases, identified filters were shipped to the selected laboratory for analysis.

PARTICLE RELEASE RESULTS

For the purpose of comparing radiation monitoring equipment at the waste emplacement room exit and Station A, usable data was obtained from five of nine powders released in the test. From the usable data, the relative performance between air samplers and sampling locations can be compared.

The rejection of data for the TiO2, Al2O3, Pd, and Rh aerosols is based on either the lack of or the physical impossibility of the results. The quantities of TiO2, Al2O3, and Pd that deposited on wall and/or floor filters were too high to have been due to the initial releases. The amount of Pd on a wall filter 1500 feet downstream of the release point indicated that all of the Pd released would have been deposited within 500 feet of the release point. The quantities of Al2O3 and TiO2 deposited on wall and floor filters was indicative of a release quantity at least 100 times the amount released. In addition, air sampler results show very little change between the amount of material collected on an air sample filter near the waste room versus a filter at Station A. Lastly, no data was obtained for the Rh aerosol because of the interference of salt in the analytical technique..

Aerosol Collection at the Underground Sampling Location

The Aerosol collection data is presented in graphical and tabulated format. The tabulated data (Attachment 1) is the micrograms of each metal collected on each air sample filter. The graphs, Attachments 16-20, plot the tabulated air sampler data that is useable along with interpolations of the average and maximum amount of material that would be expected to be collected on an air sample filter at any distance down stream of the release point.

The maximum amount of material that would be expected to be collected assumes that no material would be removed from the air stream due to deposition on the surfaces of the mine drifts and that any decrease in the average airborne concentration would be due only to the dilution of the waste room air as it exits the mine. This interpolation of the maximum amount of collectable material is referred to as "1 Fan Exp" and "2 Fan Exp" on the graph legend box.

The average amount of material that would be expected to collect on air sample filter at any point in the mine are straight line connections between the average amount of material collected on the air sample filters at each sampling location. This straight line interpolation is plotted on a log-linear scale which means that it represents a simple exponential function. This is consistent with the exponential nature of decreasing airborne concentrations where the control volume is fixed and the removal mechanisms are dilution and deposition, also exponential in nature.

Attachments 16-20 show that the total quantities of aerosols collected by CAMs 119 and 129 were nearly identical for all five of the aerosols for which data is usable (Sc, Ta, Re, Au, and W). The data demonstrates that the concentration of aerosol in the air at the end of the waste room was homogeneous and that the collection characteristics of the Continuous Air Monitors (CAMs) are indistinguishable between the north CAM 119 and the south CAM 129 CAMs.

The above mentioned attachments also show a generally good agreement between the Fixed Air Sampler (FAS) inside the waste room (WR), 200 feet from the release and the FAS at the waste room exit (WRE), 300 feet from the release. Because the WR FAS was in relatively still air and the WRE FAS was in a nominal 10 meter per second (m/s) air stream, there is reason to believe that a 10 m/s air stream does not adversely affect the collection efficiency of a FAS. In that a FAS in still air has been proven to be greater than 99% efficient at collecting airborne aerosols, it is reasonable to assume that the WRE FAS effectively samples the actual concentration of aerosols in the air exiting the waste room.

Agreement between the WR and WRE FASs was best for the Sc, Re, and Au data (Attachments 16, 18, and 19). The Ta data (Attachment 17) showed an order of magnitude variability due to data collected on the third release, which was the shift to filtration test. This result is not present in the data for the other aerosols and the reason for the poorer collection efficiencies of Ta2O5 on the third run is not known. However, the Ta2O5 data for the first two releases are in good agreement and the third release results are within an order of magnitude of the first two release results. Because of the generally good agreement in the results and because the anomaly in the data is specifically associated with only the last release, the Ta2O5 is assumed to be good data.

A comparison of the WR and WRE FAS data for the Au aerosol (Attachment 19) shows the only example where the amount of material collected on a filter appeared to increase with increasing distance from the release. The WRE FAS showed an average concentration of Au aerosol that was higher than that for the WR FAS and the low variability of the data suggests good analytical results. This result may indicate that the collection of the Au aerosol on the WRE FAS may be enhanced by the impaction of particles on the filter surface due to the high air flow velocity at the WRE. However, a similar result would then be expected but is not seen in the W results of Attachment 20. Therefore, the most likely explanation of this anomaly in the Au aerosol data is that the concentration of Au aerosol at the WRE was essentially the same as at the WR FAS and that the differences in values between the two sites is due to statistical variability in the data.

In all cases, the WRE FAS collected more aerosol than the WRE CAMs. Since the WRE FAS is in good agreement with the WR FAS, it can be assumed that it is a good approximation of the actual concentrations of aerosols resulting from the experimental release. Therefore, by comparing the WRE CAM results with the WRE FAS results, the collection efficiencies of the WRE CAMs can be estimated.

An interesting result of this test are the fractions of each aerosol that reach the WRE FAS. For the low (SC), medium (Ta), and high (Au) density 5-10 micron particles, 62%, 18%, and 12% respectively reach the WRE FAS. For small (Re), medium (Au), and large size (W), high-density particles, 46%, 18%,and 4.7% of the particles exited the WR. These results are consistent with expected behavior and show a linear relationship between particle size and density and transmission through the UG. Larger particles of similar density are removed from the air stream more rapidly due to deposition as are higher density particles of similar size.

The fraction of particles that reached the WRE FAS were calculated by dividing the amount of material collected on the WRE FAS by the amount that would be expected to collect on the filters if deposition were not a factor. The amount that would be expected to collect on the WRE FAS in the absence of deposition is equal to the ratio of the sampler flow rate divided by the room exhaust flow rate, multiplied by the total amount of each element released.

The collection efficiencies for the alpha CAMs at the WRE varied between 22% and 78% relative to the FAS (See Attachments 16-20) depending on the particle size and density. The 5-10 micron particle collection efficiencies were 40.1%, 77.6%, and 41.6% for low, medium, and high density particles respectively, for an average collection efficiency of 53.1%. A conservative approximation is to assume a collection efficiency for the WRE alpha CAMs of 50% of the FAS.

WRE Alpha CAM collection efficiencies for high density particles were 53.1%, 41.6%, and 22.2% for small, medium, and large size particles respectively. These results suggest that the filter holder configuration of the alpha CAMs results in a lower collection efficiency relative to the unobstructed filter face of a FAS. It also suggests that for the present sampling configuration, the collection efficiency of alpha CAMs for high density particles decreases dramatically for large particle sizes.

WRE Beta CAM collection efficiencies varied between 2% and 29%. For low (Sc), medium (Ta), and high-density (Au), 5-10 micron particles, beta collection efficiencies were 8.9%, 28.8%, and 1.6% respectively. For small and medium sized, high-density, the beta collection efficiencies were 2.4% and 1.6% respectively. One conclusion that can be made is that the sampling tube on the beta collection system significantly reduces the collection efficiency of the sampler compared to FAS results. Two of the three beta CAM results showed collection efficiencies below 10%. Consequently, steps are being taken to improve the collection efficiency of the Beta CAM. With the exception of the 28.8% efficiency for Ta particles, the results show higher collection efficiencies for the smaller particle sizes. The anomaly for the Ta data suggests that Ta particles are more effectively transmitted through sampling lines. The additional data for is needed to clarify this.

One of the more surprising results obtained was the difference in collection efficiencies between the WRE FAS and the FAS between waste rooms 3 & 4. The total quantities of aerosols collected at the Room 3&4 FAS were 5 to 50 times less than at the WRE whereas the dilution of the airstream from airflow through rooms 4,5, & 6 would account for at most a factor of 2 reduction. This result would not be expected considering the agreement between the WRE FAS with the WR FAS. One possible explanation is that the extra width of the panel exhaust drift, S1600 in the WIPP mine, greatly decreases air flow velocities which allows for a greater degree deposition upstream of the waste room 3 & 4(WR34) FAS. It is also possible that the effect of mixing air flows from the intersecting waste room results in higher deposition rates along the drift walls and an accelerated decrease in airborne concentration values. In either case, relocating the room exit CAMs down drift from the present room exit location could result in lower collection of airborne contamination .

Aerosol Collection at the Station A Sampling Location

Aerosol collection at the Station A sampling location showed that agreement between all samplers was quite good, especially considering the extremely low concentrations of materials detected. For the scandium aerosol, all the values were within +/- 25% except for low readings on the right leg of the A2 sampling skid(CAM 158), which showed collection efficiencies around 50% of the average values. Tantalum results were within +/- 50% of the average and also indicated lower collection efficiencies for CAM 158. Gold data showed +/- 100% agreement as did the rhenium data. Three of four data sets agreed within a factor of two and gold agreed within a factor of five. It should be noted, however, that the concentrations of Au in the exhaust air was extremely low at around 4 nanograms and the variation in the data would be expected to be greater.

Perhaps the most important results obtained from this study are the concentrations of particulates collected on the Station A filter relative to the WRE filters and the estimate of the total amount of material released from the site as a fraction of the total amount of material released in the WR. For the low (Sc), medium (Ta), and high density (Au), 5-10 micron particles, the WRE FAS collected 113, 17.4, and 1132 times more particulates than the Station A FAS averages, respectively. The WRE CAMs collected 46, 13.5, and 147 times more particulates than the Station A effluent monitor averages, respectively.

These collection ratios show the decrease in airborne concentrations of particulates released from the waste room between the WRE and Station A. If dilution of WR air were the only factor contributing to the decrease in airborne concentrations, a collection ratio of 11 would be expected. Any difference between the actual collection ratio and the dilution ratio, therefore, is an indicator of how much material is removed from the airstream between the WRE and Station A. The loss of particulates downstream of the WRE can be referred to as the deposition factor and is defined as the quotient of the actual collection ratio divided by the dilution factor. For the Sc collection ratio of 113, a deposition factor of 10 is obtained. This means that dilution accounted for a factor of 11 decrease in the airborne concentration at Station A and deposition on the drift surfaces account for a factor of 10 decrease in the airborne concentration for a total factor of ~110 (10 x 11) decrease in airborne concentrations. This means that only 10%, or 1 over the deposition fraction, of the total amount of Sc particulates that reach the WRE FAS made it to the Station A FASs.

The low collection ratio of the Ta2O5 results show that most of the Ta2O5 that reached the WRE FAS made it to Station A whereas most of the other aerosols that reached the WRE FAS was removed from the airstream as it traversed the UG exhaust drifts. This appears to be consistent with the higher beta CAM collection efficiencies seen for Ta2O5 particles compared the other aerosols, which suggest that the Ta2O5 particles are less likely to be removed from the airstream while passing through a conduit. This result suggests that it may not be possible to take credit for the removal of particulates from the airstream as a result of traversing the UG exhaust drift but that the dilution of the WR air will at least provide a higher detection sensitivity for radiation monitors located at the WRE due to the dilution factor between WR and Station A exhaust air.

An overall positive result obtained was the indication that only a small fraction of an UG release would reach the surface. The total quantity of aerosols collected on Station A filters was compared to the quantity of aerosol that would be collected if the decrease in airborne concentrations between the UG and Station A were due only to the dilution of the exhaust air. The amount of aerosol that would be expected to be collected at Station A would be the ratio of air flows between Station A samplers and the Station A effluent, times the total quantity of aerosol released. This calculation showed that approximately 5% of the Ta2O5 aerosol reach the surface and only 2.7% of the Sc2O3 aerosol reached the surface. The fraction of the total release to reach the surface or the transmission factor for the remaining two aerosols for which data is available were even lower at fractions of a percent of the total release. These results reflect favorably on the characteristics of the WIPP mine for inhibiting the release of airborne particulates from the UG.

WALL AND FLOOR RESULTS

Air filters were placed in a horizontal orientation near the mine floor and in a vertical orientation at five feet above the floor, against the mine walls. These filters were placed along the drifts to determine what levels of contamination along the surfaces of the exhaust drift might be expected in the event airborne contamination were to be released inside the waste room. The wall and floor filters remained in place for all flow configurations unlike those filters in the radiation monitoring equipment which were changed for different flow configurations. This is to say that the wall and floor data is based on 6 grams of each material released whereas air samples results are based on two grams of each material released over three separate releases.

Two observations can be made from the data. One is that surface contamination levels (SCLs) along the exhaust drift, resulting from the release of selected metals, is fairly consistent for points downstream of the WR. This can be seen in the agreement between data points at 500 and 1500 downstream of the release. The second is that SCLs along the drift would be on the order of one part per million (ppm) per 100 cm^2 per unit of material released, for respirable particles. This is seen in the data for the Sc2O3 and Re particles at 500 and 1500 downstream of the release. It should be noted, however, that the floor and wall filters were flat surfaces whereas the exhaust drift surfaces are uneven crystal surfaces. Therefore, it is possible that the amount of material deposited on the drift surfaces is perhaps some factor greater than was deposited on the flat filter surfaces.

The observation that surface contamination values throughout the drift would be fairly consistent is an interesting result. It seems reasonable to expect higher contamination values at points closer to the release point. A logical explanation for this result suggests that deposition is a product of the airborne concentration and the ratio of the air flow to drift surface area. Higher airborne concentrations near the release are offset by higher air flow to surface area ratios at points farther from the release. The net result is a somewhat uniform deposition of airborne contamination onto the drift surfaces.

An analysis of the data show that the results obtained are consistent with what might be expected. This can be seen by noting the discrepancy between floor and wall deposition values as a function of distance. 100 feet down wind of the release, the discrepancy between floor and wall deposition values is greatest. At 200 feet down wind, this discrepancy is considerably less and becomes a minimum or essentially disappears by 400 feet from the release. This trend can be seen in four of the powders for which data is available. These results show that near the release, gravitational settling is a major factor in the deposition of material and that the released aerosol has not fully dispersed within the air stream. With increasing distance from the release, gravitational settling becomes a much less significant component of deposition. Only in the case of the particles with the largest AMADs, medium-sized, high-density gold particles, is gravitational settling a consistent factor in the deposition of airborne particles. All of these results are consistent with what would be expected which suggests that this data is probably a good initial estimate of the SCLs that could be expected following a release of material from the WR.

Two trends can be inferred from the available data. One trend is associated with medium size particles, (5-10 micron), as particle density increases from 4 to 20 g/cc.(See Attachments 21, 22, and 24) Another trend is associated with ~20 g/cc material as particle size increases from a particle size range of 1-5 micron to 5-10 micron. The first trend shows that surface deposition values decrease by approximately an order of magnitude for each of two ~8 g/cc increments in particle densities. The second trend shows that for the highest density, 20 g/cc particles, surface contamination values decrease by approximately three orders of magnitude, from approximately one ppm to one ppb as the particle size range increases from 1-5 micron to 5-10 micron.(See Attachments 23, and 24)

Perhaps the most important result obtained from the wall and floor filters can be inferred by looking at the air sampling data. For all the powders released, no more than 5% of the material was released from the mine. This means that essentially all of the material was deposited along the surfaces of the exhaust drift. Therefore, low deposition fractions beyond the WR are indicative of high deposition fractions within the WR and vice versa. This observation would be important in assessing the implications of a release. Low SCLs on the exhaust drift may indicate a minor release of respirable material or it may be indicative of a large release of larger particles. Being aware that two dissimilar conclusions are possible and is important for accurately assessing the consequences of a release.

Data for the largest and most dense tungsten (W) particles (25 um and 20 g/cc) indicate that essentially all of this material was deposited on the floor of the WR immediately downstream of the release point. On only one of the eight floor and wall filters was detectable levels of W detected. Because there was only one data point from the analysis, the results have not been plotted.

CONCLUSION

The results from these tests are consistent with the expectation that the WR Radiation Monitoring equipment capture more of an airborne release than Station A. The WRE samplers collected higher quantities of aerosol particles than did Station A samplers for all particle groups. The least conservative results show that the WRE samplers would be at an order of magnitude more sensitive to a release due to the dilution of WR air prior to it reaching the Station A sampling point. Additionally, particle collection at Station A indicate that the shrouded probe is effective for collection of a representative sample for a release. Airborne concentrations drop more rapidly per unit distance from the release for larger and more dense particles.

Another anticipated result was the indication that most of the material released in a WR would not reach the surface. The highest transmission factor to the surface was around 5% of the total release. It may be that the transmission factor for the lightest and least dense particles would be much greater. However, these results show that for medium sized particles and for high-density particles, it may be reasonable to assume transmission factors of less than 5% of a total release. The results provided by these tests support the inherent confinement characteristics of the repository and quantify the sensitivity of the WRE samplers to an airborne release relative to Station A samplers.

The unique experimental approach taken has resulted in lessons learned. The most significant issue identified during the testing of the first 2 filters was the presence of sodium (Na) and chlorine (Cl) in the filter samples due to both collected salt dust and in the filter material itself. The masking of Pd gammas due to Na and Cl gammas was due to both the three or four orders of magnitude higher quantities of salt on the filters versus that of Pd and to the low energy of the Pd decay gamma. Activated Pd is seen by the emission of an 88 KeV gamma from the decay of Pd's decay product, the metastable isotope silver-109 (Ag-109m). The low energy of this gamma places it in the region of the gamma spectrum with the highest background that makes it difficult to see and most likely to be confused with the decay of other isotopes. The masking of Rh gammas due to Cl gammas is due to the short 4.4 minute half-life of the radioactive Rh isotope (Rh-104). Because the half-life of Cl is 37.3 minutes, Rh-104 decays away before the gamma background from Cl has time to subside.

Attempts were made to compensate for this interference by rinsing the salt dust off the filters and activating the filters for different lengths of time. Based on cost and additional time required, it was decided to analyze the remaining filters without the additional effort of rinsing.

The physical impossibility of the results are the basis for currently considering the Ti and Al data to be unusable.

Since data for the smallest particles (Pd and Ti) and least-dense particles (Ti and Al) are not available, it would be worthwhile to complete the collection of data by repeating the experiment using different elements. Were a future test to be performed, more exotic materials such as samarium and iridium would be used. These more exotic materials, while more expensive, would provide more accurate results for airborne contamination levels.

ATTACHMENTS

ATTACHMENT 14

△ Sticky paper close to floor.

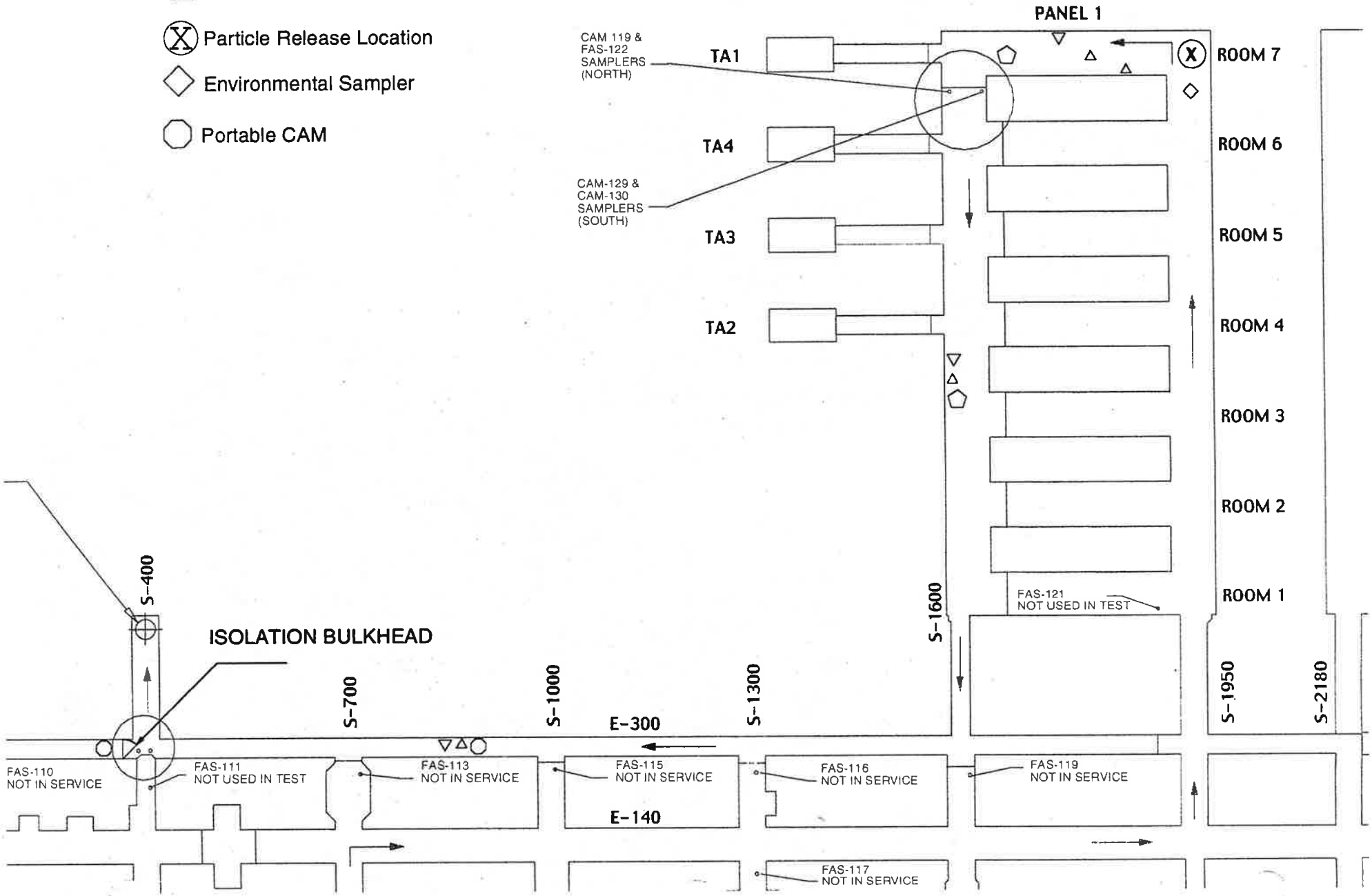
▽ Sticky paper located 6 feet in the air on the wall.

⬠ Portable Fixed Air Sampler

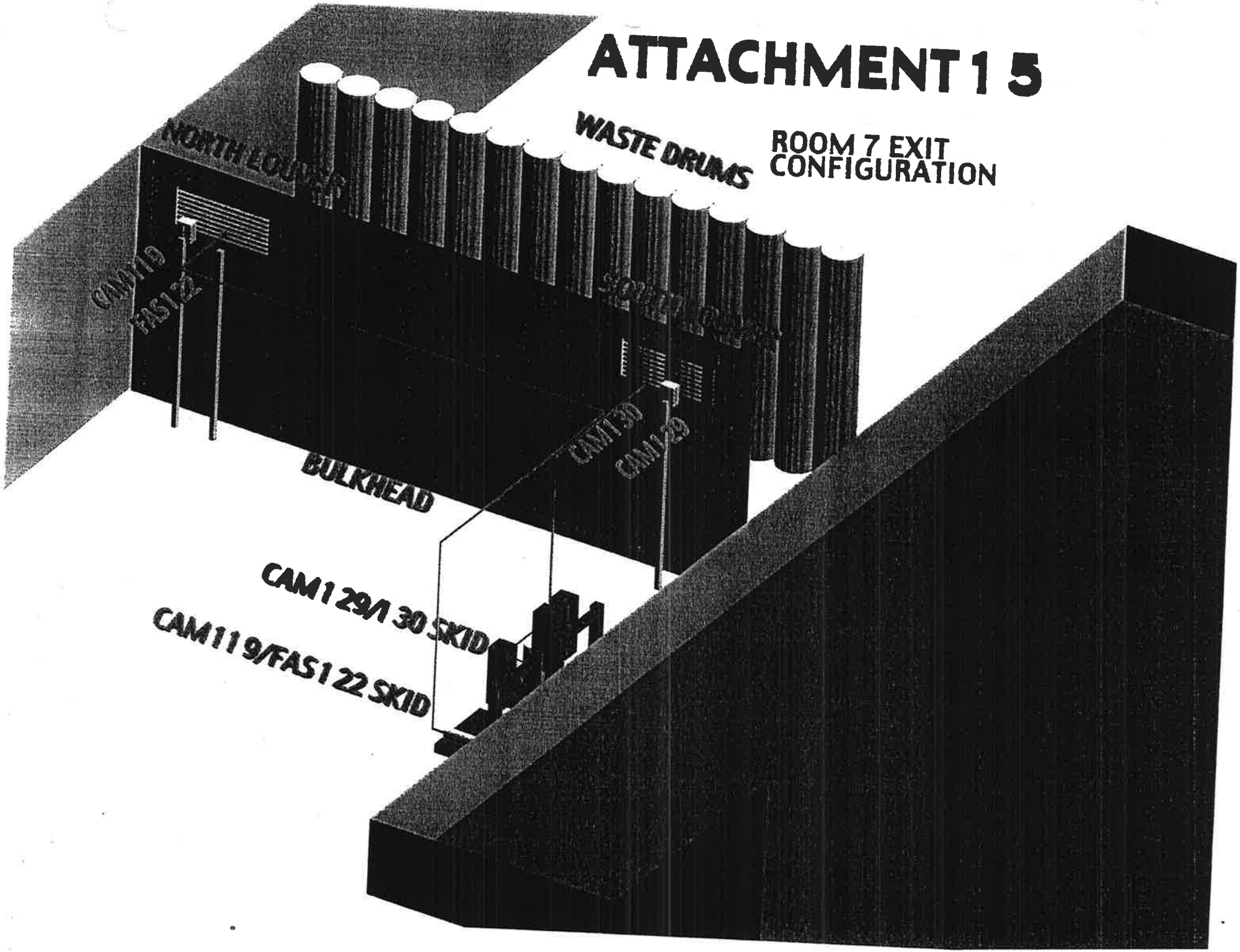
Ⓧ Particle Release Location

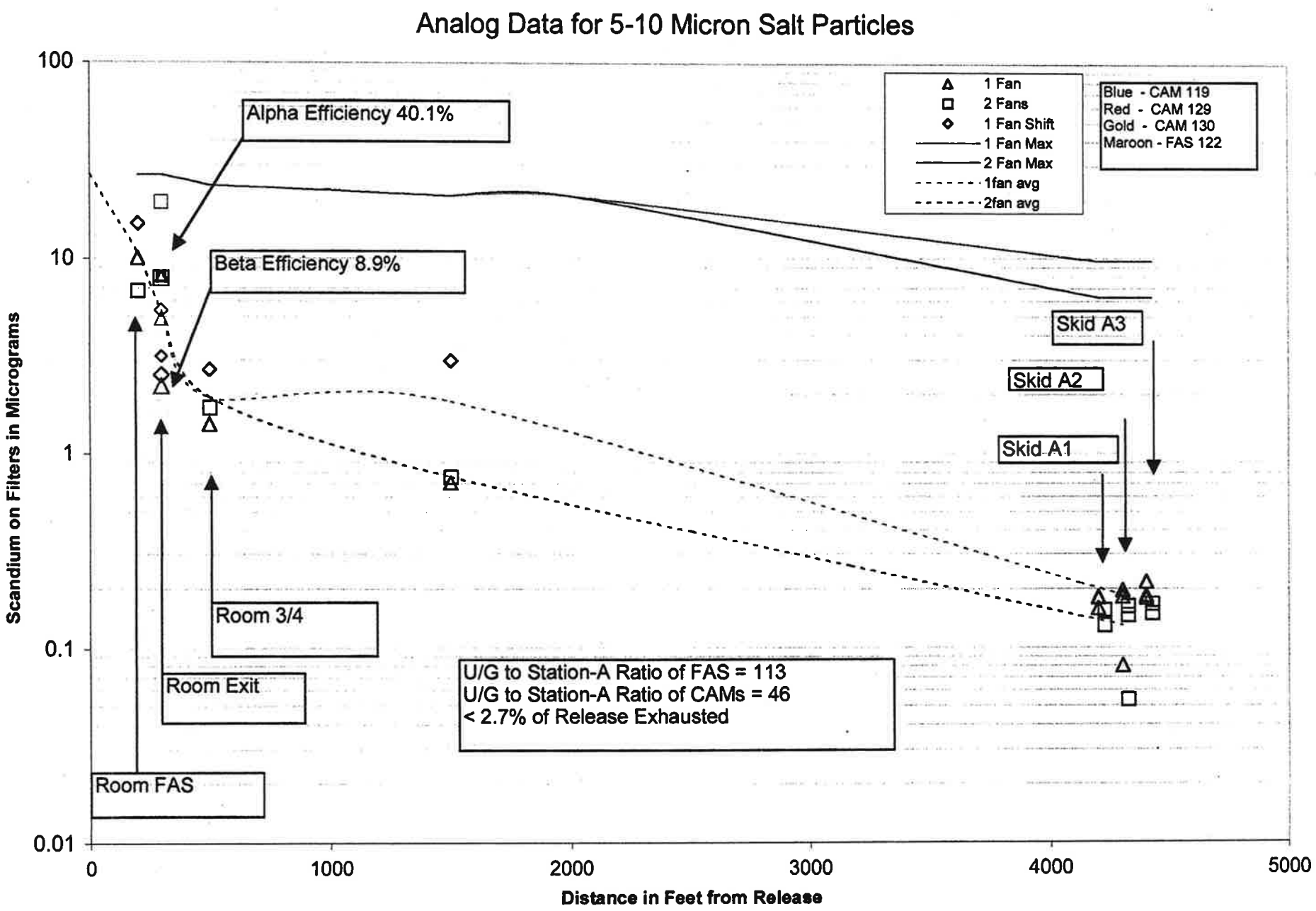
◇ Environmental Sampler

⬡ Portable CAM

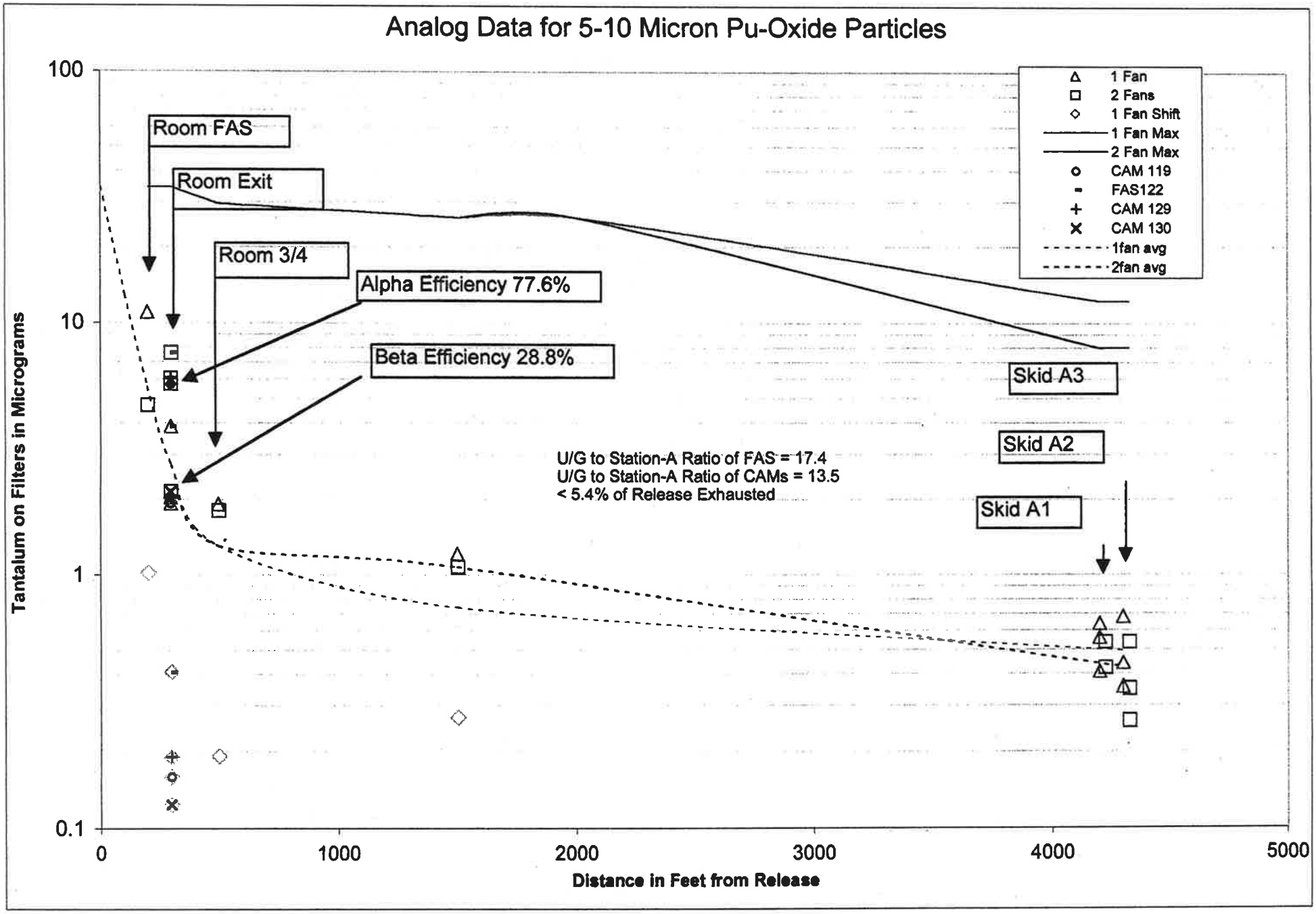


ATTACHMENT 1 5

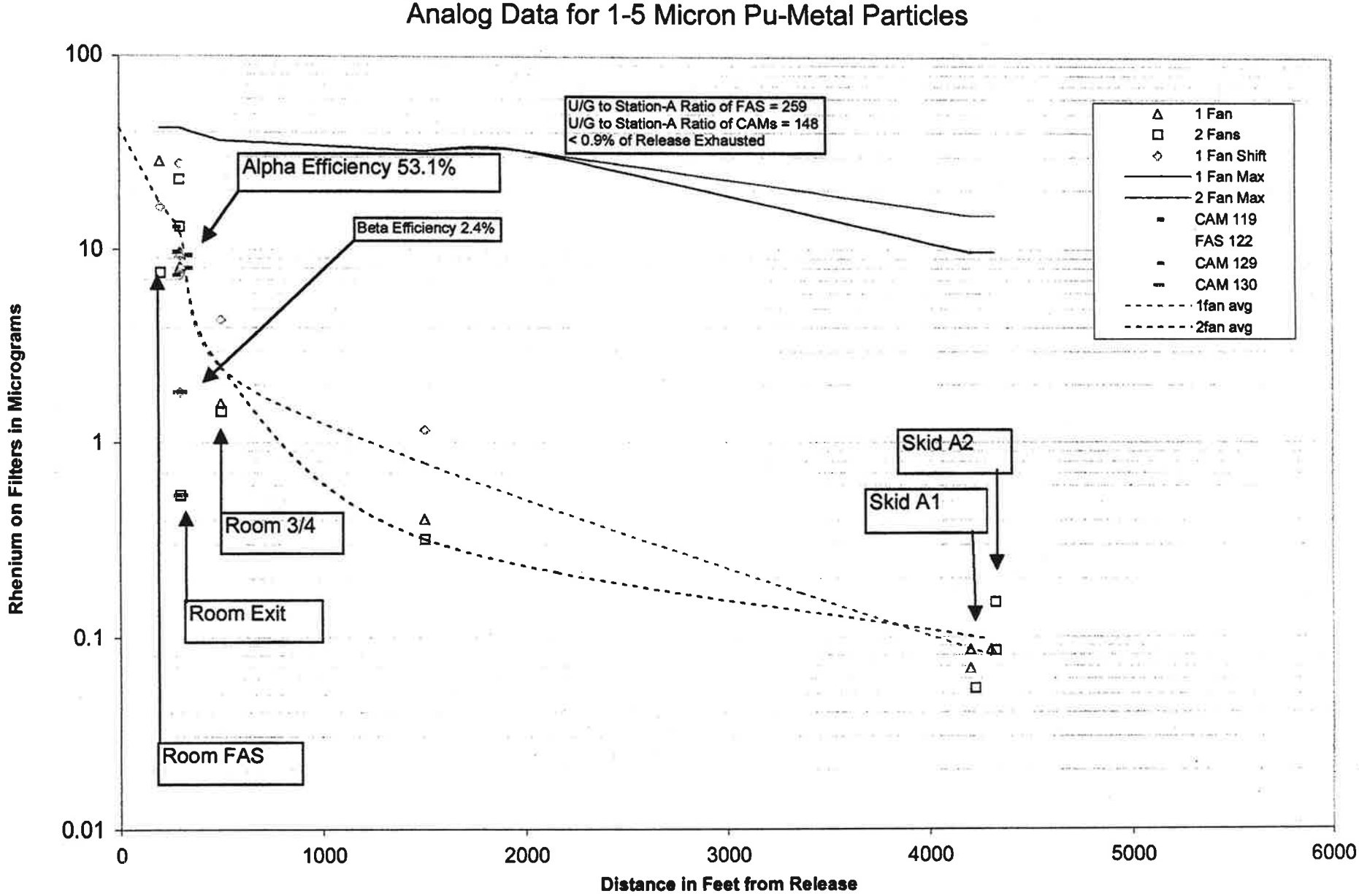




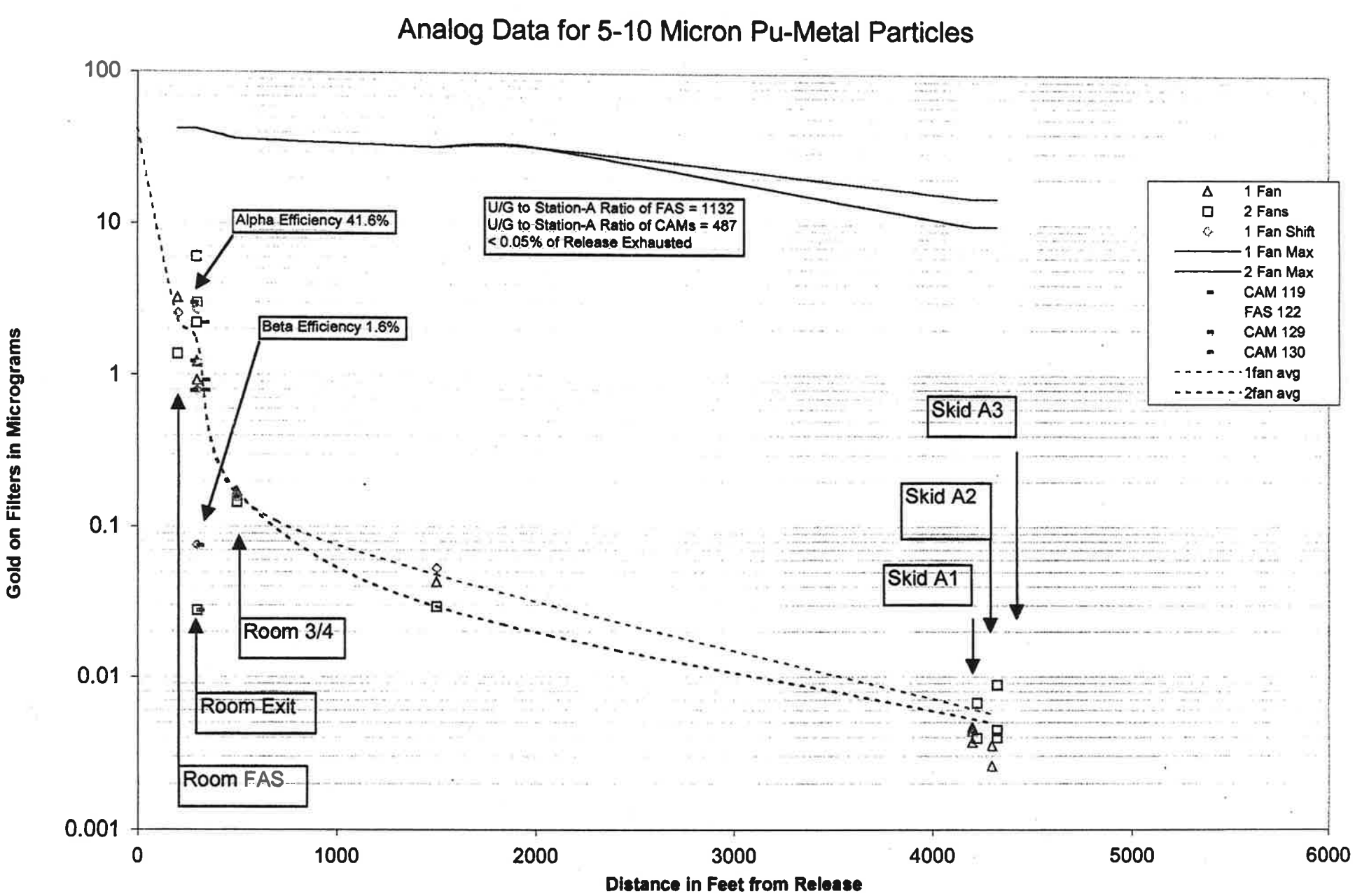
ATTACHMENT 16



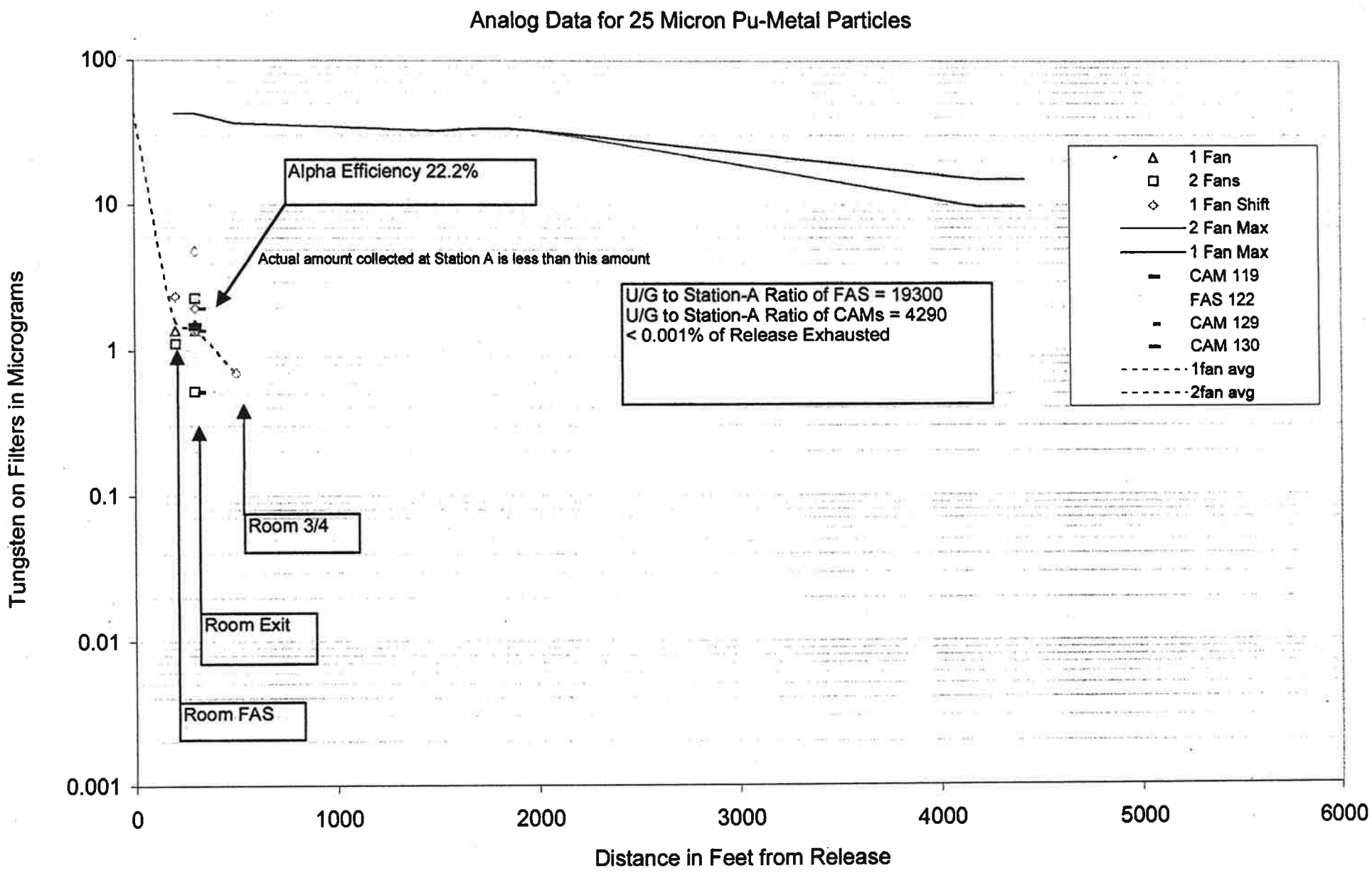
ATTACHMENT 17



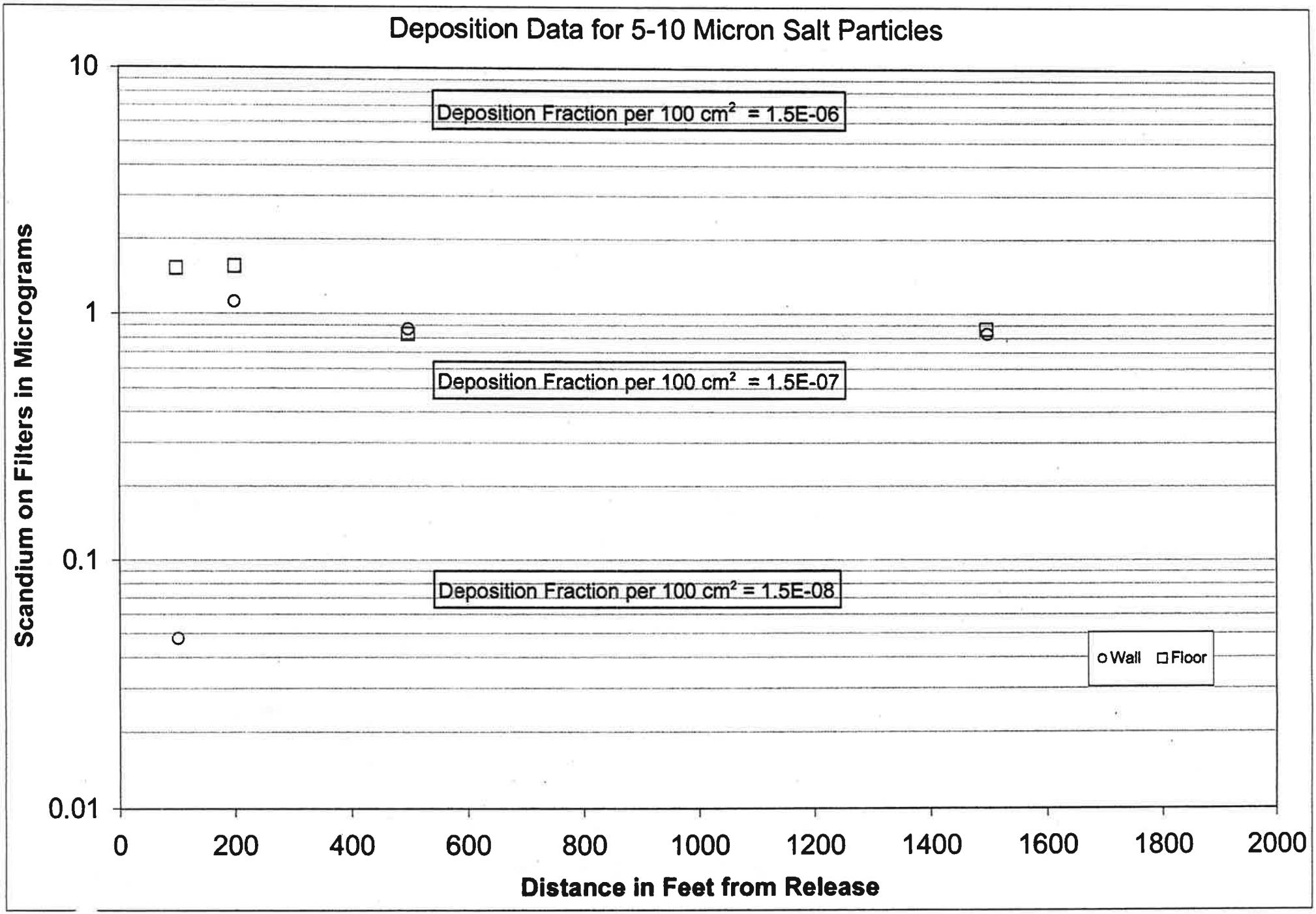
ATTACHMENT 18

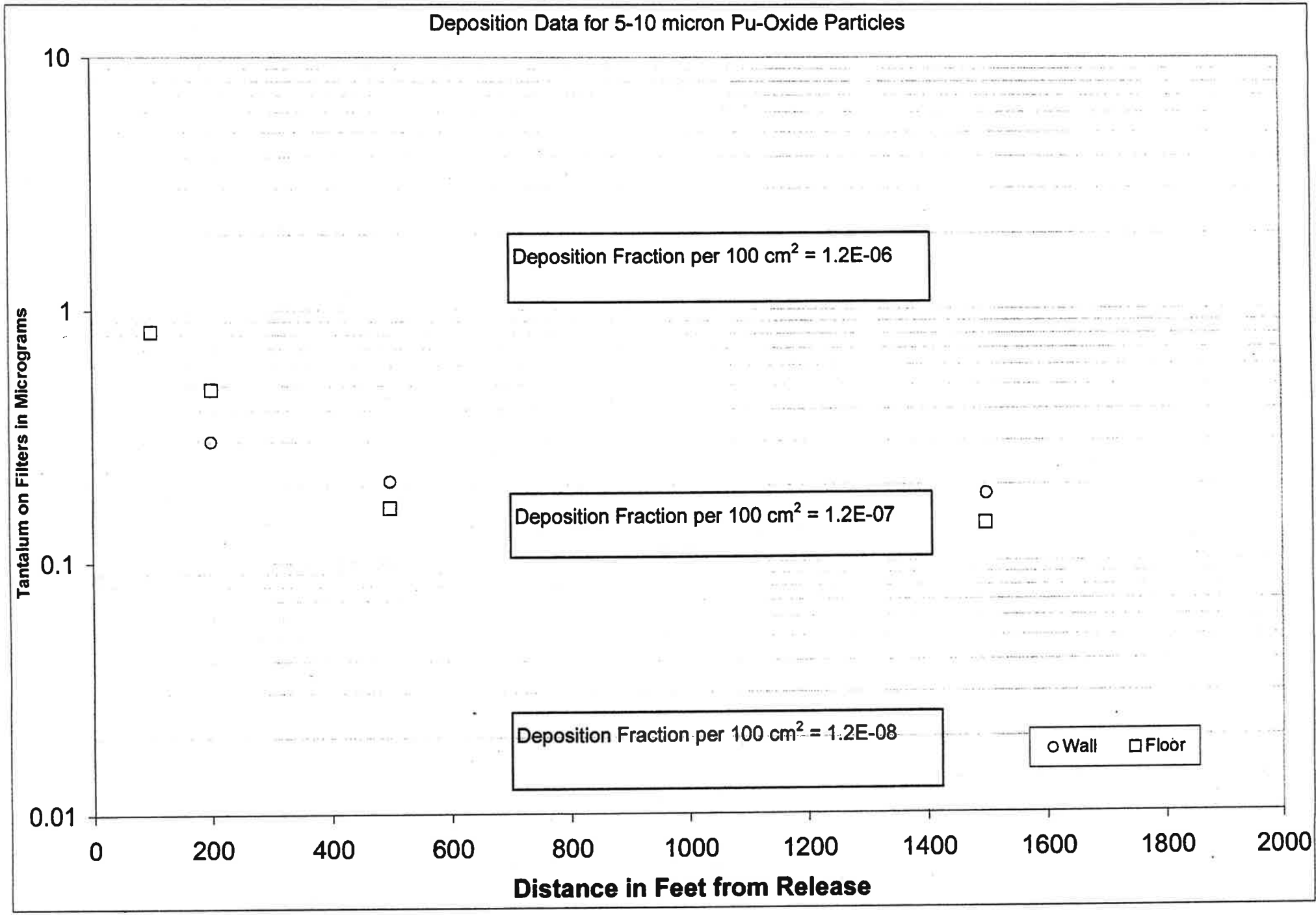


ATTACHMENT 19

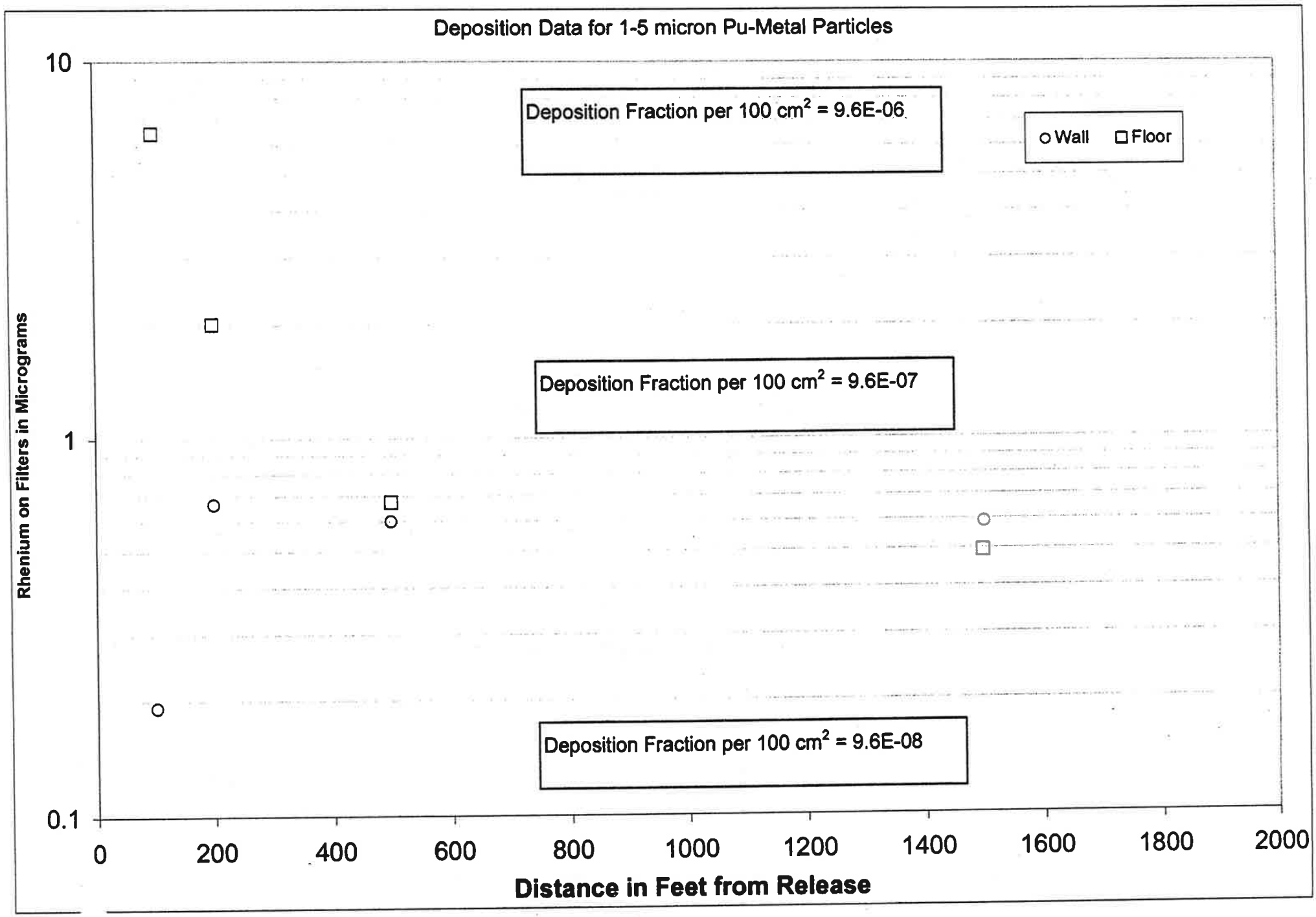


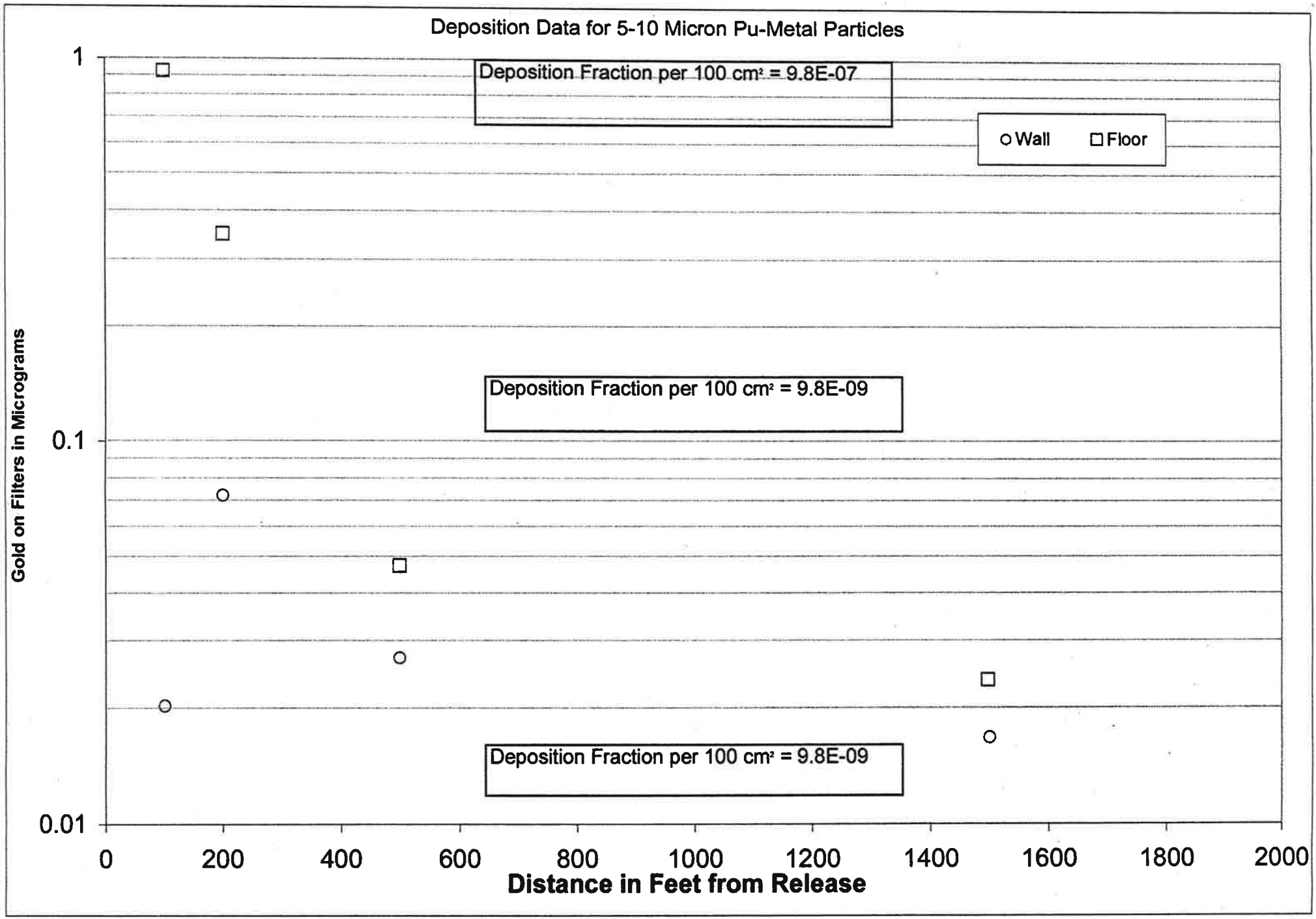
ATTACHMENT 20


Deposition Data for 5-10 Micron Salt Particles
Deposition Fraction per 100 cm² = 1.5E-06
Deposition Fraction per 100 cm² = 1.5E-07
Deposition Fraction per 100 cm² = 1.5E-08
Wall
Floor
Scandium on Filters in Micrograms
10
1
0.1
0.01
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance in Feet from Release



ATTACHMENT 22


Deposition Data for 1-5 micron Pu-Metal Particles
Deposition Fraction per 100 cm2 = 9.6E-06
Deposition Fraction per 100 cm2 = 9.6E-07
Deposition Fraction per 100 cm2 = 9.6E-08
Wall
Floor
Rhenium on Filters in Micrograms
10
1
0.1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance in Feet from Release



ATTACHMENT 24

UNDERGROUND FLOW MEASUREMENT AND PARTICLE RELEASE TEST Rev. 0

Particle Release Sample Identification and Analytical Results

		PARTICLE RELEASE SAMPLE IDENTIFICATION				SHORT LIVED PARTICLES				INTERIM LIVED PARTICLES				LONG LIVED PARTICLES					
	NAA ID	WIPP ID	ON	OFF	NOTES	Al-28		Pd-109m		Ti-51		Au-198		W-187		Re-186		Sc-46		Ta-182	
PRELIMINARY																					
	CAM 129	CAM 129	1055	1240	TWO FAN	<3.97		36.2±	9.2	ND		2.19±	0.9	0.519±	0.13	6.23±	0.2	8.03±	0.62	6.03±	0.7
	FAS 005	FAS 005	1019	1215	TWO FAN	ND		ND		<45		0.00199±	0.0003	ND		1.03±	0.14	0.145±	0.011	0.486±	0.06
BAG 1																					
	1B1	1/2 - CAM 119	1057	1244	TWO FAN	8.67 ±	1.0	12.4 ±	3.8	ND		2.96 ±	0.41	ND		13.0 ±	.2	7.86 ±	.61	5.74 ±	1.36
	1B2	4/2 - CAM 130	1054	1242	TWO FAN	2.29 ±	.62	11.1 ±	2.8	ND		0.0277 ±	0.0040	ND		0.537 ±	0.023	1.73 ±	.13	2.15 ±	.52
	1B3	6/2 - CAM 139 (blank)	1058	1244	TWO FAN	ND		ND		ND		ND		ND		ND		ND		ND	
	1B4	5/2 - FAS 222 (blank)	1057	1243	TWO FAN	ND		ND		ND		ND		ND		ND		ND		ND	
BAG 2																					
	2B1	1/3 INTO RM 7 FLR			#14 [CAN HAS PAPER TOP]	42.4 ±	4.9	ND		361 ±	45	0.923 ±	0.040	1.78 ±	0.79	6.47 ±	.11	1.52 ±	.12	0.821 ±	0.205
	2B2	1/3 INTO RM 7 WALL			#14A	55.4 ±	9.9	<24.5		391 ±	49	0.0203 ±	0.0014	ND		0.192 ±	0.024	0.0477 ±	0.0042	ND	
	2B3	2/3 INTO RM 7 WALL			#15 [CAN HAS PAPER TOP]	7240 ±	610	ND		3560 ±	560	0.0723 ±	0.0041	ND		0.957 ±	0.137	1.12 ±	.09	0.301 ±	0.092
	2B4	2/3 INTO RM 7 FLR			#16	6650 ±	570	<75.7		3190 ±	520	0.348 ±	0.019	ND		2.01 ±	.15	1.55 ±	.12	0.484 ±	0.126
	2B5	S1600 RM BTWN RM 3 & 4 WALL			#17	7820 ±	690	ND		4040 ±	660	0.0271 ±	0.0017	ND		0.601 ±	0.118	0.869 ±	0.066	0.208 ±	0.098
	2B6	S1600 RM BTWN RM 3 & 4 FLR			#18	5970 ±	470	49.0 ±	18.4	2890 ±	380	0.0472 ±	0.0026	ND		0.674 ±	0.164	0.827 ±	0.065	0.164 ±	0.072
	2B7	S700/S100/E300 FLR			#19	6540 ±	520	ND		3050 ±	400	0.0236 ±	0.0016	ND		0.494 ±	0.133	0.868 ±	0.068	0.141 ±	0.057
	2B8	S700/S100/E300 WALL			#20	7220 ±	590	<77.5		3430 ±	460	0.0166 ±	0.0011	ND		0.566 ±	0.164	0.833 ±	0.066	0.184 ±	0.082
BAG 3																					
	3B1	21/1 - ENTRANCE TO RM 7 FAS	905	1118	ON FOR ALL TESTS	ND		ND		ND		0.00822 ±	0.00059	ND		ND		0.00854 ±	0.00164	ND	
	3B2	21/2 - ENTRANCE TO RM 7 FAS	1119	1304	TWO FAN	4.24 ±	1.39	ND		43.1 ±	10.2	0.0117 ±	0.0008	ND		ND		0.0246 ±	0.0025	ND	
	3B3	21/3 - ENTRANCE TO RM 7 FAS	1304	1409	SHIFT TO FILTRATION	11.2 ±	3.8	ND		ND		0.00586 ±	0.00061	ND		ND		0.0112 ±	0.0017	ND	
	3B4	22/1 - 2/3 INTO RM 7 FAS	857	1116	ONE FAN	ND		131 ±	21	<57.0		3.20 ±	.14	1.39 ±	.35	28.4 ±	.4	10.1 ±	.8	11.0 ±	2.6
	3B5	22/2 - 2/3 INTO RM 7 FAS	1116	1305	TWO FAN	10.8 ±	4.4	<18.2		<29.5		1.36 ±	.14	1.12 ±	.34	7.59 ±	.14	6.77 ±	.53	4.72 ±	1.14
	3B6	22/3 - 2/3 INTO RM 7 FAS	1305	1407	SHIFT TO FILTRATION	ND		74.0 ±	13.8	<73.1		2.53 ±	.25	2.40 ±	.68	16.4 ±	.3	15.1 ±	1.2	1.02 ±	.25
	3B7	23/1 - BTWN RM 3 & 4 FAS	824	1049	ONE FAN	17.4 ±	1.9	<9.75		<29.6		0.170 ±	0.017	ND		1.60 ±	.06	1.41 ±	.11	1.91 ±	.46
	3B8	23/2 - BTWN RM 3 & 4 FAS	1049	1238	TWO FAN	18.6 ±	5.4	ND		ND		0.145 ±	0.015	ND		1.45 ±	.06	1.70 ±	.13	1.80 ±	.44
	3B9	23/3 - BTWN RM 3 & 4 FAS	1238	1503	SHIFT TO FILTRATION	ND		44.9 ±	10.7	ND		0.156 ±	0.007	0.702 ±	0.242	4.38 ±	.10	2.67 ±	.21	0.193 ±	0.065
	3B10	24/1 - S700/S1000/E300 FAS	818	1043	ONE FAN	3.88 ±	.93	<7.75		<23.7		0.0427 ±	0.0020	ND		0.406 ±	0.040	0.709 ±	0.055	1.21 ±	.29
	3B11	24/2 - S700/S1000/E300 FAS	1043	1233	TWO FAN	<7.93		ND		41.6 ±	14.8	0.0291 ±	0.0021	ND		0.320 ±	0.021	0.760 ±	0.059	1.07 ±	.16
	3B12	24/3 - S700/S1000/E300 FAS	1233	1357	SHIFT TO FILTRATION	<20.7		22.8 ±	7.7	<51.5		0.0523 ±	0.0027	ND		1.16 ±	.03	2.96 ±	.23	0.271 ±	0.043
BAG 4																					
	4B1	5/1 - STATION A1 CAM 153	802	1020	SKID A1 - ONE FAN	ND		ND		ND		0.00460 ±	0.00067	ND		0.0856 ±	0.0172	0.182 ±	0.014	0.636 ±	0.095
	4B2	5/2 - STATION A1 CAM 153	1020	1216	SKID A1 - TWO FAN	5.47 ±	1.25	ND		28.4 ±	11.9	0.00392 ±	0.00076	ND		ND		0.156 ±	0.012	0.535 ±	0.081
	4B3	6/1 - STATION A1 CAM 154	805	1022	SKID A1 - ONE FAN	ND		ND		67.7 ±	21.1	0.00439 ±	0.00087	ND		0.0679 ±	0.0186	0.160 ±	0.012	0.561 ±	0.084
	4B4	6/2 - STATION A1 CAM 154	1022	1219	SKID A1 - TWO FAN	3.59 ±	.83	ND		<21.5		0.00866 ±	0.00087	ND		0.0533 ±	0.0204	0.130 ±	0.010	0.422 ±	0.064
	4B5	8/1 - STATION A2 CAM 157	756	1025	SKID A2 - ONE FAN	3.53 ±	1.04	<8.58		24.4 ±	8.7	0.00349 ±	0.00067	ND		0.0858 ±	0.0222	0.197 ±	0.015	0.678 ±	0.102
	4B6	8/2 - STATION A2 CAM 157	1025	1220	SKID A2 - TWO FAN	ND		ND		<32.8		0.00441 ±	0.00075	ND		ND		0.163 ±	0.013	0.535 ±	0.080
	4B7	9/1 - STATION A2 CAM 158	800	1027	SKID A2 - ONE FAN	<8.35		ND		<33.8		ND		ND		ND		0.0805 ±	0.0063	0.355 ±	0.055
	4B8	9/2 - STATION A2 CAM 158	1027	1222	SKID A2 - TWO FAN	ND		ND		<33.9		0.00394 ±	0.00121	ND		0.0845 ±	0.0233	0.0537 ±	0.0042	0.261 ±	0.041
	4B9	2/2 - FAS 122	1100	1245	RM 7 FAS - TWO FAN	ND		81.4 ±	15.9	83.0 ±	22.6	5.98 ±	.28	2.34 ±	1.19	22.8 ±	.4	19.5 ±	1.5	7.58 ±	1.01
	4B10	7/1 - STATION A1 FAS 001	807	1021	SKID A1 - ONE FAN	5.05 ±	1.12	<10.1		30.9 ±	9.5	0.00369 ±	0.00076	ND		ND		0.181 ±	0.014	0.407 ±	0.056
	4B11	7/2 - STATION A1 FAS 001	1021	NO OFF TIME/No filter in canister								ND		ND		ND		ND		ND	
	4B12	10/1 - STATION A2 FAS 002	758	1029	SKID A2 - ONE FAN	<28.6		ND		ND		0.00258 ±	0.00085	ND		ND		0.183 ±	0.014	0.440 ±	0.060
	4B13	10/2 - STATION A2 FAS 002	1029	1221	SKID A2 - TWO FAN	4.21 ±	.94	ND		28.6 ±	9.4	0.00881 ±	0.00088	ND		0.151 ±	0.061	0.147 ±	0.011	0.348 ±	0.048
	4B14	11/1 - STATION A3 FAS 005	750	1019	SKID A3 - ONE FAN	3.48 ±	1.01	ND		37.5 ±	9.4	0.0148 ±	0.0012	ND		ND		0.186 ±	0.014	0.434 ±	0.059
	4B15	12/1 - STATION A3 FAS 006	752	1015	SKID A3 - ONE FAN	<9.61		ND		ND		0.00771 ±	0.00116	ND		ND		0.217 ±	0.017	0.507 ±	0.069
	4B16	12/2 - STATION A3 FAS 006	1015	1215	SKID A3 - TWO FAN	ND		ND		ND		0.00739 ±	0.00099	ND		ND		0.167 ±	0.013	0.419 ±	0.057
	4B17	13/1 - STATION A3 FAS 007	754	1017	SKID A3 - ONE FAN	ND		ND		ND		0.00386 ±	0.00101	ND		ND		0.180 ±	0.014	0.433 ±	0.059
	4B18	13/2 - STATION A3 FAS 007	1017	1215	SKID A3 - TWO FAN	ND		ND		ND		0.00225 ±	0.00061	ND		ND		0.150 ±	0.012	0.378 ±	0.052
	NA	25/1 - S400/S90/E300 FAS	814	1040	ONE FAN																
	NA	25/2 - S400/S90/E300 FAS	1040	1229	TWO FAN																
	4B19	25/3 - S400/S90/E300 FAS	1229	1351	SHIFT TO FILTRATION	8.23 ±	.95	ND		28.6 ±	6.7	ND		ND		ND		0.00176 ±	0.00078	ND	
	4B20	WIPP EAST	824	3/27/98	ALL CONDITIONS	548 ±	39	ND		41.9 ±	12.5	0.00273 ±	0.00105	ND		0.183 ±	0.036	0.0720 ±	0.0057	ND	
	4B21	FAR FIELD #31	824	3/27/98	ALL CONDITIONS	321 ±	25	<25.2		ND		0.00579 ±	0.00116	ND		ND		0.0420 ±	0.0034	0.0298 ±	0.0137
BAG 5																					
	NA	1/3 CAM 119	1244	1411	SHIFT TO FILTRATION	6.86 ±	1.85	42.6 ±	12.7	ND		0.778 ±	0.034	1.42 ±	.80	6.09 ±	.06	2.50 ±	.19	0.159 ±	0.027
	NA	2/3 FAS 122	1245	1413	SHIFT TO FILTRATION	ND		92.2 ±	40.8	ND		2.67 ±	.12	4.86 ±	2.63	20.0 ±	.2	5.39 ±	.41	0.406 ±	0.065
	NA	3/3 CAM 129	1241	1407	SHIFT TO FILTRATION	ND		49.3 ±	16.8	ND		0.761 ±	0.034	1.99 ±	1.09	7.40 ±	.06	3.12 ±	.24	0.190 ±	0.032
	NA	4/3 CAM 130	1242	1408	SHIFT TO FILTRATION	ND		ND		ND		0.0747 ±	0.0043	ND		1.32 ±	.02	1.29 ±	.10	0.124 ±	0.022
BAG 6																					
	NA	1/1 CAM 119	840	1057	ONE FAN	17.5 ±	3.9	40.6 ±	11.3	ND		1.21 ±	.07	1.53 ±	.92	7.47 ±	.09	2.18 ±	.17	1.92 ±	.30
	NA	2/1 FAS 122	840	1100	ONE FAN	ND		ND		ND		1.20 ±	.07	ND		20.5 ±	.2	4.87 ±	.36	3.88 ±	.60
	NA	3/1 CAM 129	837	1053	ONE FAN	ND		ND		ND		0.912 ±	0.050	1.38 ±	.80	6.42 ±	.06	2.17 ±	.17	2.04 ±	.31
	NA	4/1 CAM 130	838	1054	ONE FAN																
		FLUROPORE		NEW	N/A	NA		NA		NA		ND		ND		ND		0.000538	0.000157	ND	
		FAS A-3-3		3/23/98	N/A	NA		NA		NA		ND		ND		ND		0.00354 ±	0.00050	ND	
		AL-WFF TEST 1		1998	N/A	NA		NA		NA		ND		ND		0.115 ±	0.008	0.0523 ±	0.0041	ND	

UNDERGROUND FLOW MEASUREMENT AND PARTICLE RELEASE TEST Rev. 0

		PARTICLE RELEASE SAMPLE IDENTIFICATION			
	NAA ID	WIPP ID	ON	OFF	NOTES
PRELIMINARY					
	CAM 129	CAM 129	1055	1240	TWO FAN
	FAS 005	FAS 005	1019	1215	TWO FAN
BAG 1					
	1B1	1/2 - CAM 119	1057	1244	TWO FAN
	1B2	4/2 - CAM 130	1054	1242	TWO FAN
	1B3	6/2 - CAM 139 (blank)	1058	1244	TWO FAN
	1B4	5/2 - FAS 222 (blank)	1057	1243	TWO FAN
BAG 2					
	2B1	1/3 INTO RM 7 FLR			#14 [CAN HAS PAPER T
	2B2	1/3 INTO RM 7 WALL			#14A
	2B3	2/3 INTO RM 7 WALL			#15 [CAN HAS PAPER T
	2B4	2/3 INTO RM 7 FLR			#16
	2B5	S1600 RM BTWN RM 3 & 4 WALL			#17
	2B6	S1600 RM BTWN RM 3 & 4 FLR			#18
	2B7	S700/S100/E300 FLR			#19
	2B8	S700/S100/E300 WALL			#20
BAG 3					
	3B1	21/1 - ENTRANCE TO RM 7 FAS	905	1118	ON FOR ALL TESTS
	3B2	21/2 - ENTRANCE TO RM 7 FAS	1119	1304	TWO FAN
	3B3	21/3 - ENTRANCE TO RM 7 FAS	1304	1409	SHIFT TO FILTRATION
	3B4	22/1 - 2/3 INTO RM 7 FAS	857	1116	ONE FAN
	3B5	22/2 - 2/3 INTO RM 7 FAS	1116	1305	TWO FAN
	3B6	22/3 - 2/3 INTO RM 7 FAS	1305	1407	SHIFT TO FILTRATION
	3B7	23/1 - BTWN RM 3 & 4 FAS	824	1049	ONE FAN
	3B8	23/2 - BTWN RM 3 & 4 FAS	1049	1238	TWO FAN
	3B9	23/3 - BTWN RM 3 & 4 FAS	1238	1503	SHIFT TO FILTRATION
	3B10	24/1 - S700/S1000/E300 FAS	818	1043	ONE FAN
	3B11	24/2 - S700/S1000/E300 FAS	1043	1233	TWO FAN
	3B12	24/3 - S700/S1000/E300 FAS	1233	1357	SHIFT TO FILTRATION
BAG 4					
	4B1	5/1 - STATION A1 CAM 153	802	1020	SKID A1 - ONE FAN
	4B2	5/2 - STATION A1 CAM 153	1020	1216	SKID A1 - TWO FAN
	4B3	6/1 - STATION A1 CAM 154	805	1022	SKID A1 - ONE FAN
	4B4	6/2 - STATION A1 CAM 154	1022	1219	SKID A1 - TWO FAN
	4B5	8/1 - STATION A2 CAM 157	756	1025	SKID A2 - ONE FAN
	4B6	8/2 - STATION A2 CAM 157	1025	1220	SKID A2 - TWO FAN
	4B7	9/1 - STATION A2 CAM 158	800	1027	SKID A2 - ONE FAN
	4B8	9/2 - STATION A2 CAM 158	1027	1222	SKID A2 - TWO FAN
	4B9	2/2 - FAS 122	1100	1245	RM 7 FAS - TWO FAN
	4B10	7/1 - STATION A1 FAS 001	807	1021	SKID A1 - ONE FAN
	4B11	7/2 - STATION A1 FAS 001	1021		NO OFF TIME/No filter in car
	4B12	10/1 - STATION A2 FAS 002	758	1029	SKID A2 - ONE FAN
	4B13	10/2 - STATION A2 FAS 002	1029	1221	SKID A2 - TWO FAN
	4B14	11/1 - STATION A3 FAS 005	750	1019	SKID A3 - ONE FAN
	4B15	12/1 - STATION A3 FAS 006	752	1015	SKID A3 - ONE FAN
	4B16	12/2 - STATION A3 FAS 006	1015	1215	SKID A3 - TWO FAN
	4B17	13/1 - STATION A3 FAS 007	754	1017	SKID A3 - ONE FAN
	4B18	13/2 - STATION A3 FAS 007	1017	1215	SKID A3 - TWO FAN
	NA	25/1 - S400/S90/E300 FAS	814	1040	ONE FAN
	NA	25/2 - S400/S90/E300 FAS	1040	1229	TWO FAN
	4B19	25/3 - S400/S90/E300 FAS	1229	1351	SHIFT TO FILTRATION
	4B20	WIPP EAST	824	3/27/98	ALL CONDITIONS
	4B21	FAR FIELD #31	824	3/27/98	ALL CONDITIONS
BAG 5					
	NA	1/3 CAM 119	1244	1411	SHIFT TO FILTRATION
	NA	2/3 FAS 122	1245	1413	SHIFT TO FILTRATION
	NA	3/3 CAM 129	1241	1407	SHIFT TO FILTRATION
	NA	4/3 CAM 130	1242	1408	SHIFT TO FILTRATION
BAG 6					
	NA	1/1 CAM 119	840	1057	ONE FAN
	NA	2/1 FAS 122	840	1100	ONE FAN
	NA	3/1 CAM 129	837	1053	ONE FAN
	NA	4/1 CAM 130	838	1054	ONE FAN
		FLOUROPORE		NEW	N/A
		FAS A-3-3		3/23/98	N/A
		AL-WFF TEST 1		1998	N/A

ATTACHMEN

Particle Release Sample Identification and Analytical Results

VED PARTICLES				INTERIM LIVED PARTICLES						LONG LIVED PARTICLES					
d-109m		Ti-51		Au-198		W-187		Re-186		Sc-46		Ta-182	
36.2±	9.2	ND		2.19±	0.9	0.519±	0.13	6.23±	0.2	8.03±	0.62	6.03±	0.7
ND		<45		0.00199±	0.0003	ND		1.03±	0.14	0.145±	0.011	0.486±	0.06
12.4 ±	3.8	ND		2.96 ±	0.41	ND		13.0 ±	.2	7.88 ±	.61	5.74 ±	1.38
11.1 ±	2.8	ND		0.0277 ±	0.0040	ND		0.537 ±	0.023	1.73 ±	.13	2.15 ±	.52
ND		ND		ND		ND		ND		ND		ND	
ND		ND		ND		ND		ND		ND		ND	
ND		381 ±	45	0.923 ±	0.040	1.78 ±	0.79	6.47 ±	.11	1.52 ±	.12	0.821 ±	0.205
<24.5		391 ±	49	0.0203 ±	0.0014	ND		0.192 ±	0.024	0.0477 ±	0.0042	ND	
ND		3560 ±	580	0.0723 ±	0.0041	ND		0.667 ±	0.137	1.12 ±	.09	0.301 ±	0.092
<75.7		3190 ±	520	0.348 ±	0.019	ND		2.01 ±	.15	1.55 ±	.12	0.484 ±	0.126
ND		4040 ±	660	0.0271 ±	0.0017	ND		0.601 ±	0.118	0.869 ±	0.068	0.208 ±	0.098
49.0 ±	18.4	2890 ±	380	0.0472 ±	0.0028	ND		0.674 ±	0.164	0.827 ±	0.065	0.164 ±	0.072
ND		3050 ±	400	0.0236 ±	0.0016	ND		0.494 ±	0.133	0.868 ±	0.068	0.141 ±	0.057
<77.5		3430 ±	460	0.0168 ±	0.0011	ND		0.586 ±	0.164	0.833 ±	0.066	0.184 ±	0.082
ND		ND		0.00622 ±	0.00059	ND		ND		0.00854 ±	0.00164	ND	
ND		43.1 ±	10.2	0.0117 ±	0.0008	ND		ND		0.0246 ±	0.0025	ND	
ND		ND		0.00586 ±	0.00061	ND		ND		0.0112 ±	0.0017	ND	
131 ±	21	<57.0		3.20 ±	.14	1.39 ±	.35	28.4 ±	.4	10.1 ±	.8	11.0 ±	2.6
<18.2		<29.5		1.36 ±	.14	1.12 ±	.34	7.59 ±	.14	6.77 ±	.53	4.72 ±	1.14
74.0 ±	13.8	<73.1		2.53 ±	.25	2.40 ±	.68	16.4 ±	.3	15.1 ±	1.2	1.02 ±	.25
<9.75		<29.6		0.170 ±	0.017	ND		1.60 ±	.06	1.41 ±	.11	1.91 ±	.46
ND		ND		0.145 ±	0.015	ND		1.45 ±	.06	1.70 ±	.13	1.80 ±	.44
44.9 ±	10.7	ND		0.156 ±	0.007	0.702 ±	0.242	4.38 ±	.10	2.67 ±	.21	0.193 ±	0.065
<7.75		<23.7		0.0427 ±	0.0020	ND		0.406 ±	0.040	0.709 ±	0.056	1.21 ±	.29
ND		41.6 ±	14.8	0.0291 ±	0.0021	ND		0.320 ±	0.021	0.760 ±	0.059	1.07 ±	.16
22.8 ±	7.7	<51.5		0.0523 ±	0.0027	ND		1.16 ±	.03	2.96 ±	.23	0.271 ±	0.043
ND		ND		0.00460 ±	0.00087	ND		0.0856 ±	0.0172	0.182 ±	0.014	0.636 ±	0.095
ND		28.4 ±	11.9	0.00392 ±	0.00076	ND		ND		0.156 ±	0.012	0.535 ±	0.081
ND		67.7 ±	21.1	0.00439 ±	0.00087	ND		0.0679 ±	0.0186	0.160 ±	0.012	0.561 ±	0.084
ND		<21.5		0.00666 ±	0.00087	ND		0.0533 ±	0.0204	0.130 ±	0.010	0.422 ±	0.064
<8.58		24.4 ±	8.7	0.00349 ±	0.00067	ND		0.0859 ±	0.0222	0.197 ±	0.015	0.678 ±	0.102
ND		<32.8		0.00441 ±	0.00075	ND		ND		0.163 ±	0.013	0.535 ±	0.080
ND		<33.8		ND		ND		ND		0.0805 ±	0.0063	0.355 ±	0.055
ND		<33.9		0.00394 ±	0.00121	ND		0.0845 ±	0.0233	0.0537 ±	0.0042	0.261 ±	0.041
81.4 ±	15.9	83.0 ±	22.6	5.98 ±	.28	2.34 ±	1.19	22.8 ±	.4	19.5 ±	1.5	7.58 ±	1.01
<10.1		30.9 ±	9.5	0.00369 ±	0.00076	ND		ND		0.181 ±	0.014	0.407 ±	0.056
				ND		ND		ND		ND		ND	
ND		ND		0.00258 ±	0.00085	ND		ND		0.183 ±	0.014	0.440 ±	0.060
ND		28.6 ±	9.4	0.00881 ±	0.00088	ND		0.151 ±	0.061	0.147 ±	0.011	0.348 ±	0.048
ND		37.5 ±	9.4	0.0148 ±	0.0012	ND		ND		0.186 ±	0.014	0.434 ±	0.059
ND		ND		0.00771 ±	0.00116	ND		ND		0.217 ±	0.017	0.507 ±	0.069
ND		ND		0.00739 ±	0.00099	ND		ND		0.167 ±	0.013	0.419 ±	0.057
ND		ND		0.00386 ±	0.00101	ND		ND		0.180 ±	0.014	0.433 ±	0.059
ND		ND		0.00225 ±	0.00081	ND		ND		0.150 ±	0.012	0.378 ±	0.052
ND		28.6 ±	6.7	ND		ND		ND		0.00176 ±	0.00078	ND	
ND		41.9 ±	12.5	0.00273 ±	0.00105	ND		0.183 ±	0.036	0.0720 ±	0.0057	ND	
<25.2		ND		0.00579 ±	0.00116	ND		ND		0.0420 ±	0.0034	0.0298 ±	0.0137
42.6 ±	12.7	ND		0.778 ±	0.034	1.42 ±	.80	6.09 ±	.06	2.50 ±	.19	0.159 ±	0.027
92.2 ±	40.9	ND		2.67 ±	.12	4.86 ±	2.63	20.0 ±	.2	5.39 ±	.41	0.408 ±	0.065
49.3 ±	16.8	ND		0.781 ±	0.034	1.99 ±	1.09	7.40 ±	.08	3.12 ±	.24	0.190 ±	0.032
ND		ND		0.0747 ±	0.0043	ND		1.32 ±	.02	1.29 ±	.10	0.124 ±	0.022
40.8 ±	11.3	ND		1.21 ±	.07	1.53 ±	.92	7.47 ±	.09	2.18 ±	.17	1.92 ±	.30
ND		ND		1.20 ±	.07	ND		20.5 ±	.2	4.87 ±	.38	3.88 ±	.60
ND		ND		0.912 ±	0.050	1.38 ±	.80	6.42 ±	.08	2.17 ±	.17	2.04 ±	.31
IA		NA		ND		ND		ND		0.000538	0.000157	ND	
IA		NA		ND		ND		ND		0.00354 ±	0.00050	ND	
IA		NA		ND		ND		0.115 ±	0.008	0.0523 ±	0.0041	ND	

.YZED, ND = NOT DETECTED)