*Evaluation of Dust-Related
Health Hazards Associated
with Air Coring at G-Tunnel,
Nevada Test Site*

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EXECUTIVE SUMMARY

An industrial hygiene study evaluated the health hazards associated with dust resulting from an air coring technical feasibility test performed by Los Alamos National Laboratory in G-Tunnel on the Nevada Test Site for the Yucca Mountain Project funded by the U. S. Department of Energy (DOE). This study was divided into four tasks.

TASK 1 - BULK ANALYSIS

One erionite and one mordenite bulk mineral sample from Yucca Mountain and one commercial natural erionite sample were examined by scanning electron microscopy (SEM) and energy dispersive x-ray (EDX) analysis. Two of the three samples contained significant quantities of microscopic fibers and fiber bundles. The third sample (the Yucca Mountain erionite) was amorphous with very few discernible fibers. EDX analysis of each sample indicated the common presence of aluminum, silicon, potassium, and calcium as major compositional elements, but the respective spectra were so similar that they were indistinguishable from each other. It was concluded that x-ray diffraction analysis (XRDA) is also necessary for proper identification/quantification of erionite and mordenite. SEM should be used for morphology, EDX used for elemental composition, and XRDA used for positive crystal structure identification and quantification.

TASK 2 - DUST COLLECTION EQUIPMENT EVALUATION

An evaluation of the proposed dust control equipment for the dry drilling equipment was conducted by use of the available manufacturer's technical literature, user experience, and regulatory agency experience. We attempted to identify potential emission sources and to quantify (where possible) emission rates, and we suggested potential emission/exposure controls. Based on available data on silica content, type, and particle size, and on proposed air coring (dry drilling) operations, it was estimated that allowable exposures to silica-containing dust could range from 0.07 to 1.5 mg/m³ (total dust) at the drilling sites. We concluded that actual airborne concentrations of dust might approach or exceed these values during normal operations. Therefore, the project management was prepared to control emissions and exposures during prototype air coring. Emission controls were provided where feasible; employees were trained to use air-purifying respirators, which they were fit with and which they wore, and work practices were developed to minimize emissions and personal exposures. Examples of emission controls were the addition of an exhaust ventilation duct from the collar/drill stem area and a second duct from the top of the dust collector for fugitive dust control.

TASK 3 - FIELD SAMPLING

During March and April 1988, 112 personal and area air-particulate membrane filter samples and 14 cascade impactor sets (10 filters each) were collected as the prototype air coring of hole AC-1 (cored in Demonstration Drift) and hole AC-2 (cored in Laser Drift) progressed. Most of the modifications were made to the dust collection system during AC-1.

Gravimetric sample analysis indicated that the total dust concentrations for AC-1 ranged from 0.27-3.12 mg/m³ (average = 1.36 mg/m³) to 0.16-0.5 mg/m³ (average = 0.35 mg/m³) for AC-2, a significant decrease. (The background for both drilling sites was 0.05 mg/m³).

Determination of the respirable mass and x-ray diffraction of quartz, cristobalite, and tridymite was made by a contract laboratory. The respirable dust range was 0.32-2.74 mg/m³ (average = 1.02 mg/m³) for AC-1 and 0.17-0.43 mg/m³ (average = 0.27 mg/m³) for AC-2. Again, a reduction in dust was seen for AC-2 when compared with AC-1. No cristobalite or tridymite was detected on any sample. One sample contained measurable quartz (0.04 mg). The laboratory reported quartz on four other samples, but the quantity was within the lower limit of detection and quantification of the analytical instrumentation.

The calculated quartz time weighted averages (TWA) were below the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for quartz (TLV/TWA = 0.1 mg/m^3) because of the short durations of the drilling operations. If these operations were performed for 8 hours at the observed dust levels, the allowable 8-hour TLVs could be exceeded. Silica analysis of one AC-1 bulk sample and one AC-2 bulk indicated 6.8% quartz detected for the AC-1 sample and 11.0% for the AC-2 sample. (No cristobalite or tridymite was detected in these samples.)

Phase contrast microscopic analysis of collected samples indicated few fibers. No fiber was identified as a zeolite; however CaSO_4 fibers were detected and identified. Sulfaset, a plaster-of-paris (CaSO_4)-based packing mud was used to stabilize the collar/spider to the Laser Drift face. The collection/detection of these fibers (not considered a health hazard because of the low concentration) demonstrates that the monitoring/analytical techniques used can detect fibrous-shaped particles at very low concentrations ($<0.05 \text{ fibers/cm}^3$).

Photon induced x-ray emission analysis determined the elemental content of 10 samples and the two bulk samples previously discussed. Comparison of the elemental analysis with published whole rock chemical analysis showed a similar distribution of elements. When the trace element compositions were compared with ACGIH TLVs for these elements, it was concluded that there is no trace element hazard to area personnel.

Forty-three membrane filter air samples were examined by SEM/EDX. All particles observed were either nonfibrous particles or loosely bound agglomerates of nonfibrous particles. No fibers were detected. The bulk samples were also examined by SEM/EDX, and again no fibers were detected.

Andersen cascade impactors were used for collecting particles and quantifying the particle size distribution of the airborne material and total dust concentration in the range of $0.4\text{-}10 \text{ }\mu\text{m}$ aerodynamic diameter. The data indicated the AC-1 particle size distribution was $1.9 \text{ to } 3.8 \text{ }\mu\text{m}$ mass median aerodynamic diameter (MMAD), standard deviation ($\text{SD}=2.5\text{-}3.8$). The gross concentration average was 3.37 mg/m^3 for AC-1. The particle size distribution for AC-2 was $0.97 \text{ to } 1.47 \text{ }\mu\text{m}$ MMAD ($\text{SD}=6.06\text{-}9.8$). The gross concentration average was 0.57 mg/m^3 .

A significant number of the particles were smaller than $0.4 \text{ }\mu\text{m}$, as shown by the high percentages of total amount of the aerosol collected on the final filters. A large portion of the aerosol was identified as diesel exhaust particles, normally in the $0.25\text{-}0.26\text{-}\mu\text{m}$ size range, which would not impact on any of the Andersen impactor stages. The AC-2 samples showed a smaller particle size than those from AC-1.

The diesel "mucker" (without an exhaust scrubber) operated more frequently in the vicinity of AC-2 than near AC-1. The lower dust levels observed in AC-2 are attributed to the progressively implemented dust control measures designed into the dust collection system. Most (86-90%) of the gross concentration is within the respirable size range. Respiratory protection should be available in case of an emission excursion.

RESULTS AND CONCLUSIONS

- (1) SEM/EDX and XRDA are required for specific identification/quantification of fibrous zeolites.
- (2) A supplementary exhaust system is required.
- (3) Crystalline silica analysis detected no cristobalite or tridymite. One quartz positive (0.04 mg/m^3) was detected, and four quantities [0.02 mg/m^3] were within the level of detection and quantification for the analytical instrumentation. Calculated TWAs were lower than the ACGIH quartz TLV/TWA.
- (4) Zeolite fibers were not detected in AC-1 and AC-2 airborne particulate samples collected during air coring.

- (5) The dust control system was effective in the sampled configuration.
- (6) Diesel exhaust particulates from vehicles working in the G-Tunnel area were detected.

TASK 4 - RECOMMENDATIONS FOR EXPLORATORY SHAFT FACILITY AT YUCCA MOUNTAIN

Based on the findings presented in this report, we recommend that the following be implemented in future drilling activities.

- (1) General dilution ventilation and local exhaust ventilation must be provided to the drilling site.
- (2) Air supplied to the drill hole must be balanced at all times with the dust collection equipment.
- (3) Area employees (workers and investigators) must be fitted for, provided with, and trained to wear air-purifying respirators for emergency situations.
- (4) Dust control equipment should be properly maintained and in operation during any dry, or air, drilling activity.
- (5) All potential emission sources should be identified in advance of drilling, and emission control strategies developed.
- (6) Vehicle exhaust emissions should be kept as low as reasonably achievable.
- (7) Safe operation procedures should be developed and implemented.
- (8) Drilling operating should adhere to existing health and safety requirements applicable to the site.
- (9) The potential hazard (based on geologic mapping) to the personnel working in the Yucca Mountain area mandates that similar sampling and analysis for fibrous zeolites, especially mordenite, be performed during drilling at Yucca Mountain to determine the hazards and appropriate protection for area personnel.
- (10) Animal inhalation studies with mordenite (identified as being one of the primary zeolites in the Yucca Mountain tuffs) should be conducted to determine the biological effects of this fibrous zeolite.

**EVALUATION OF DUST-RELATED HEALTH
HAZARDS ASSOCIATED WITH AIR CORING AT G-TUNNEL,
NEVADA TEST SITE**

by

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ABSTRACT

The Yucca Mountain Project (formerly the Nevada Nuclear Waste Storage Investigations Project) was established by the U.S. Department of Energy (DOE) to evaluate the potential for storing high-level radioactive wastes in geologic formations near the Nevada Test Site (NTS). Before *in situ* tests at Yucca Mountain, field-scale tests are being conducted at NTS, where similar welded tuffs with properties and *in situ* stress states are located. Hydrologists recommended that drilling or coring in support of characterization tests be performed dry because of concerns that liquid drilling fluids could perturb the hydrology.

Dry drilling, or air coring, presents a concern about health protection for the drilling personnel. Water normally used as a circulating fluid also reduces air contaminants generated by the drilling equipment. Extensive core drilling and characterization of the Yucca Mountain mineralogy indicate two potential health hazards to persons exposed to dust and fibers generated at the site. First, the rock generally has a high silica content. Achieving the current occupational exposure levels for crystalline silica during dry drilling requires excellent dust control. Second, natural zeolites are also abundant. Some zeolites such as mordenite and erionite are fibrous, leading to concerns that inhalation of zeolitic dusts containing such fibers may result in asbestos-like lung diseases, including mesothelioma. Very little is known about the hazards of dusts containing fibrous zeolites, especially mordenite, which has been identified as "mappable" in the Yucca Mountain tuffs. However, limited epidemiologic and toxicologic studies performed with erionite indicate that fibrous zeolites may be of concern.

An industrial hygiene study (IH) was conducted as part of an air coring technical feasibility test performed by the Los Alamos National Laboratory. The IH study 1) found the potential for exposures to airborne silica and nuisance dusts to be within regulatory requirements and 2) determined the commercial dust control equipment monitored to be effective, as tested, when used in conjunction with a good area ventilation system and sound industrial hygiene practices. Fibrous zeolites were not detected in the drilling of those two holes. Recommendations for the Yucca Mountain studies are 1) dust collection and control equipment equivalent or superior to that monitored must be used for any dry (air) drilling activity and must be used with good general dilution ventilation and local exhaust ventilation provided on major emission sources; 2) good industrial hygiene work practices must be implemented, including monitoring any area where zeolitic fibers are suspect; and 3) a study should be conducted to determine the biological effects of the fibrous zeolite, mordenite.

1. INTRODUCTION

1.1 PURPOSE

The Yucca Mountain Project (YMP) (formerly the Nevada Nuclear Waste Storage Investigations Project) was established to evaluate the potential for storing high-level radioactive wastes in geologic formations on or adjacent to the Nevada Test Site (NTS). Yucca Mountain has been chosen as the primary evaluation site, and site characterization is planned. Field-scale tests are being conducted at G-Tunnel, located on the NTS some 40 km from Yucca Mountain, before initiating *in situ* tests in the Exploratory Shaft Facility (ESF) at Yucca Mountain. Welded tuffs with properties and *in situ* stress states similar to that of Yucca Mountain tuffs are located in the G-Tunnel Underground Facility.

U.S. Geological Survey hydrologists have recommended to all principal investigators that drilling or coring in support of their tests be performed dry (that is, with air as the circulating fluid) if any possibility exists that liquid drilling fluids could perturb the hydrology.¹ Hydrologists and other investigators are aware that air coring technology currently is not well developed for underground mining. The Prototype Air Coring Test conducted by Los Alamos National Laboratory addresses the technical feasibility of air coring short, horizontal holes in fractured welded tuff; identifies related problem areas; and provides holes for subsequent prototype tests.²

Dry drilling (air coring) presents a health protection concern because water normally used as a circulating fluid also reduces air contaminants generated by drilling. This study provides data on the airborne concentrations of dusts and fibers from air coring at G-Tunnel.

Work to date at Yucca Mountain has included extensive core drilling and characterization of site mineralogy. These data indicate two areas of concern about potential health hazards to persons exposed to dust and fibers generated from rock at the site. First, the rock generally has high percentages of silica ranging from 20% to >70%.³ The health hazards of inhaling crystalline silica have been recognized for more than 50 years. Clinical symptoms from crystalline silica exposure are not evident until many years later. Excellent dust control procedures will be required to achieve the current

occupational exposure levels during dry drilling of rock containing high levels of silica. Therefore, the adequacy of controls must be addressed before drilling operations start at Yucca Mountain.

Second, natural zeolites (predominately clinoptilolite, mordenite, and heulandite) are also abundant at Yucca Mountain. Some zones contain as much as 90% natural zeolites.³ The zeolites, mordenite and erionite are fibrous, leading to concerns about inhalation that result in asbestos-like lung diseases. Erionite has been identified as a fracture-lining mineral in a sample from only one borehole; mordenite, however, is reported to be abundant and can be mapped between many drill holes and at many depths.³ Very little is known about the hazards associated with dusts containing fibrous zeolites, especially mordenite, but limited animal toxicology studies performed with erionite indicate that it may have far greater potential for causing lung tumors, including malignant mesothelioma, than does asbestos (causing almost 100% tumor incidence in rats, compared with about 20% for asbestos).⁴⁻⁶ Mesothelioma is usually associated only with asbestos exposure. Epidemiologic studies of a village in Turkey where airborne erionite is present also indicate high incidence of lung diseases.⁷⁻⁹ Because these diseases will not manifest themselves for many years after exposure, the adequacy of engineering controls must be evaluated before drilling begins at Yucca Mountain.

1.2. SCOPE

This study was designed to (1) identify and evaluate the potential for exposures to airborne silica, nuisance dusts, and fibrous zeolites and (2) evaluate the effectiveness of the commercial dust control equipment attached to the drilling apparatus.

1.3. OBJECTIVE

The objective of the study was to evaluate the potential exposure of drilling workers and scientific investigators to airborne dusts and fibers so that protective measures (engineering controls, administrative controls, and personnel protective equipment) can be incorporated into the drilling and scientific/experimental project at the ESF.

2. CURRENT REGULATIONS

The current American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value/time weighted average (TLV/TWA) and Occupational Safety and Health Administration (OSHA) regulations for the potential hazards encountered in this study are listed in Tables I and II. Currently there is no regulation or TLV for zeolite fibers; however, studies indicate that some of these fibers are considerably more toxic than asbestos fibers.

3. DESCRIPTION OF WORK

3.0.1. OVERVIEW. Evaluation of potential exposure to airborne dusts and fibers is a subpart of, "The Prototype Air Coring of Short, Horizontal Holes in Fractured Welded Tuff." These efforts are in support of the YMP.

Early evaluations of core samples at both Yucca Mountain and G-Tunnel indicate two areas of concern about potential health hazards: high levels of silica and significant levels of various zeolites within the rock. Effective dust control systems will be required to minimize worker exposure during prototype drilling in G-Tunnel and must be required during site characterization at Yucca Mountain.

Evaluation of the potential health hazards and controls was divided into four tasks:

BULK ANALYSIS (TASK 1). Bulk samples of core material from G-Tunnel and Yucca Mountain were analyzed to assess the potential for producing airborne fibers from the various zeolites. This analysis resulted in a preliminary evaluation of the potential exposure associated with such airborne materials.

EVALUATION OF DUST COLLECTION EQUIPMENT (TASK 2). Dust control/collection equipment was evaluated by a review of the manufacturer's technical literature, user experience, and regulatory agency experience to define the probable level of efficiency expected with such air-cleaning systems.

FIELD SAMPLING (TASK 3). A field study was performed during the prototype air coring pro-

TABLE I

ACGIH TLV AND BIOLOGICAL EXPOSURE INDICES FOR 1987-88

Substance	TLV/TWA
Silica, SiO ₂	
Quartz	0.1 mg/m ³ , respirable dust
Cristobalite	0.05 mg/m ³ , respirable dust
Tridymite	0.05 mg/m ³ , respirable dust
Nuisance Particulates (Most Dusts)	10 mg/m ³ total dust
Asbestos	
Amosite	0.5 fiber/cm ³ , A1
Chrysotile	2 fiber/cm ³ , A1
Crocidolite	0.2 fiber/cm ³ , A1
Other Forms	2.0 fiber/cm ³ , A1

ject at G-Tunnel to evaluate the potential for exposure to airborne crystalline silica and zeolite fibers and to determine the effectiveness of the dry drilling dust control equipment in operation.

RECOMMENDATIONS FOR YUCCA MOUNTAIN (TASK 4). Recommendations for operating procedures and health/safety requirements to be implemented during ESF studies at Yucca Mountain were developed on the basis of the other tasks.

4. PROJECT APPROACH

4.1. BULK ANALYSIS (TASK 1)

4.1.1. BACKGROUND (TASK 1). Extensive core drilling and mineralogic characterizations of Yucca Mountain indicate that the rock contains significant quantities of crystalline silica and natural zeolites.³ The hazards posed by inhalation of crystalline silica are well recognized. Little is known, however, about possible hazards associated with inhaling zeolitic dusts. Certain zeolites (erionite and mordenite) are known to be present in the geologic

TABLE II
OCCUPATIONAL HEALTH AND SAFETY ADMINISTRATION REGULATIONS

SUBSTANCE		mg/m ³
<u>29 CFR 1910.1000, (3c.) (7-1-87 Edition) Table Z-3;</u>		
<u>Crystalline:</u>		
Quartz (Respirable)		$\frac{10 \text{ mg/m}^3}{\% \text{SiO}_2 + 2}$ ^a
Quartz (Total Dust)		$\frac{30 \text{ mg/m}^3}{\% \text{SiO}_2 + 2}$
Cristobalite:	Use 1/2 the value calculated from the count or mass formulae for quartz.	
Tridymite:	Use 1/2 the value calculated from the formulae for quartz.	
Inert or Nuisance Dust:		
Respirable	15	5 mg/m ³
Total Dust	50	15 mg/m ³
<u>29 CFR 1910.1001 Asbestos et al.</u>		
Action Level	0.1 f/cm ³ TWA	
Permissible Exposure Limit (PEL)	0.2 f/cm ³ TWA (determined by Phase Contrast Microscopy or better)	
Zeolite Fibers	No Regulation or TLV	

^a Conclusion and SiO₂ determined from specific size selection.

An employee's exposure to any material listed in Table Z-3 of 29 Code of the Federal Regulations (CFR) 1910.1000, in any 8-hour work shift of a 40-hour work week, shall not exceed the 8-hour TWA given for that material in the table.

formations of Yucca Mountain. Mordenite content at Yucca Mountain is reported to be sufficient for geologic mapping,³ whereas the presence of erionite is considered rare and has been confirmed only once, as a fracture coating.³ Both of these zeolites evoke special concern because of their unique fibrous morphology. Erionite has been implicated as the etiologic agent of concern in producing asbestos-like lung diseases in both man and animals.⁴⁻⁹

Animal toxicology studies conducted with erionite indicate that it may have a greater potential for causing primary lung tumors (including mesothelioma) than does asbestos. Some investigators feel that this potential for tumor production is related to fiber "respirability" and microscopic fibrous morphology.¹⁰⁻¹¹ No toxicologic or epidemiologic information concerning health effects of inhaled mordenite has been found in a search of the literature. Dusts produced from both of these fibrous zeolites are of concern because of compositional/morphological similarities and implied resultant health effects related to exposures to other naturally occurring siliceous fibrous minerals of similar sizes (namely the various types of asbestos).

4.1.2. INTRODUCTION (TASK 1). As part of our participation in this project, we used existing LANL, Industrial Hygiene Group (HSE-5), capabilities to recognize, identify, detect, and measure the occurrence of erionite/mordenite in anticipated field-collected airborne material.

This capability was limited to sample evaluation using scanning electron microscopy (SEM) for morphology assessment and energy dispersive x-ray (EDX) analysis for elemental composition determinations. This section summarizes the findings of these efforts performed before the field sampling task began.

4.1.3. MATERIALS AND METHODS (TASK 1). Exploratory fiber assessment (SEM/EDX) experiments have been limited to the examination of three bulk zeolitic materials.

Two bulk mineral samples (one erionite and one mordenite) were obtained from the Geological/Geochemistry Group (ESS-1) at LANL, and one natural erionite mineral sample was purchased from a commercial mineral supply house (Minerals Unlimited, Ridgecrest, California). Both samples obtained from ESS-1 were small chips (~2 mg) of material originating from Yucca Mountain core ma-

terials. The commercial erionite was labeled "Erionite, Pine Valley, Eureka County, Nevada." Both mineral samples obtained from ESS-1 had been characterized by x-ray diffraction analysis (XRDA) and were confirmed as (1) erionite (ESS-1 fracture coating scraped from 1296.2-1296.8 ft, UE-25a #1) and (2) mordenite (ESS-1, USW G-4, banded layer sample 1788.7-1788.9). The commercial (Pine Valley, Nevada) erionite sample was confirmed as 95+% erionite by XRDA (ESS-1) and defined as a suitable reference material for subsequent HSE-5 erionite/fiber assessment comparison experiments.

Each sample was mounted on a carbon planchet, was carbon coated, and was examined with an American Metals Research (AMR) model 1000 scanning electron microscope at 20, 50, 100, 200, 500, 1000, 2000, 5000, and 10000 magnification to determine the locale and visibility of fibers and to select appropriate fields for photographs, fiber content assessment, and EDX analysis. Sections of each sample were photographed at various magnifications. Examples of the microscopic appearance of each sample are shown in Figs. 1-4. Also shown in Figs. 1-4 are EDX spectra obtained from selected

areas of each sample. The commercial sample of erionite (Pine Valley, Nevada) was examined by SEM/EDX in two different states: bulk and milled. Each form is illustrated in Figs. 1 and 2.

Figure 1 illustrates an SEM view taken at 1000x and an EDX spectrum obtained from the bulk sample of the Pine Valley (PV) erionite. Figure 2 illustrates similar SEM/EDX information obtained from a milled sample of the same PV erionite. EDX spectra obtained from both milled and unmilled samples are essentially identical, but comparative SEM photomicrographs illustrate that milling of the bulk sample decreases fiber size (diameter and length) and enhances the number of free fibers present in the sample.

Figure 3 shows SEM/EDX data obtained from an ESS-1 sample labeled as erionite (scraped from Yucca Mountain core-sample fracture coating taken at 1296.2 to 1296.8 ft). This sample was a small amorphous chip (~2 x 3 x 1 mm nonfibrous with an off-white waxy luster) with no fibers detected at magnifications of 20 to 10000x. This finding is inconsistent with the reported fibrous habit of erionite.¹² The EDX spectrum obtained from this nonfibrous ESS-1 bulk core material is very similar to the commercial (fibrous) PV erionite sample.

*Figure 1. SEM Photomicrograph (1000x) and EDX Spectrum:
Pine Valley erionite-Bulk Sample.*

**Figure 2. SEM Photomicrograph (1000x) and EDX Spectrum:
Pine Valley erionite-Milled Sample.**

*Figure 3. SEM Photomicrograph (1000x) and EDX Spectrum:
ESS-1 erlonite-fracture coating scraped from Yucca Mountain
core sample UE-25a #1 (1296.2-1296.8 ft).*

*Figure 4. SEM Photomicrograph (1000x) and EDX Spectrum:
ESS-1 mordenite USW G-4 1788.7-1788.9 ft.*

Figure 4 illustrates SEM/EDX information obtained from examination of the single sample of mordenite (ESS-1 USW G-4 1788.7-1788.9 ft). The SEM photomicrograph of this sample shows the classical long, thin fibrous structure of this material. The EDX spectrum of this mordenite sample is very similar to the respective spectra of the two erionite samples examined in this comparative evaluation.

4.1.4. RESULTS (TASK 1).

4.1.4.1. SEM. Examination of all three samples at various magnifications by SEM indicated that two of the three samples contained significant quantities of microscopic fibers and fiber bundles. The PV erionite and Yucca Mountain mordenite contained many free fibers, as well as fiber bundles, aggregates, and amorphous material. The fibrous material constituting the PV erionite sample has the general appearance of microscopic wood splinters of variable size with nonuniform lengths and diameters. The single Yucca Mountain mordenite sample contained many symmetrical, uniform-diameter microscopic fibers of various lengths (similar in microscopic appearance to bundles of fine-diameter fibrous glass). Fiber diameters of this ESS-1 mordenite sample range from ~0.08 to 3.0 μm . Very few free fibers were detected in this sample. The single sample of Yucca Mountain erionite was amorphous, with very few discernible fibers.

4.1.4.2. EDX. EDX analysis of each sample (Yucca Mountain erionite, Yucca Mountain mordenite, and PV erionite) indicates the common presence of aluminum, silicon, potassium, and calcium as major compositional elements in all samples. Of more concern is the finding that the respective spectra are so similar that they are indistinguishable from each other. This limited EDX comparison thus suggests that EDX cannot distinguish mordenite from erionite.

4.1.5. BULK ANALYSIS CONCLUSIONS (TASK 1).

- (1) This SEM/EDX work is considered preliminary and limited in scope and effort. Only three locally available reference samples (two erionite and one mordenite)

were examined for this program, with mixed results.

- (2) Two of three reference zeolite samples examined by SEM contained free fibers, miniature fiber aggregates, and fiber bundles of a size considered potentially "respirable" (<3- μm diam $\times$ <200- μm long)¹⁰ if induced into an airborne state.
- (3) Milling of the commercial PV erionite decreased fiber size (both diameter and length) and increased the number of free fibers in the sample.
- (4) One reference erionite sample (Yucca Mountain fracture coating scraped from 1296.2-1296.8 ft, UE-25a #1) had no detectable fibers when examined by SEM at magnifications up to 10000x. This finding is not consistent with the crystal habit of erionite,¹¹ and the inconsistency needs further investigation.
- (5) EDX analysis indicated the common presence of aluminum, silicon, potassium, and calcium, and traces of iron and sodium in all three zeolite reference samples.
- (6) EDX analysis alone does not provide sufficient elemental/compositional information to distinguish erionite from mordenite. XRDA is needed for specific mineral identification/confirmation.
- (7) A minimum combination of SEM/EDX/XRDA is necessary for proper identification/quantification of the two fibrous minerals of concern. SEM is necessary for morphology, EDX for elemental composition, and XRDA for positive crystal structure identification and quantification.
- (8) Analytical efforts should focus on the assessment of mordenite as the principal fibrous zeolite of concern at the repository site because of the relative abundance of this material at Yucca Mountain, NTS, in comparison with the documented rare occurrence of erionite.³

4.2 EVALUATION OF DUST COLLECTION EQUIPMENT (TASK 2)

Based on available data on silica content, type, and particle size and on proposed dry drilling operations, it was estimated that allowable exposures to silica-containing dust could range from 0.07 to 1.5 mg/m³ (total dust) at the drilling sites, depending on the silica content of the dust. We concluded that actual airborne concentrations of dust might approach or exceed these values during normal operations, based on preliminary evaluations conducted as part of this work. (See Appendix A for calculations.) Therefore, project management prepared to control emissions and exposures during drilling (e.g., emission controls were provided where feasible, employees were trained and fitted for air-purifying respirators, and work practice training was provided to minimize emissions and personal exposures).

4.2.1. METHODS (TASK 2). Dust collection equipment was evaluated in two stages: a pretest evaluation of proposed control equipment and an on-site observation of controls actually used. The findings of the pretest evaluation were reported in an interim report¹³ and are summarized in paragraph 4.2.3.

At the test site, observations were conducted during prototype drilling to identify emission sources, characterize emissions, and qualitatively evaluate control measures. For the most part, our preliminary findings and estimates were confirmed at the site during testing.

4.2.2. EMISSION SOURCES. As part of the study, we attempted to identify potential emission sources, quantify (where possible) emission rates, and suggest potential emission/exposure controls.

Potential emission sources are:

- fugitive emissions from dust collection equipment (hoses, boot, fittings, and so forth);
- fugitive emissions from the dust collector itself;
- process emissions from vibrating equipment, moving equipment, and drilling operations;
- fugitive emissions from dust reentrainment (air movement, moving equipment, people moving about);
- background sources of airborne dust from other tunnel operations; and
- direct emissions from contaminated clothing and equipment.

The only fugitive emission quantified before drilling was that from the dust collector and the collection equipment. However, special efforts were made to reduce all emissions and to minimize employee exposures through respirator use, work practices, and equipment maintenance.

4.2.3. PRETEST AND ON-SITE EVALUATION OF DUST CONTROL EQUIPMENT (TASK 2).

4.2.3.1. Background. Dust control for the prototype drilling operations at G-Tunnel consisted of a commercial dust collector attached to the drilling equipment.

Before on-site testing, available literature from the manufacturer, users, and regulatory agencies was reviewed to estimate literature was the level of control expected under actual work conditions. No experimental or test activities were performed before or during on-site testing.

The pretest review considered the following factors, noted below, with the constraint that data and/or information were not available in many cases:

- published efficiency of the bag filter media for respirable size dusts;
- first-stage efficiency for dust size, concentrations expected to be produced, and health significance;
- air-flow/pressure-drop characteristics of the system blower, which together with the information obtained in 4.2.4., indicate the operational requirements for filter cake removal;

- effectiveness of cake removal procedures, based on published technical literature (by the manufacturer and others), which indicates operational requirements and potential problems;
- air/cloth ratio (ratio of the volume of gas to the filter area) and how this relates to probable filter performance;
- design capture velocity and collection efficiency;
- seal design characteristics; and
- filtrate removal procedures and the potential for secondary sources of particle release.

Potential sources of information included:

- manufacturer of the equipment proposed for use,
- users of the systems proposed for G-Tunnel and the ESF,
- the project drilling consultant,
- U.S. Bureau of Mines and Mine Safety and Health Administration,
- available literature, and
- unpublished research reports.

4.2.4. EMISSION AND EXPOSURE CONTROLS (TASK 2). Generally, emission and exposure controls fall into three categories:

- those that control at the emission source (local exhaust ventilation, process controls, equipment modifications, work practice controls, wet methods, enclosure, and housekeeping);
- those that interrupt or reduce the path of the contaminant as it travels from the emission site to the breathing zone of employees (isolation of employee, dilution ventilation); and

- those that protect at the breathing zone (respirators, supplied air islands).

For prototype drilling, the following controls were used to minimize dust emissions and exposures.

- (1) A dust collector was installed on the drill shaft exhaust system.
- (2) Local exhaust ventilation was provided by use of dust collection collar or boot at the drill shaft. (See Fig. 5 for details.)
- (3) A secondary duct was extended from the main duct to the area of the boot to control fugitive emissions from the boot.
- (4) The exhaust air from the dust collector was ducted to the main exhaust system. (Alternatively, a second filter could have been fitted to the outlet of the primary filter if sufficient static pressure had been available.)
- (5) Employees were encouraged to use emission-reducing work practices (e.g., selecting appropriate drill speeds, placing equipment properly, controlling equipment, minimizing vibrations, keeping the area clean, not drilling during collection equipment malfunction, and so forth).
- (6) Dilution ventilation was provided to maintain airborne concentrations of dust at acceptable levels.
- (7) Respirators were provided and maintained.
- (8) Rigorous maintenance of dust control equipment was emphasized.
- (9) The number of people and the amount of machinery traffic in the area were limited.

Other dust emission controls that could have been used (but were not) include:

- dust suppression materials used on the tunnel floor (e.g., wet sawdust, sand, or other suitable material) and

Figure 5. Exhaust ventilation at face.

- housekeeping to remove settled dust from drilling and attendant equipment.

Because it is difficult to quantitatively characterize emission sources, it is also difficult to suggest which controls were most effective. Based on actual employee exposures measured during drilling, it appears that all controls were useful and important and should be used in any such drilling work in the future.

4.2.4.1. Findings. The prototype drilling project used an Atlas Copco dust collector, the DCT-90. Appendix B presents the manufacturer's literature describing the equipment. Similar equipment is available from other manufacturers.

The dust collector was equipped with a two-stage separator. The first stage was a baffled-inertial separator capable of removing most of the large dust particles. The second stage was a bag or envelope-type fabric filter consisting of 18 filter bags. (Shaking the bag cleaned the unit.)

Extensive inquiries were made in an attempt to establish the collection efficiency of the proposed equipment, but we had no success. Copco's literature claims filter efficiencies of "nearly 100%" for particles smaller than 5 μm in diameter. Atlas Copco was asked to conduct efficiency tests. This information may be available sometime in the

future, but it will represent efficiencies in laboratory conditions, not those in actual use.

Collector emission calculations presented in Appendix A have assumed a high level of collection efficiency, +99.5%. This efficiency is consistent with that of the general type of collection equipment used. (See efficiency data published by Vandergrift, Stairmand, and American Air Filter Co., Inc., in Appendix B. These data suggest that inertial collectors in series with fabric filters provide collection efficiencies of 95.0-99.9% by weight.)

4.2.4.2. Dust Collection Equipment Conclusions (Task 2). On the basis of available information and our on-site observations, we conclude the following about the collection system.

- (1) We do not know the exact collection efficiency of the air cleaner, but it was assumed to approach 99.5% during favorable operating conditions (basic data in Appendix B; drilling contractor's experience).
- (2) The first-stage filter can remove 60%-80% of the dust reaching the collector (data in Appendix B).

- (3) The filter may quickly load up, requiring cleaning and maintenance on a regular basis, e.g., every 1.5 ft of drilling during routine operations (on-site drilling experience).
- (4) Any similar air cleaners should be required to provide the flow rates and static pressures required to operate the local exhaust system, i.e., DCT-90 exhausts up to 62" acfm against 6-in. water gauge pressure.
- (5) Testing of selected drilling equipment under actual drilling conditions may be required to evaluate the suitability of the collection equipment for routine and ongoing drilling operations (on-site assessment).
- (6) Cleaning of the collection equipment and disposal of the dust are labor intensive and require careful handling to avoid personnel exposure (on-site drilling experience).
- (7) The close-capture design of the local exhaust hood (boot) provided a high degree of dust control at the drill shaft. However, the boot requires maintenance and careful positioning (on-site drilling experience).
- (8) A supplementary exhaust system is required 1) to remove emissions from the air cleaner, 2) to control fugitive emissions, and 3) to provide dilution ventilation to the area.

Additional observations made during prototype drilling are found in Section 5. ON-SITE OBSERVATIONS.

4.3. FIELD SAMPLING (TASK 3)

Field air sampling was conducted during prototype air coring in G-Tunnel at NTS to (1) evaluate the potential worker exposure to crystalline silica and fibrous zeolites and (2) evaluate the effectiveness of the dry drilling dust-control equipment in operation. The evaluation of these potential hazards represents an extension of the normal industrial hygiene support provided by Reynolds Electrical and Engineering Company (REECo) and constitutes a special hazard evaluation study. All

activities were coordinated with REECo Industrial Hygiene.

The first air cored hole (AC-1) was drilled at the face of G-Tunnel's Demonstration Drift (Fig. 6). An electric Longyear 38 drill and an Atlas Copco DCT 90/9504 were positioned at the AC-1 drill site. The DCT collar surrounded the drill stem and had an attached flexible hose (approximately 4-in. diam and 16-ft long) that carried the cuttings and dust from the hole to the dust collector. The collar was mounted to the tunnel face by a three-legged apparatus (named the spider) with metal foot plates held in place by rock bolts. Pressurized air was injected into the hole through the drill to cool the bit and transport the cuttings out of the hole. Additional suction on the cuttings was provided by the DCT's venturi-designed ejector. The tunnel exhaust system at the AC-1 area consisted of a 20-in. duct, with an airflow of 7000 cfm, attached to the ceiling along the right side of the drift. The second air cored hole (AC-2) was drilled in the right wall (from the face) of G-Tunnel's Laser Drift (Fig. 7). The exhaust ventilation in Laser Drift was 6600 cfm.

Field air sampling included (1) obtaining and evaluating the applicability and limitations of REECo air sampling data collected during past G-Tunnel mining operations; (2) making all arrangements with REECo and other NTS organizations for performing the air-sampling task; (3) collecting the air samples during the air coring project; (4) analyzing samples and interpreting data; and (5) developing the evaluation report.

Two types of air samples were obtained: (1) personal samples, those collected with personal sampling pumps connected to a filter cassette placed on the lapel of the worker involved in drilling or experimental activities; and (2) area samples, those collected with sampling pumps with attached filter cassettes positioned in locations of interest, such as near the drill stem penetration of the drift wall or on the dust collector. Cascade impactor samples were collected and were also considered area samples.

4.3.1. QUALITY ASSURANCE (QA) PROCEDURES (TASK 3). This study was classified as a YMP QA Level II study because it has direct bearing on the health of the workers involved in the prototype tests and potentially on the health of the Yucca Mountain workers. As a Level II study, the strict QA constraints required the development of detailed quality assurance procedures (DPs) for the

Figure 6.

(a) Demonstration Drift location of air core hole #1 (AC-1).

(b) Sketch of AC-1 area.

Figure 7.

(a) Laser Drift location of air core hole #2 (AC-2).

(b) Sketch of AC-2 area.

use of the sampling media, sampling equipment, and analytical procedures utilized in this task. Appendix C contains a list of the detailed procedures developed for this study. The LANL YMP (NNWSI) QA Manual¹⁴ contains an updated copy of each procedure and subsequent change orders.

4.3.2. EQUIPMENT (TASK 3).

4.3.2.1 SKC and DuPont Alpha 1 personal sampling pumps. Personal sampling pumps were used to collect area and personal air particulate samples to be used in the evaluation. A personal sampling pump is a small (~2.5 lb, ~735 cm³) vacuum pump powered by a rechargeable battery pack. A prepared membrane filter cassette is attached to the pump with a length of flexible tubing. The pump draws air through the membrane filter, collecting available particulate material from the air (Fig. 8). Detailed procedures were developed for preparation and use of these pumps during sampling at G-Tunnel.

A Gilian Gilibrator (an electronic bubble flowmeter), shown in Fig. 9, was used to calibrate each pump's airflow before and after each sampling period. The Gilibrator was calibrated by the LANL calibration laboratory,¹⁵ and the following correction factor was provided by personnel of the LANL Statistics Group (A-1) for the Gilibrator flow tube (#751-S) used in the pump calibrations at the G-tunnel preparation site.¹⁶

Corrections for Gilibrator readings between

$$717.3\text{cm}^3 \leq y \leq 5748\text{cm}^3$$

$$\hat{x} = (y - 48.16178)/1.01204.$$

$$\text{Error (1 SD)}^2 = 0.976348 y^2 c^2/n - 0.012638 (y - 48.16178)$$

$$+ 5.14758 \times 10^{-6} (y - 48.16178)^2 + 13.217311,$$

where $c = 0.00875y$.

Detailed procedures indicated that temperature and elevation corrections would be made according to the OSHA Field Operation Manual.¹⁷ Temperature corrections were not necessary because the differential temperature between the preparation (calibration) site and sampling site was within the OSHA temperature limit.

Likewise, corrections for altitude differentials were not required because the 500-ft elevation difference was never met as the preparation site was 6115-ft elevation and the Demonstration Drift and Laser Drift where the samples were collected were both at ~6205 ft.

4.3.2.2. Air Particulate Membrane Filters.

Membrane filters were prepared and used as the air sampling collection media. The individual membrane was positioned (loaded) on top of a support pad in a disassembled cassette; the cassette was reassembled and closed tightly. Plastic tape was used to secure the cassette sections and was color coded to identify the membrane type within. A unique identification number was assigned to each membrane filter and was engraved on the exterior of the cassette.

4.3.2.3. Cascade Impactors. Andersen cascade impactors were used for collecting and quantifying the particle size distribution of the airborne particulate material and total dust concentration of 10 to 0.4- μm aerodynamic diameter.

4.3.3. DATA, ANALYTICAL PROCEDURES, AND RESULTS (TASK 3). The field air particulate sampling was performed during March and April 1988, as the air coring of AC-1 and AC-2 progressed. One hundred and twelve air particulate membrane filter samples and 14 cascade impactor sets (10 filters each) were collected. One unidentified (blind) blank was provided with each sample set submitted for analysis. Unless stated otherwise, LANL Group HSE-5 used the methods listed in Appendix C (DPs) to perform the analyses described in this section.

4.3.3.1. Polyvinylchloride (PVC) Membrane Filters. PVC membranes (5- μm pore size, 37-mm diam) were used for (1) total dust measurement, (2) determination of the respirable fraction, and (3) crystalline silica analysis.

4.3.3.1.1. Gravimetric or Total Dust Analysis. The 37-mm PVC membranes were desiccated, weighed, and loaded into three-piece styrene acrylonitrile air monitor cassettes, which were then sealed and engraved. At the G-Tunnel sampling site, the cassettes were attached to the sampling pumps in the open-face mode, and

Figure 8. SKC Sampling Pump on DCT.

***Figure 9. Calibration of testing pumps
with the Gilibrator.***

available air particulates were collected. After sampling, the cassettes were capped and sealed, then transported back to Los Alamos. The membranes were again desiccated and weighed to determine the total accumulation of air particulate material.

Table III lists the sampling date, core hole, and location of the samples during collection of the 10 gravimetric samples.

Table IV lists the gravimetric (total dust) concentrations calculated from weight gain and the sampling flow rates. Sample PV-3 provided the background concentrations (0.05 mg/m^3) for core hole AC-1. The weight gain for AC-1 (Demonstration Drift) samples ranges from $0.27\text{--}3.12 \text{ mg/m}^3$ (average = 1.36 mg/m^3), with the largest concentrations seen during the modification of the dust collection system. During AC-2 (Laser Drift) air coring, the background concentration was also 0.05 mg/m^3 (PV-17), but the range was $0.16\text{--}0.5 \text{ mg/m}^3$ (average = 0.35 mg/m^3), a significant decrease. Complete gravimetric (PV) sample data for AC-1 and AC-2 are located in Appendix D-1.

4.3.3.1.2. Respirable Mass and Crystalline Silica. Silica samples were collected on 5- μm pore size, 37-mm-diam PVC membrane filters. These filters were weighed, loaded into two-piece filter cassettes, sealed with shrink bands by DataChem (formerly Utah Biomedical Laboratory, Inc. of Salt Lake City, Utah), and then shipped to Los Alamos. Upon receipt, they were inscribed with the appropriate sample numbers.

At the G-Tunnel sample preparation site, the (filter-containing) cassettes were placed on clean 10-mm nylon cyclones and attached by flexible tubing to personal sampling pumps calibrated at a nominal 1.7 liters/min. At the sampling site, each cyclone/cassette was positioned on a worker's lapel near the breathing zone. These samplers were worn by the REECO driller and the drilling helper (and sometimes by the LANL drilling consultant) because of their direct involvement in air coring operations. After collection, the cassettes were sealed and returned to DataChem. The analytical laboratory personnel reweighed the membranes to determine the weight gain (respirable mass) and

TABLE III
GRAVIMETRIC SAMPLING LOCATIONS

Sample Date	Sample No.	Sampling Location
AC-1		
03/22/88	PV 3	BACKGROUND, right side: 5 ft above floor and 20 ft above face
03/24/88	PV 5	On Right wall, approximately 16 ft from drill
03/30/88	PV 9	Area sample at drill (left overnight)
03/30/88	PV 15	Begin/Extensometer Drift, inside curve, right side
03/30/88	PV 6	Right wall, approximately 16 ft face, set for work shift
04/07/88	PV 13B	BLANK - PV samples
AC-2		
04/13/88	PV 17	BACKGROUND, Rock bolt left of collar (spider)
04/14/88	PV 31	Left wall by drill collar (spider)
04/14/88	PV 47	Hanging behind DCT
04/20/88	PV 36	Hanging on wire (middle of personnel area)
04/20/88	PV 22	Rock bolt between DCT and drill collar (spider)

AC-1 is first core hole (located in Demonstration Drift).

AC-2 is second core hole (located in Laser Drift).

TABLE IV
GRAVIMETRIC SAMPLE DATA

Sample No.	Sample Date	Total Mass (μg)	Run Time (m)	Air Volume (m ³)	Total Dust Conc. (mg/m ³)
AC-1					
PV 3	03/22/88	118	992	2.3739	0.0497
PV 5	03/24/88	389	65	0.1249	3.1145
PV 6	03/30/88	692	338	0.6365	1.0872
PV 9	03/30/88	1652	900	1.7253	0.9575
PV 15	03/30/88	128	206	0.4668	0.2742
AC-2					
PV 17	04/13/88	66	720	1.237	0.0534
PV 22	04/20/88	58	211	0.3622	0.1601
PV 31	04/14/88	340	372	0.7053	0.4821
PV 36	04/20/88	121	218	0.4694	0.2578
PV 47	04/14/88	342	368	0.6837	0.5002
PV 13B	04/07/88	-20	0	0	0

then performed the silica analysis according to the National Institute of Occupational Safety and Health (NIOSH) 7500 x-ray powder diffraction method.¹⁸ [The NIOSH 7500 procedure warns of possible interference from feldspars or other aluminosilicates in the low limit of detection (LOD).]

4.3.3.1.3. Crystalline Silica Analysis. Table V shows the sampling date, core hole, and collection location of each sample. The driller wore four cyclone samplers during AC-1 and wore three during AC-2; helpers wore two samplers during AC-1 and only one during AC-2. A helper performed the DCT cleaning or was in the collar/DCT area when leaks occurred; frequently, the drilling consultant was also in this area.

The x-ray diffraction analysis detected quartz, cristobalite, and tridymite. Table VI provides the results of the silica analysis. (See Appendix D-2 for complete data.) FW-625 contained measurable quartz, quantified at 0.04 mg. This area sampler was positioned such that it captured fugitive dust during collar leaks. Quartz was reported as

"(0.02 mg)" for 4 samples and 1 blank. This value was within the LOD = 0.015 mg and the lower limit of quantification (LOQ = 0.03 mg) for the DataChem instrumentation. Calculations of the quartz 8-hour TWAs for these samples collected during the short-term drilling operations showed that values were lower than the ACGIH TLV/TWA for respirable silica.

Table VI also lists the total respirable dust collected. The range for AC-1 was 0.32-2.74 mg/m³, with an average = 1.02 mg/m³, and 0.17-0.43 mg/m³, with an average = 0.27 mg/m³ for AC-2. Again the dust reduction was seen for AC-2 when compared with AC-1.

These values are consistent with those reported (less than 15.5 lg or below the LOD) by REEC Co Industrial Hygiene for REEC Co silica samples collected during AC-1. The only REEC Co respirable dust sample was collected on the driller, with a concentration of 0.86 mg/m³.¹⁹

DataChem's technical manager ordered and personally checked a rerun analysis on blind blank FW 400-B and affirmed the presence of the appro-

TABLE V
SILICA SAMPLING LOCATIONS

Sample Date	Sample ID	Sampling Location
AC-1		
03/22/88	FW 610	BACKGROUND-Demonstration Drift, on DCT ~4 ft floor
03/22/88	FW 611	BACKGROUND-Right side, approx. 8 ft face, ~4 ft floor
03/23/88	FW 612	PS ^a -helper, DCT & collar leak
03/23/88	FW 616	PS-driller
03/24/88	FW 619-B	BLIND BLANK - FW samples
03/25/88	FW 614	PS-driller
03/25/88	FW 613	PS-drilling consultant
03/29/88	FW 615	PS-driller
03/29/88	FW 624	PS-helper (no weight gain)
03/29/88	FW 625	Demonstration Drift face between DCT & collar
03/29/88	FW 622	PS-drilling consultant
03/29/88	FW 621	PS-investigator
03/30/88	FW 627	Demonstration Drift, right wall above impactor
03/30/88	FW 620	PS-driller
03/30/88	FW 626	Demonstration Drift, left wall above impactor
03/30/88	FW 623	PS-drilling consultant
04/05/88	FW 407-B	BLIND BLANK - FW samples
AC-2		
04/13/88	FW 630	BACKGROUND-Laser-On drill hoist chain
04/14/88	FW 632	PS-driller
04/14/88	FW 633	15 ft Dr wall, centered between DCT & wall, approximately 4 ft floor
04/14/88	FW 631	Laser Drift, Right wall in line w/DCT
04/19/88	FW 391	PS-driller
04/19/88	FW 394	Wire hanger 6 ft high in personnel area
04/19/88	FW 634-B	BLIND BLANK - FW samples
04/20/88	FW 392	PS-(wearer Out of Area approx. 25 m AM + approx. 45 m PM)
04/20/88	FW 393	Laser, rock bolt 6-ft from drill collar
04/20/88	FW 396	Laser Incline just below core boxes
04/20/88	FW 398	PS-driller
04/20/88	FW 399	Wire hanger 6 ft high in personnel area
04/20/88	FW 641	PS-driller
04/20/88	FW 395	Laser Drift, on front of DCT
04/21/88	FW 400-B	BLIND BLANK - FW samples

^a - personal sample.

TABLE VI
CRYSTALLINE SILICA REPORT

NOTE: Cristobalite or Tridymite was not detected in any sample.

Sample	Total Mass (mg)	Air Volume (m ³)	Run Time (min)	Respirable Dust (mg) (m ³)	Quartz		8-Hour TWA		
					Mass (mg)	Conc. mg/m ³			
AC-1									
FW 610	0.03	0.168	102	0.18	ND ^a	(0.12)	(0.03)		
FW 611	0.05	1.702		0.03	ND				
FW 612	0.20	0.172		1.16	(0.02) ^b				
FW 616	0.12	0.127		0.94	ND				
FW 619-B	-0.02	0.257	73	0	ND	(0.17)	(0.03)		
FW 614	0.18	0.121		1.49	(0.02) ^b				
FW 613	0.29	0.106		65	2.74			(0.02) ^b	(0.19)
FW 615	0.18	0.357		0.5	ND				
FW 624	-0.01	0.224	125	0	ND	0.05			
FW 625	0.52	0.205		2.54	0.04 ^c				
FW 622	0.14	0.216		0.65	ND				
FW 621	0.11	0.198		0.54	ND				
FW 627	0.11	0.568		0.19	ND				
FW 620	0.14	0.275		0.51	ND				
FW 626	0.38	0.574		0.66	ND				
FW 623	0.13	0.402		0.32	ND				
FW 407-B	1.03 ^d	0.088		0	ND				
AC-2									
FW 630	0.03	1.23		257	0.02		ND	(0.05)	(0.03)
FW 632	0.15	0.366	0.41		ND				
FW 633	0.10	0.427	0.23		ND				
FW 631	0.13	0.588	0.22		ND				
FW 391	0.12	0.454	0.26		ND				
FW 394	0.15	0.459	0.33		ND				
FW 634-B	0	0.324	0		ND				
FW 392	0.10	0.435	0.23		(0.02) ^b				
FW 393	0.10	0.426	0.23		ND				
FW 396	0.04	0.318	0.13		ND				
FW 398	0.10	0.312	0.32		ND				
FW 399	0.11	0.253	0.43		ND				
FW 641	0.11	0.630	0.17		ND				
FW 395	0.13	0.426	0.31		ND				
FW 400-B	0.03	0.420	0	(0.02) ^{b,d}	0				

^aNot detected (ND)

^bLOD = 0.015 mg

^cLOQ = 0.03 mg

^dSample rechecked by DataChem

ACGIH TLV/TWA

Total Respirable Dust = 10 mg/m³

Quartz (respirable) = 0.1 mg/m³

priate peaks indicating quartz. Regarding the indicated weight gain for blind blank FW 407-B, the manager checked the DataChem notebook and with the analyst regarding the duplicate weighings of both the prepared membrane and the submitted sample. He suggested that possibly a contaminant (dust speck or filter cutting) was picked up inadvertently during pre-weighing of the membrane and then knocked off during loading into the cassette.

After careful consideration, it was determined that these blank analyses would not jeopardize any interpretation of the results.

Bulk samples were selected from the DCT collection bag for AC-1 Run #7 in Demonstration Drift and AC-2 Runs #8 through #12 in Laser Drift. Splits of these were sent to DataChem for analysis. Table VII provides the quartz bulk analysis. Again no cristobalite or tridymite was detected. There was 6.8% quartz detected in the AC-1 dust and 11.0% detected in the AC-2 dust.

4.3.3.2. Mixed Cellulose Ester Fiber (MCEF) Membranes. MCEF membranes (0.8- μ m pore size, 25-mm gridded) loaded into three-piece, 2-in., electrically conductive, 25-mm carbon-filled polypropylene air monitor cassettes were used for fiber counting. Table VIII provides the sampling information for the fiber samples. Complete data on each sample are in Appendix D-3.

4.3.3.2.1. Phase Contrast Microscopy. The objective of this procedure was to provide information about concentrations of airborne mineral fibers produced during dry drilling operations at the YMP worksite. Samples were field collected on membrane-filter (cellulose ester) substrates for various intervals during dry drilling workdays. Particulate-loaded filters were evaluated for fiber content by use of a microscopic fiber counting method derived from the existing airborne asbestos monitoring standard (NIOSH Method 7400).²⁰ This method employs phase contrast microscopy and relies on the microscopist to distinguish fibers from nonfibers. [Fibers are defined as any particle having an aspect ratio (length versus width) $\geq 3:1$.] Fibers were counted by phase contrast microscopy, with well-defined rules at a fixed magnification of 400x, and the accumulated fiber counts were then translated to airborne fiber concentration levels for subsequent risk assessment evaluation.

Thirty-seven individual membrane filters (including six blank filters) were examined microscopically for fiber content. Few fibers were detected on any of these samples. Fiber count results obtained from these samples fell into two general categories: (1) filters containing primarily non-fibrous particulates with very few fibers discernible at 400x (i.e., fiber counts consistent with

TABLE VII
BULK SILICA SAMPLES

Sample No.	Sample Date	Quartz (%)	Cristobalite (%)	Tridymite (%)
AC-1-R7 #3	03/29/88	6.8	ND	ND
AC-2-R8-12 #3	04/13/88	11.0	ND	ND

ND = Not detected

LOD = 0.75%

LOQ = 1.5%

TABLE VIII
FIBER SAMPLING LOCATIONS

Sample No.	Sample Date	Sampling Location
AC-1		
CE 52	03/22/88	BACKGROUND sample, positioned on drill
CE 53	03/23/88	Right wall, ~3 ft behind impactor, ~6 ft above floor
CE 54	03/23/88	Left wall, approximately 6.5 ft above face
CE 55	03/23/88	Hanging above drill rig
CE 75B	03/24/88	BLIND BLANK - CE samples
CE 50B	03/28/88	BLIND BLANK - CE samples
CE 56	03/25/88	PERSONAL SAMPLE
CE 57	03/25/88	PERSONAL SAMPLE
CE 45B	04/04/88	BLIND BLANK - CE samples
CE 49B	04/04/88	BLIND BLANK - CE samples
CE 58	03/31/88	At drill to left of operator
CE 59	03/30/88	Left wall, even with drill
CE 60	03/30/88	Behind drill, to the left
CE 61	03/30/88	Right wall near DCT
CE 62	03/30/88	Between wall and drill
CE 64	03/30/88	On face in Demonstration Drift
CE 65	03/30/88	Between wall and drill rig
CE 66	03/30/88	Right wall near DCT
CE 67	03/30/88	At face in Demonstration Drift
CE 68	03/31/88	Left wall just behind drill plane
CE 69	03/30/88	Right wall near impactor at CE sample site
CE 74	03/30/88	At drill rig between drill and wall
AC-2		
CE 71	04/13/88	BACKGROUND, on Rock bolt left of drill collar
CE 72	04/14/88	On wall approximately 5 ft to right of drill collar
CE 73B	04/15/88	BLIND BLANK - CE samples
CE 1	04/14/89	Hanger between drill and table (personal area)
CE 2	04/14/88	On wall between DCT and drill collar
CE 4	04/14/88	On wall, approximately 5 ft right of drill collar
CE 6	04/14/88	On wall between DCT and drill collar
CE 3	04/20/88	On water box in middle of drift
CE 7	04/20/88	On DCT
CE 8	04/20/88	On DCT
CE 12	04/20/88	On wall by impactor, between drill and table
CE 13	04/20/88	On DCT
CE 17	04/20/88	On water box in middle of drift
CE 19	04/20/88	On wall behind DCT
CE 20B	04/26/88	BLIND BLANK - CE samples

blank/background levels), and (2) filters that were uncountable because of high particulate loading (high loading levels of deposited particulates obscure and mask possible collected fibers, making fiber detection/counting impossible). Fiber counts were obtained (from countable filters) by counting the minimum 100 optical fields. Individual fiber count results from this 37-sample field test series are listed in Table IX.

The general observation/conclusion of these fiber assessment analyses is that very few fibers were in the airborne dust samples collected. The primary particulate material on all filter samples was nonfibrous.

Only two membranes (CE 6 and CE 72), of all filters examined, contained obvious, well-defined fibrous particulates. These fibrous particles were few, unusual because of their presence in only 2 of 35 samples, and conspicuously different in morphology from anticipated erionite/mordenite previously observed in reference materials. Both samples (CE 6 and CE 72) were collected at the same general locale (near the drilling face) during the same drilling interval on the same sampling day.

Filters CE 6 and CE 72 contained fiber concentrations of 16.5 and 34.0 fibers/mm², respectively. These filter deposit concentrations translate to airborne concentration of <0.05 fibers/cm³ for CE 6 and 0.2 fibers/cm³ for CE 72, when respective sampled air volumes are included. Thus, sample CE 72 is the only sample of this 35-sample field test series that contained an airborne fiber concentration level approaching the current permissible exposure limit (PEL) established for asbestos (currently 0.2 fibers/cm³). It is important, however, to emphasize that the PCM, SEM/EDX evaluation sample CE 72, indicates that the sample did not contain asbestos, erionite, or mordenite. The collected fibers in samples CE 6 and CE 72 have been identified as crystalline CaSO₄, typically regarded as a nuisance dust for which the ACGIH TLV/TWA is 10 mg/m³. These crystals have optical properties, morphology, and elemental composition consistent with the fibrous crystals in the mortar (Sulfaset from Randustrial Co., Cleveland, Ohio) used at the YMP test drilling site. Sulfaset is a plaster-of-paris (CaSO₄)-based packing mud used for sealing the drill collar to the drilling (rock) face.

TABLE IX
YUCCA MOUNTAIN PROJECT AIR CORING FIELD TEST FIBER
COUNT AND AIRBORNE CONCENTRATION DATA^a

Sample No.	Fibers Counted per 100 Optical Fields	Sampling Volume (L)	Airborne Fiber Conc. (f/cm ³)	Comments
CE 52	2	1278.0	-	Uncountable ^b
CE 53	-	129.1	-	Uncountable ^b
CE 54	-	122.7	-	Uncountable ^b
CE 55	-	106.3	-	Uncountable ^b
CE 75	0	-	-	Filter Blank
CE 50	2	-	-	Filter Blank
CE 56	-	121.7	-	Uncountable ^b
CE 57	4	147.4	<0.05	Deposit Nonfibrous
CE 45	1	-	-	Filter Blank
CE 49	2	-	-	Filter Blank
CE 58	2	29.9	<0.05	Deposit Nonfibrous
CE 59	3	109.7	<0.05	Deposit Nonfibrous
CE 60	1	55.0	<0.05	Deposit Nonfibrous

CE 61	-	27.1	-	Very Few Particles Back-up Separator Paper In Place
CE 62	7	57.3	0.06	Few Fibers-Deposit Nonfibrous
CE 64	6	62.3	0.05	Few Fibers-Deposit Nonfibrous
CE 65	4	43.9	<0.05	Few Fibers-Deposit Nonfibrous
CE 66	4	54.2	<0.05	Few Fibers-Deposit Nonfibrous
CE 67	4	31.1	0.06	Few Fibers-Deposit Nonfibrous
CE 68	4	31.1	0.06	Few Fibers-Deposit Nonfibrous
CE 69	3	30.2	0.05	Vehicle Exhaust
CE 74	3	86.0	<0.05	Vehicle Exhaust
CE 1	2	127.8	<0.05	Deposit Nonfibrous
CE 2	3	127.5	<0.05	Deposit Nonfibrous
CE 4	2	37.0	<0.05	Deposit Nonfibrous
CE 6	13	-	<0.05	Some Fibers-Deposit Light
CE 71	1	1436.4	<0.05	Deposit Nonfibrous
CE 72	27	58.5	0.22	Some Fibers-Unusual Morphology
CE 73	2	-	-	Filter Blank
CE 3	3	121.4	<0.05	Vehicle Exhaust
CE 7	2	185.5	<0.05	Deposit Nonfibrous
CE 8	1	61.8	<0.05	Deposit Nonfibrous
CE12	2	290.8	<0.05	Deposit Nonfibrous
CE 13	2	123.7	<0.05	Deposit Nonfibrous and Vehicle Exhaust
CE 17	2	121.4	<0.05	Vehicle Exhaust
CE 19	1	60.7	<0.05	Deposit Very Light
CE 20	1	-	-	Filter Blank

Total Filters = 37 (including 6 blanks)

^aFiber counts obtained by phase contrast microscopy at 400x magnification.

^bFibers were uncountable because of high particulate loading.

It is likely that the fibrous CaSO_4 crystals collected on samples CE 6 and CE 72 originated from this packing mud (Fig. 10).

The collection and detection of these fibrous CaSO_4 crystals demonstrate that the monitoring/analytical techniques used can detect fibrous-shaped particulates at very low airborne concentrations (<0.05 fibers/cm³). The geologists have confirmed our finding by stating that fibrous zeolites have not been identified in these areas.

4.3.3.3. Nuclepore Polycarbonate Membranes. The membranes (0.2- μm pore size, 25-mm diam) loaded into 25-mm, 2-in. styrene acrylonitrile, air monitor cassettes were used as samples to be analyzed by (a) photon-induced x-ray emission (PIXE) analysis and (b) SEM with EDX.

(a) Photon-Induced X-Ray Emission Analysis was performed by Elemental Analysis Corporation (EAC), Tallahassee, Florida. PIXE analysis provides nondestructive detection and quantification for the elements sodium through uranium. Ten filter samples and two blind blanks were analyzed. The elemental determination for each sample is presented in Appendix D-4. Table X contains the date collected, core hole, and location of the sampler in the drift.

According to the Fenix & Scisson G-Tunnel geologist, both core holes were drilled in the welded Grouse Canyon Member tuff, Unit B, with AC-1 in the lower section and AC-2 in the upper section. When the PIXE analyses of the samples are compared with the whole-rock chemical analyses found in Connolly and Keil²¹ (Table XI),

Figure 10. Sulfaset (light area) anchoring spider/collar to wall in Laser Drift.

TABLE X
PIXE SAMPLING LOCATIONS

Sample Date	Sample No.	Sampling Location
AC-1		
03/29/88	NP 52	PERSONAL SAMPLE on investigator
03/30/88	NP 59	Left wall (approx. 8 ft from face) even with drill
03/30/88	NP 55	On wall of Extensiometer/ Demonstration curve
AC-2		
04/12/88	NP 47B	BLIND BLANK - PIXE sample set
04/19/88	NP 56	On face ~6.5 ft Right of collar, ~7 ft from DCT
04/19/88	NP 5	On DCT front
04/20/88	NP 22	On wire (middle of personnel area)
04/20/88	NP 4	On DCT
04/21/88	NP 27	On wall between DCT and drill collar
04/21/88	NP 10	On face, between collar (approx. 5 ft) and DCT
04/21/88	NP 14	On DCT front
04/28/88	NP 32B	BLIND BLANK - PIXE sample set

we see the similar distribution of elements. PIXE, however, reports individual elements, not oxides.

Samples NP 52 from AC-1 and NP 14 from AC-2 were chosen for trace element comparisons with the ACGIH threshold limit values. Table XII lists these data. The quantities reported for these representative samples would not cause a hazard to area personnel.

After the PIXE data were reviewed, it also became evident that each Nuclepore polycarbonate membrane filter contained bromine. We subsequently learned that the manufacturer uses bromine as a hardener in the production of the membranes and does not mention that in the literature. Fortunately, quantification of tracers such as lithium bromide was not part of the study.

PIXE analyses were performed on splits of the bulk samples AC-1 Run #7 and AC-2 Runs #8-12 and found to contain approximately the same elemental distribution as the membrane-filter samples.

4.3.3.4. Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) Analysis. Table XIII gives the collection dates, the core hole, and the sampling locations for the samples examined by SEM/EDX. Complete data for each sample are found in Appendix D-5.

Fifty membrane-filter air samples (including seven blank samples) were examined in the scanning electron microscope, with no fibers detected. All particles observed on the collection membranes were either nonfibrous or loosely bound agglomerates of nonfibrous particles. The majority of all filters contained very few particles. (A fiber is defined as any elongated particle having a minimum 3:1 aspect ratio.)

The membrane filters were prepared and analyzed according to detailed procedures. Each filter section had 100-300 fields screened, looking specifically for fibers, at 5000x magnification. Fifty to one hundred of these fields were examined in detail at 10000x magnification.

The first six filters from the field task series were prepared with a carbon-coating technique for subsequent EDX analysis. Each of these filters had photomicrographs (3) and EDX spectra obtained from them. Examples of these data are shown in Figs. 11 and 12.

Because resolution was poor with carbon coating on such fine particulates, the remaining filters were gold sputter coated, making it much easier and faster to search/screen for fibers on the collection filter surface. Only one photomicrograph was taken from each of these filters for documentation/recording (Fig. 13).

The significant observation of these SEM/EDX particle examination experiments was that no fibrous particles were detected on any of these membrane-filter-collected samples.

One bulk sample was selected from each of the DCT cuttings/collection bag for AC-1 Run #7 and AC-2 Runs #8-12. Splits of these samples were submitted for SEM/EDX analysis. The samples were prepared, gold-coated, and analyzed according to detailed procedures. No fibrous particles were detected for these two samples.

TABLE XI

WHOLE-ROCK CHEMICAL ANALYSES OF TUFF SAMPLES FROM G-TUNNEL 20

Analysis Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Unit													
Designation	TBS	A	A	A	A	B	B	B	B	C	C	C	UTZ
Sample	HB-MPBX	RMD-2	G10#5	G10#5	G10#1	RMD-4	RMD-6	RMD-9	G10#1	RMD-10	ED-2	G10#1	ED-5
	20.7		1353.8	1361.3	1368.2				1343.4			1343.4	
Oxide Wt%													
SiO ₂	67.46	64.26	68.46	73.43	80.14	74.73	71.33	72.83	72.25	73.63	73.83	71.01	63.48
TiO ₂	0.20	0.18	0.25	0.25	0.15	0.19	0.26	0.24	0.34	0.28	0.30	0.33	0.39
Al ₂ O ₃	11.88	11.66	14.80	12.98	8.60	11.25	13.00	11.80	13.20	12.16	12.54	13.50	14.30
Fe ₂ O ₃	2.73	3.38	3.90	2.77	2.00	2.50	2.46	2.24	3.07	2.65	3.09	2.92	2.99
FeO	0.01 ^a	0.40	0.11	0.75	0.12	1.13	1.60	2.51	0.23	0.73	0.19	0.31	0.04
MnO	0.121	0.156	0.170	0.152	0.094	0.132	0.154	0.148	0.147	0.145	0.147	0.162	0.153
MgO	0.205	0.26	0.084	0.084	0.042	0.06	0.06	0.10	0.10	0.05	0.112	0.11	0.56
CaO	1.66	2.07	0.14	0.14	0.13	0.19	0.33	0.36	0.24	0.18	0.19	0.16	1.85
Na ₂ O	1.52	2.33	2.54	3.05	2.12	3.40	4.25	3.95	4.53	3.47	2.70	4.06	1.29
K ₂ O	3.12	3.24	8.12	5.12	4.85	5.30	5.53	4.84	5.19	5.40	5.70	6.33	5.38
H ₂ O ⁺	6.08	6.81	0.66	0.52	1.05	0.54	0.34	0.34	0.63	0.79	0.48	0.83	5.61
H ₂ O ⁻	4.60	5.22	0.28	0.21	0.19	0.08	0.08	0.14	0.16	0.13	0.21	0.185	3.53
P ₂ O ₅	0.019	0.01	0.019	0.020	0.010	0.02	0.12	0.04	0.027	0.031	0.034	0.041	0.039
SrO	0.002	0.003	0.001 ^a	0.001 ^a	0.001 ^a	0.001 ^a	0.001 ^a	0.001 ^a	0.002 ^a	0.001 ^a	0.001 ^a	0.001 ^a	0.007
S	0.01	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a	0.01 ^a
Total	99.60	99.98	99.53	99.48	99.50	99.52	99.51	99.54	100.1	99.65	99.52	99.95	99.54
CaO ^b	33.9	33.9	1.9	2.4	2.6	3.0	4.4	5.3	3.2	2.8	3.2	2.1	30.1
Na ₂ ^b	28.1	34.5	31.6	46.4	38.9	47.9	51.5	52.4	55.2	48.0	40.5	48.3	17.8
K ₂ O ^b	38.0	31.6	66.5	51.2	58.5	49.1	44.1	42.3	41.6	49.2	56.3	49.6	52.1
Agpaltic Index	0.495	0.629	0.876	0.813	1.02	1.01	0.998	0.994	0.990	0.969	0.846	1.00	0.546
Na/F (molecular)	0.740	1.09	0.475	0.905	0.664	0.975	1.17	1.24	1.33	0.977	0.720	0.974	0.342

^aAmount shown is below detection limit.^bMolecular proportions, normalized to 100%.

TABLE XII
TRACE ELEMENT HAZARD ANALYSIS

Elements	AC-1 NP 52 (mg/m ³)	AC-2 NP 14 (mg/m ³)	ACGIH ²¹ TLV (mg/m ³)
Aluminum	0.0022	0.0031	10
Silicon	0.0072	0.0138	10 ^a
Phosphorus	0	0.0002	0.1
Sulfur	0.0017	0.002	5
Chlorine	0.0005	0.0006	1.5
Potassium	0.0009	0.0021	10 (as Potassium Silicate)
Calcium	0.0012	0.0018	10 (as Calcium Silicate)
Titanium	0.0003	0.0002	10 ^a (as Titanium Dioxide)
Chromium	0.003	0.0007	0.5
Manganese	0	0.0013	5
Iron	0.0015	0.0078	5
Nickel	<0.05 µg/m ³	<0.05 µg/m ³	0.1 (if soluble)
Copper	<0.05 µg/m ³	<0.05 µg/m ³	1
Zinc	<0.05 µg/m ³	<0.0002	10 (as Zinc Oxide dust)
Bromine	0.0001	0.0018	0.7
Strontium	0.0001	0	0
Molybdenum	0.0001	0	5 (if soluble)
Antimony	0.0001	0	0.5
Lead	0.001	<0.05 µg/m ³	0.15 (as dusts)

^aThe value is for total dust containing no asbestos and <1% free silica.

TABLE XIII
SEM/EDX SAMPLING LOCATIONS

Sample Date	Sample No.	Location	Run Time (m)
AC-1			
03/22/88	NP 71	BACKGROUND-Demonstration Drift	100
03/23/88	NP 72	ACI ^a Location, left side of Demonstration Drift	81
03/23/88	NP 73	Right wall Demonstration drift, near ACI ~6 ft above floor	72
03/25/88	NP 74	Personal sample on investigator	64.7
03/25/88	NP 75	Personal sample on investigator	68.7
03/30/89	NP 52	Personal sample on investigator	60
03/30/88	NP 59	Left wall (~8 ft from face) even with drill	30
03/30/88	NP 55	On wall of Extensiometer/Demonstration curve	68.5
03/30/88	NP 51	On DCT	15
03/30/88	NP 53	Right side Demonstration Drift even with drill	30
03/30/88	NP 54	Personal sample on investigator	50
03/30/88	NP 57	On DCT	30
03/30/88	NP 63	On DCT	15
03/30/88	NP 68	On wall of Extensiometer/Demonstration Curve	30
03/30/88	NP 69	On DCT (removed from set/contaminated)	0
04/08/88	NP 49B	BLINK BLANK - NP sample set	50
04/08/88	NP 48B	BLIND BLANK	0
AC-2			
04/12/88	NP 47B	BLANK-PIXE sample set	0
04/13/88	NP 50	BACKGROUND-on front of DCT	720
04/14/88	NP 2	On DCT	362.9
04/14/88	NP 1	On DCT	377
04/14/88	NP 64	On water box between drill and table	70.7
04/18/88	NP 67	On water box	30
04/18/88	NP 62	On water box	30
04/19/88	NP 56	On face ~6.5 ft right of collar, ~7 ft from DCT	120
04/19/88	NP 5	On DCT front	60
04/19/88	NP 66	On DCT	27
04/19/88	NP 61	Between DCT and drill collar, 5 ft right of spider	120
04/19/88	NP 35	Wall behind DCT	34
04/19/88	NP 34	Wall behind DCT	45
04/19/88	NP 24	Back wall between table and hanger	101
04/19/88	NP 19	On water box	30
04/19/88	NP 17	On water box	30
04/19/88	NP 12	On water box, approximately 9.5 ft from DCT	30
04/19/88	NP 9	On front of DCT (small leak at DCT bag)	30
04/19/88	NP 6	On water box, approximately 9.5 ft from DCT	30

04/19/88	NP 7	On water box, approximately 9.5 ft from DCT	60
04/20/88	NP 22	On wire (middle of personnel area)	209.5
04/20/88	NP 4	On DCT	152.9
04/20/88	NP 29	At DCT	102
04/20/88	NP 28	On water box	60
04/20/88	NP 26	On water box	60
04/20/88	NP 16	Personal sample on investigator	63
04/21/88	NP 27	On wall between DCT and drill collar	104
04/21/88	NP 10	On face, between collar (~5 ft) and DCT	2 ^a 2
04/21/88	NP 14	On DCT front	293.4
04/26/88	NP 40B	BLANK - NP sample set	0
04/26/88	NP 33B	BLANK - NP sample set	0
04/26/88	NP 58B	BLANK - NP sample set	0
04/28/88	NP 32B	BLANK - PIXE sample set	0

^aAndersen Cascade Impactor.

Figure 11. SEM Photomicrograph (1000x) and EDX Spectrum of NP0071-2.

Figure 12. SEM Photomicrograph (2000x) and EDX Spectrum of NP0072-1.

Figure 13. SEM Photomicrograph of NP0014 at 5000x.

4.3.3.5. Andersen Cascade Impactors, Model 2000 Mark II. These impactors were used for collecting and quantifying the particle size distribution of the airborne particulate material and total dust concentration in the range of 10-0.4- μm aerodynamic diameter. Ten desiccated/weighed Gelman DM800, 81-mm polyvinylchloride-acrylonitrile copolymer membrane filters were used on the preseparator, on impactor stages 0-7, and as the final or back-up filter (Fig. 14). A handtruck-mounted vacuum pump (with 3/4-HP motor and dual manifold) was used to draw air through the impactor sample sets. A calibrated 10 liters/revolution Singer Dry Gas Meter was used for calibrating the impactor/vacuum pump before each sampling session. Figure 15 shows the impactor and vacuum pump in Demonstration Drift. (This figure clearly shows the airborne dust.)

4.3.3.5.1 Respirable Size Analysis By Cascade Impactors. The data for these samples are found in Appendix D-6. Table XIV indicates the date and location of the sample sets.

The particle size distribution was determined with the Model 2000 Andersen Cascade Impactor, operated at 1 acfm flow rate, with flow calibrations conducted at the sampling site preparation area.

A computer program designed for reducing raw impactor data was used in the analysis. It takes into consideration the reduced atmospheric pressure (from sea level) that affects the "slip" of the particle as it goes through the impactor jet. Log-probability graphs of the diameter versus cumulative percent values were prepared for each sample. Figures 16a and b show the log-probability graph and the chart of the data generated by the computer program. The data for AC-2 did not fit a log-normal distribution and indicated a possible bimodal distribution. This result is attributed to the large number of diesel particles found on the latter stages and final filter of the impactor samples. Such amounts are commonly found in mine and underground environments where diesel engines are used.

For AC-1 in Demonstration Drift, the particle size distribution ranged from 1.9- μm to 3.8- μm mass median aerodynamic diameter (mmad) with a

Figure 14. Investigator preparing impactor filters.

Figure 15. Cascade impactor (mid right) and vacuum pump (lower right) in Demonstration Drift.

TABLE XIV
CASCADE IMPACTOR SAMPLING LOCATIONS

Sample Date	DM Filter Set	Sampling Location
AC-1		
03/23/88	DM 06A	Left side Demonstration Drift, approximately 12 ft from face
03/23/88	DM 05A	Right side Demonstration Drift, approximately 12 ft from face
03/24/88	DM 07A	BACKGROUND-Demo. Drift-Muckers recently in main tunnel
03/24/88	DM 08A	BACKGROUND-Demo. Drift-Muckers recently in main tunnel
03/24/88	DM 03A	(Negative weights for all but final stage, UNUSABLE)
03/25/88	DM 04A	Left impactor position (12 ft from Demo. Drift face)
03/29/88	DM 02A	Left wall, approximately 12 ft from Demonstration Drift face
03/29/88	DM 01A	Right wall, approximately 12 ft from Demonstration Drift face
AC-2		
04/14/88	DM 10A	Center of Laser Drift, approximately 15 ft from face
04/19/88	DM 09A	(Negative weights for Stages 2-7, UNUSABLE DATA)
04/19/88	DM 12A	(Negative weights for Stages 1-7, UNUSABLE DATA)
04/20/88	DM 13A	Wall opposite core hole, approximately 20 ft between table and drill
04/20/88	DM 14A	Between laser core hole and DCT, near wall
04/21/88	DM 15A	Center of Laser Drift, approximately 15 ft from face

Figure 16.

(a) Log Probability Graph of Sample DM-SA compared to computer results.

MMAD = 2.25260 μm
 DELTA = 0.30240 μm
 SIGMA = 2.77644
 CORRELATION = 0.99146
 INPACTOR CONCENTRATION IS 3.53 mg/m^3

STG	NUM JETS	JET CMS	SEP CMS	RATIO	STOKES	ECD MICRONS	PC ACC OBS	PC ACC CALC	SQUARE ERROR
1	9	0.2550	0.2286	0.896	0.470	11.00	100.00	100.00	0.000E+00
2	96	0.1887	0.2286	1.211	0.470	9.76	91.85	92.46	0.169E-02
3	400	0.0914	0.2286	1.500	0.470	6.17	86.07	83.84	0.911E-02
4	400	0.0711	0.2286	3.214	0.470	4.22	78.43	73.07	0.295E-01
5	400	0.0533	0.2286	4.286	0.470	2.86	53.85	59.27	0.191E-01
6	400	0.0343	0.2286	6.667	0.470	1.823	32.79	41.79	0.568E-01
7	400	0.0254	0.2286	9.000	0.470	0.891	17.15	18.19	9.160E-02
8	201	0.0254	0.2286	9.000	0.470	0.533	7.70	7.90	0.177E-03
9	0	0	0	0	0.470	0.348	5.19	3.36	0.414E-01

(b) Computer program results of Sample DM-SA.

geometric standard deviation sigma of 2.5-3.8. Gross concentrations averaged 3.37 mg/m^3 .

For AC-2 in Laser Drift, the particle size distribution ranged from $0.97\text{-}\mu\text{m}$ to $1.47\text{-}\mu\text{m}$ mmad and had a sigma of 6.06-9.8. Gross concentrations for AC-2 samples averaged 0.57 mg/m^3 .

These impactor samples indicate a significant number of particles smaller than $0.4 \mu\text{m}$, as shown by the high percentage of the total amount of aerosol collected on the final filters. Many of these smaller particles are identified as diesel exhaust particles. Diesel exhaust particles are found in the $0.25\text{-}0.26\text{-}\mu\text{m}$ size range and thus would not affect any of the Andersen impactor stages.²³ Any further particle sizing or separation would require additional sampling with equipment appropriate for this size range.

Samples from AC-2 contained smaller particles. This condition may be attributable to the lower dust level and the influence of the diesel exhaust particle size. The "mucker" (without an exhaust scrubber) operated more frequently in the vicinity of AC-2 during sampling. The ventilation of Laser Drift was such that more of the diesel particles and fine floor dust raised by the mucker were carried into the AC-2 area during sampling than into the AC-1 area.

4.3.3.5.2 Conclusions from the Impactor Data. Dry (air) coring generates a small dust particle. Eighty-six to ninety percent of the gross concentration is within the respirable range as described by Hines.²⁴ The lower dust levels observed in AC-2 are attributed to the progressively implemented dust control measures designed into the dust collection system. Some emission still occurred but at a much lower concentration.

5. ON-SITE OBSERVATIONS

Shortly after air coring of AC-1 began, dust emissions vented from around the DCT collar and from the attachment position of the plastic cuttings/collection bag at the bottom of the dust collector. All personnel in the drill area were wearing required safety equipment, including Mine Safety Appliance (MSA) Ultravue powered air-purifying respirators (PAPRs) (Figure 17). The REECO industrial hygiene measurements showed this dust emission to be approximately 22 mg/m^3 with the Mini-Ram (a hand-held, light-scattering photometer).¹⁸ LANL drilling personnel had expected initial leaks in the DCT system, but they did

not know what the severity would be. The drilling was stopped. The tunnel exhaust system cleared the dust from the area within 5-10 min.

To modify the DCT collar, the LANL drilling consultant designed rubber rings (approximately 6-in. diam) to act as seals when placed tightly between the collar and the drill stem. The seals were constructed by on-site REECO personnel. Additional dust control was provided by an 8-in-diam exhaust duct extended from the main tunnel exhaust line positioned in front of the collar to capture any subsequent fugitive dust emissions. A second 8-in-diam duct was placed at the top vent of the dust collector to capture and exhaust any emissions from this area. The airflow of the 8-in. lines was measured at 380 cfm. The second emission site was sealed by securely taping the metal clamp and top of the cuttings/collection bag to the DCT cyclone.

During AC-1, the DCT cleaning procedures were developed and modified as needed. At prescribed intervals, the drilling helper reduced the DCT intake air and turned on the air to the two DCT vibrators (air-activated) ball bearings within a race, which shook the 18 secondary-stage filter bags inside the upper DCT section, allowing the accumulated dust to fall down through the cyclone (bottom section) and into the plastic cuttings/collection bag. Also, the helper vigorously pounded on the DCT's external shell with a hammer to assist the vibrators. The pounding increased the high noise level of the unit. Manual fluctuation of the DCT pressurizing air also helped clean the filters. A procedure was also developed for changing the DCT plastic cuttings/collection bags. Industrial hygiene suggested closing and securing the filled bag before removal from the bottom of the DCT to decrease the potential for emissions from the open bag.

6. RESULTS AND CONCLUSIONS FOR G-TUNNEL PROTOTYPE AIR CORING

- (1) SEM/EDX and XRDA are required for specific identification/quantification of the fibrous zeolites, erionite, and mordenite.
- (2) Cleaning the collection equipment and disposing of collected material (dust) are labor intensive and require care to avoid area contamination and personnel exposure.

Figure 17. Personnel in AC-1 are wearing PAPRs and air-monitoring equipment.

- (3) A supplementary exhaust system is required (a) to remove emissions from the air cleaner, (b) to control fugitive emissions, and (c) to provide dilution ventilation to the area.
- (4) Modifications to the dust collection system reduced the measured respirable dust mass from an average of 1.02 mg/m^3 during AC-1 to 0.27 mg/m^3 for AC-2.
- (5) Crystalline silica analysis detected no cristobalite or tridymite. One quartz positive (0.04 mg/m^3) was detected, and four quantities (0.02 mg/m^3) were within the level of detection and quantification of the analytical instrumentation. When 8-hour TWAs were calculated for these samples, they were below the ACGIH TLV/TWA for quartz (0.1 mg/m^3) because of the short duration of the drilling operations (Table VI). Analysis of the bulk samples from both core holes shows available quartz in the bagged dust from the DCT. The very low quantities reported in the air particulate samples indicate that the modified dust control system was efficient when it functioned properly. Crystalline silica was not a significant problem during air coring of AC-1 and AC-2. However, quartz could become a problem if air coring operations are extended to 8-hours at the observed concentrations and efficient dust collection systems are not used and maintained properly.
- (6) Zeolite fibers were not detected in AC-1 and AC-2 airborne particulate samples collected during air coring.
- (7) The dust control system in the sampled configuration was effective. The dust control system is defined as the electric drill, Atlas-Copco DCT, the G-Tunnel exhaust ventilation system, the G-Tunnel Safety and Health work practices, etc.

- (8) Diesel particulates from vehicles working in the G-Tunnel area were detected. Vehicle exhausts should be controlled to maintain acceptable air quality (on a case-by-case basis). NIOSH has recommended that "Diesel exhaust should be regarded as a potential occupational carcinogen on the basis of evidence from available studies, and employers should take steps to limit worker exposure to the greatest extent feasible."²⁵

7. RECOMMENDATIONS FOR EXPLORATORY SHAFT FACILITY AT YUCCA MOUNTAIN (TASK 4)

Based on the findings presented in this report, we recommend that the following be implemented in future drilling activities.

- (1) General dilution ventilation must be provided to the drilling site to control employee exposures to fugitive dust and vehicle emissions.
- (2) Local exhaust ventilation must be provided on major emission sources (e.g., drill stem/collar opening).
- (3) Air supplied to the drill hole must be balanced at all times with the dust collection equipment. (Imbalance creates excess emissions.)
- (4) Area employees (workers and investigators) must be fitted for, provided with, and trained to wear air-purifying respirators. The respirators would be used only in emergency situations when the worker or investigator is required in the area during large emissions.
- (5) Dust control equipment, equivalent to or superior to the Atlas-Copco DCT, should be in operation during any dry or air drilling activity. (Dust collection principles employed by these devices apply to all particle shapes.)
- (6) Dust collection equipment should be used as part of and exhausted to the local exhaust ventilation system.
- (7) All potential emission sources should be identified in advance of drilling, and emission control strategies developed. This recommendation should be implemented on a case-by-case basis because emission sources will vary from site to site.
- (8) Air particle sampling and analysis should be provided to evaluate the effectiveness of the controls.
- (9) Dust collection equipment should be tested before start-up and monitored periodically throughout drilling to ensure adequate performance.
- (10) Vehicle exhausts should be kept as low as reasonably achievable (by routine vehicle tuneups, addition of scrubbers, good local exhaust, or dilution ventilation).
- (11) All equipment should be correctly maintained and kept in working order. No drilling operations should be conducted if dust collection equipment is not functioning properly.
- (12) Safe operation procedures should be developed and implemented to ensure continued safe operation of equipment.
- (13) Employees should be trained before they begin the job and during the job to perform their work such that emissions and exposures are minimized.
- (14) Contingency plans should be developed in advance to cope with equipment failures. Such plans should include the shutdown of drilling operations in the event that control equipment (i.e., tunnel ventilation) systems fail.
- (15) Drilling operations should adhere to existing health and safety requirements applicable to the site (e.g., REEC_o and Mine Safety and Health Association requirements).
- (16) One should not conclude that zeolite fibers do not exist because they were not detected in the limited sampling data collected from

air coring tests in G-Tunnel tuffs. The potential hazard to personnel working in the Yucca Mountain area (based on geologic mapping) mandates that similar sampling and analysis for fibrous zeolites, especially mordenite, be performed during drilling at Yucca Mountain to determine the hazards and appropriate protection for personnel.

- (17) Animal inhalation studies with fibrous mordenite (identified as being one of the primary zeolites in the Yucca Mountain tuffs) should be conducted to determine the biological effects of this fibrous zeolite.

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APPENDIX A

ESTIMATES OF EXPECTED EXPOSURE CONCENTRATION TO DRILL DUST

Unfortunately, there is little information with which to quantify the emission sources, except for fugitive emissions from the dust collector.

Terms used in calculation are defined below:

W_f = emission to air (mg/m^3)

C = concentration of dust in air (mg/m^3)

K = mixing factor (unitless)

W_t = weight of rock drilled out of hole (does not include rock core)
(mg/min)

W_s = weight of rock material collected in preseparators (mg/min)

W_c = weight of dust collected in air cleaner (mg/min)

N = efficiency of air cleaner (unitless)

D_2 = outside diameter of drilled material (in.)

D_1 = outside diameter of core (in.)

L = length of drilled core (in.)

t = time of drilling (min)

S.G. = specific gravity of rock (water)

Q_s = air supplied to the drill area (actual ft^3/min)

Q_r = air returned (or exhausted) from the drill area (acfm)

Vol = volume of air in tunnel between drill face and some distance back
from the face (ft^3)

h = height of tunnel (ft)

ℓ = length of tunnel (ft)

T = temperature of tunnel air ($^{\circ}\text{F}$)

d = density correction for air at temperature and pressure (unitless)

Estimated values of the input terms, obtained from manufacturer's data and from drill operations descriptions, are summarized below:

$$K = 0.80$$

$$S.G. = 3, \text{ unitless}$$

$$L/t = 0.60 \text{ in./min}$$

$$W_s = 0.9 W_t \text{ mg/min}$$

$$D_1 = 2.5 \text{ in.}$$

$$Q_s = Q_r = 3500 \text{ acfm}$$

$$D_2 = 3.79 \text{ in.}$$

$$h = 20 \text{ ft}$$

$$T = 65^\circ\text{F}$$

$$f = 30 \text{ ft}$$

$$d = 0.80$$

$$N = 99.5\%$$

The following equations were used to estimate C , the expected airborne concentration of dust in air.

$$C = \frac{\text{Weight of Material Generator/Time}}{\text{Volume of Air}} \times \frac{1}{K} \quad (\text{A-1})$$

$$W_c = W_t = W_s \quad (\text{A-2})$$

$$W_f = (W_t - W_s) (1 - N) \quad (\text{A-3})$$

$$W_T = 0.0129 (D_{22} - D_{12}) \frac{L}{T} (S.G.) \times 10^6 \quad (\text{A-4})$$

$$W_F = 0.0129 (D_{22} - D_{21}) \frac{L}{T} \frac{SG}{10^{-6}} WS (1 - N) \quad (A-5)$$

and

$$Q_{OUT} = Q_{IN} - Q_{LOST} \quad (A-6)$$

$$Q_{EXHAUSTED\ IN} = Q_{OUT} + Q_{EXCESS} \quad (A-7)$$

$$W_T = 0.0129 (D_{22} - D_{12}) \frac{L}{T} (S.G.) \times 106 \text{ in.} \frac{\text{mg}}{\text{min}}$$

$$= 0.0129 (37902 - 2.52) (0.6) (3.0) (106)$$

$$= 0.1884 \times 106 \text{ mg/min}$$

$$W_F = (W_T) (0.1) (1 - 0.995)$$

$$= (0.1884 \times 106) (0.1) (0.005)$$

$$W_F = 94.2 \frac{\text{mg}}{\text{min}}$$

$$C = \frac{\text{mg/min} (3.53)}{Q_S} \times \frac{L}{K}$$

$$= \frac{(94.2) (35.3)}{3500} \times \frac{1}{0.8}$$

$$= 1.2 \text{ mg/m}^3$$

APPENDIX B

COLLECTOR EFFICIENCY

DCT units

Like most dust removal equipment, DCT units have a suction hood which is positioned over the drill hole to suck up the dust. A hose transports the dust to a separation unit for accumulation. The necessary partial vacuum is created with an air-powered ejector, or, in certain cases, with a fan. One basic design difference in different types of dust extractor equipment is the positioning of the ejector or fan. This positioning determines whether the system works with overpressure or with a partial vacuum. DCT dust collection equipment works with a partial vacuum throughout the entire system. The ejector or fan, which creates a partial vacuum, is positioned at the final stage, after the filter unit. This offers several advantages, including:

- = no leakage of dust in the event of a hose leak or damage to the suction hose
- = the ejector or fan operates in clean, filtered air, keeping wear to a minimum
- = less load on the filters when the ejector is used, since the operative air of the ejector does not need to pass through the filters, nor come into contact with any oil that may be contained in the compressed air.

Fig. 19:45 Hand-held rock drill with dust collecting equipment

DCT separates almost all injurious stone dust

In DCT equipment dust separation is a two-stage process. A cyclone separates about 90 per cent of the stone dust, including all particles larger than 200 micrometres (0.2 millimetres) in size. The remainder of the dust, including the dangerous fine particles (less than 0.5 micrometres) is separated to practically 100 per cent in the filtration unit. The filters are encased inside a robust metal container, the lower part of which is designed as a coarse filter and where vital components are protected with anti-wear rubber. The container prevents mechanical wear and protects the filters during unfavourable weather conditions. It also houses the filter cleaning equipment and the drive ejector. On larger DCT units, the ejector is positioned on top of the container and can be replaced with a separately positioned centrifugal fan if preferred.

DCT design features

The smaller DCT units have a cylindrical container which encases a number of hose filters, while the larger DCT units have rectangular sections containing flat filters. Separation of the dust in the hose filters occurs internally, whereas the flat filters separate the dust externally.

31134-1

Fig. 19:46 DCT dust collecting equipment, smaller size

1. separator with hose filters
2. suction hood
3. suction hose
4. ejector
5. brake ejector

- Key:
- 1 Inertial Collector
 - 2 Medium Efficiency Cyclone
 - 3 Low Resistance Cellular Cyclones
 - 4 High Efficiency Cyclone
 - 5 Impingement Scrubber (Doyle Type)
 - 6 Self Induced Spray Deduster
 - 7 Void Spray Tower
 - 8 Fluidized Bed Scrubber
 - 9 Irrigated Target Scrubber (Peabody Type)
 - 10 Electrostatic Precipitator
 - 11 Irrigated Electrostatic Precipitator
 - 12 Flooded-Disc Scrubber Low-Energy
 - 13 Flooded-Disc Scrubber Med.-Energy
 - 14 Venturi-Scrubber, Med.-Energy
 - 15 High-Efficiency Electrostatic Precipitator
 - 16 Venturi Scrubber - High Energy
 - 17 Shaker-Type Fabric Filter
 - 18 Reverse-Jet Fabric Filter

(from Stairmand)

Extrapolated fractional efficiency of control devices. (From Vandergrift.)

94P-15063-C

RANGE OF PARTICLE SIZES, CONCENTRATION, & COLLECTOR PERFORMANCE

COMPILED BY S. SYLVAN APRIL 1952 : COPYRIGHT 1952 AMERICAN AIR FILTER CO. INC.

ACKNOWLEDGEMENTS OF PARTIAL SOURCES OF DATA REPORTED:

FRANK M.C. - AMERICAN AIR FILTER - SIZE AND CHARACTERISTICS OF AIR BORNE SOLIDS - 1931

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APPENDIX C
DETAILED PROCEDURES

<u>DETAILED PROCEDURE</u>	<u>TITLE</u>	<u>EFFECTIVE DATE</u>
TWS-HSE5-DP-201 (R0)	Air Particulate Sampling Preparation Procedure for SEM Evaluation.	11-06-87
TWS-HSE5-DP-202 R0	Operating Instructions for AMRAY Model 1000 Scanning Electron Microscope and Kevex Model 7000 Energy Dispersive X-Ray Analyzer for Evaluation of Air Samples Collected on Nuclepore Filters.	11-06-87
TWS-HSE5-DP-206 R0	Fiber Counting Procedure.	09-21-87
TWS-HSE5-DP-211 R0	Preparation and Use of Air Particulate Filter Sampling Devices.	10-27-87
TWS-HSE5-DP-212 R0	Preparation, Calibration and Use Cascade Impactors.	09-09-87
TWS-HSE5-DP-213 R0	Procedures for the Calibration and Use of SKC Personal Sampling Pumps.	09-21-87
TWS-HSE5-DP-214 R0	Procedures for the Calibration and Use of Alpha-1 Personal Sampling Pumps.	09-21-87
TWS-HSE5-DP-215 R0	Procedures for the Calibration of the Singer Dry Gas Meter.	09-08-87

Copies of these DPs and all subsequent changes are contained in the Los Alamos National Laboratory Quality Assurance Documents for the Yucca Mountain Project 1988.

APPENDIX D-1

GRAVIMETRIC SAMPLE ANALYTICAL DATA

SAMPLE NO.: PV 3
SAMPLE DATE: 03/22/88

CORE HOLE: AC-1
LOCATION: BACKGROUND, right side: 5 ft
from floor, 20 ft from face

PRE-WEIGHT (gm): 0.019838
POST-WEIGHT (gm): 0.019956
WEIGHT GAIN (gm): 0.000118 (μg) 118

INDICATED FLOW (liters/m): 2.47
CORRECTED FLOW (liters/m): 2.393
RUN TIME (m): 992

AIR VOLUME (liters): 2373.9 (m^3) 2.3739
WEIGHT PER VOL (gm/liters): 0.00000005
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 49.707 (mg/m^3)

SAMPLE NO.: PV 5
SAMPLE DATE: 03/24/88

CORE HOLE: AC-1
LOCATION: On right wall, approximately 16 ft
from drill

PRE-WEIGHT (gm): 0.02263
POST-WEIGHT (gm): 0.023019
WEIGHT GAIN (gm): 0.000389 (μg) 389

INDICATED FLOW (liters/m): 1.993
CORRECTED FLOW (liters/m): 1.922
RUN TIME (m): 65

AIR VOLUME (liters): 124.93 (m^3) 0.1249
WEIGHT PER VOL (gm/liters): 0.00000311
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 3114.5 (mg/m^3)

SAMPLE NO.: PV 6
SAMPLE DATE: 03/30/88

CORE HOLE: AC-1
LOCATION: Right wall, approximately 16 ft from
face, set for work shift

PRE-WEIGHT (gm): 0.021936
POST-WEIGHT (gm): 0.022628
WEIGHT GAIN (gm): 0.000692 (μg) 692

INDICATED FLOW (liters/m): 1.954
CORRECTED FLOW (liters/m): 1.883
RUN TIME (m): 338

AIR VOLUME (liters): 636.45 (m^3) 0.6365
WEIGHT PER VOL (gm/liters): 0.00000109
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 1087.2 (mg/m^3)

SAMPLE NO.: PV 9
SAMPLE DATE: 03/30/88

CORE HOLE: AC-1
LOCATION: Area sample on drill (left overnight)

PRE-WEIGHT (gm): 0.019402
POST-WEIGHT (gm): 0.021054
WEIGHT GAIN (gm): 0.001652 (μg) 1652

INDICATED FLOW (liters/m): 1.988
CORRECTED FLOW (liters/m): 1.917
RUN TIME (m): 900

AIR VOLUME (liters): 1725.3 (m^3) 1.7253
WEIGHT PER VOL (gm/liters): 0.00000096
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 957.51 (mg/m^3)

SAMPLE NO.: PV 15
SAMPLE DATE: 03/30/88

CORE HOLE: AC-1
LOCATION: Begin/Extens. Drift, inside curve,
right side

PRE-WEIGHT (gm): 0.02005
POST-WEIGHT (gm): 0.020178
WEIGHT GAIN (gm): 0.000128 (μg) 128

INDICATED FLOW (liters/m): 2.34
CORRECTED FLOW (liters/m): 2.265
RUN TIME (m): 206.1

AIR VOLUME (liters): 466.82 (m^3) 0.4668
WEIGHT PER VOL (gm/liters): 0.00000027
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 274.21 (mg/m^3)

SAMPLE NO.: PV 17
SAMPLE DATE: 04/13/88

CORE HOLE: AC-2
LOCATION: BACKGROUND, rock bolt left of
collar (spider)

PRE-WEIGHT (gm): 0.019685
POST-WEIGHT (gm): 0.019751
WEIGHT GAIN (gm): 0.000066 (μg) 66

INDICATED FLOW (liters/m): 1.787
CORRECTED FLOW (liters/m): 1.718
RUN TIME (m): 720

AIR VOLUME (liters): 1237 (m^3) 1.237
WEIGHT PER VOL (gm/liters): 0.00000005
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 53.355 (mg/m^3)

SAMPLE NO.: PV 22
SAMPLE DATE: 04/20/88

CORE HOLE: AC-2
LOCATION: Rock bolt between DCT and drill
collar (spider)

PRE-WEIGHT (gm): 0.019912
POST-WEIGHT (gm): 0.01997
WEIGHT GAIN (gm): 0.000058 (μg) 58

INDICATED FLOW (liters/m): 1.784
CORRECTED FLOW (liters/m): 1.715
RUN TIME (m): 211.2

AIR VOLUME (liters): 362.21 (m^3) 0.3622
WEIGHT PER VOL (gm/liters): 0.00000016
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 160.13 (mg/m^3)

SAMPLE NO.: PV 31
SAMPLE DATE: 04/14/88

CORE HOLE: AC-2
LOCATION: Left wall by drill collar (spider)

PRE-WEIGHT (gm): 0.019902
POST-WEIGHT (gm): 0.020242
WEIGHT GAIN (gm): 0.00034 (μg) 340

INDICATED FLOW (liters/m): 1.967
CORRECTED FLOW (liters/m): 1.896
RUN TIME (m): 372

AIR VOLUME (liters): 705.31 (m^3) 0.7053
WEIGHT PER VOL (gm/liters): 0.00000048
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 482.06 (mg/m^3)

SAMPLE NO.: PV 36
SAMPLE DATE: 04/20/88

CORE HOLE: AC-2
LOCATION: Hanging on wire (middle of
personnel area)

PRE-WEIGHT (gm): 0.022456
POST-WEIGHT (gm): 0.022577
WEIGHT GAIN (gm): 0.000121 (μg) 121

INDICATED FLOW (liters/m): 2.227
CORRECTED FLOW (liters/m): 2.153
RUN TIME (m): 218

AIR VOLUME (liters): 469.35 (m^3) 0.4694
WEIGHT PER VOL (gm/liters): 0.00000026
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 257.78 (mg/m^3)

SAMPLE NO.: PV 47
SAMPLE DATE: 04/14/88

CORE HOLE: AC-2
LOCATION: Hanging behind DCT

PRE-WEIGHT (gm): 0.023795
POST-WEIGHT (gm): 0.024137
WEIGHT GAIN (gm): 0.000342 (μg) 342

INDICATED FLOW (liters/m): 1.928
CORRECTED FLOW (liters/m): 1.858
RUN TIME (m): 368

AIR VOLUME (liters): 683.74 (m^3) 0.6837
WEIGHT PER VOL (gm/liters): 0.0000005
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 500.22 (mg/m^3)

SAMPLE NO.: PV 13B
SAMPLE DATE: 04/07/88

CORE HOLE: AC-1
LOCATION: BLANK - PV samples

PRE-WEIGHT (gm): 0.02013
POST-WEIGHT (gm): 0.020108
WEIGHT GAIN (gm): -0.00002 (μg) -20

INDICATED FLOW (liters/m): 0
CORRECTED FLOW (liters/m): 0
RUN TIME (m): 0

AIR VOLUME (liters): 0 (m^3) 0
WEIGHT PER VOL (gm/liters): 0
WEIGHT PER VOL ($\mu\text{g}/\text{m}^3$): 0 (mg/m^3)

APPENDIX D-2

SILICA SAMPLE ANALYTICAL DATA

SAMPLE ID: FW 391

SAMPLE DATE: 04/19/88

CORE HOLE: AC-2

LOCATION: Personal Sample [Personal Sample (PS)-driller]

PUMP FLOW [corrected] (liters/m): 1.679

RUN TIME (min): 270.1

AIR VOLUME (liters): 453.5

TOTAL WT. GAIN (mg): 0.12

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 392

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: Personal Sample (PS)-(WEARER was Out of Area approximately 25 min AM + approximately 45 min PM)

PUMP FLOW [corrected] (liters/m): 1.693

RUN TIME (min): 257

AIR VOLUME (liters): 435.1

TOTAL WT. GAIN (mg): 0.10

QUARTZ (mg): (0.02) LOD

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 393

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: Laser Drift, rock bolt 6 ft from drill collar

PUMP FLOW [corrected] (liters/m): 1.66

RUN TIME (min): 256.6

AIR VOLUME (liters): 426

TOTAL WT. GAIN (mg): 0.10

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 394

SAMPLE DATE: 04/19/88

CORE HOLE: AC-2

LOCATION: Wire hanger 6 ft high (in personnel area)

PUMP FLOW [corrected] (liters/m): 1.7

RUN TIME (min): 270

AIR VOLUME (liters): 459

TOTAL WT. GAIN (mg): 0.15

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 395

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: Laser Drift, on front of DCT

PUMP FLOW [corrected] (liters/m): 1.662

RUN TIME (min): 256.1

AIR VOLUME (liters): 425.6

TOTAL WT. GAIN (mg): 0.13

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 396

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: Laser Drift incline just below core boxes

PUMP FLOW [corrected] (liters/m): 1.656

RUN TIME (min): 192

AIR VOLUME (liters): 318

TOTAL WT. GAIN (mg): 0.04

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 398

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: Personal Sample (PS)-driller

PUMP FLOW [corrected] (liters/m): 1.704

RUN TIME (min): 183

AIR VOLUME (liters): 311.8

TOTAL WT. GAIN (mg): 0.10

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 399

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: Wire hanger 6 ft high (in personnel area)

PUMP FLOW [corrected] (liters/m): 1.718

RUN TIME (min): 263.9

AIR VOLUME (liters): 253.4

TOTAL WT. GAIN (mg): 0.11

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 400-B

SAMPLE DATE: 04/21/88

CORE HOLE: AC-2

LOCATION: BLIND BLANK - FW samples

PUMP FLOW [corrected] (liters/m): 0

RUN TIME (min): 0

AIR VOLUME (liters): 420.1

TOTAL WT. GAIN (mg): 0.03

QUARTZ (mg): (0.02) LOD

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 407-B

SAMPLE DATE: 04/05/88

CORE HOLE: AC-1

LOCATION: BLIND BLANK - FW samples

PUMP FLOW [corrected] (liters/m): 1.753

RUN TIME (min): 50

AIR VOLUME (liters): 87.7

TOTAL WT. GAIN (mg): 1.03

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 610

SAMPLE DATE: 03/22/88

CORE HOLE: AC-1

LOCATION: BACKGROUND - Demo. Drift, on DCT approximately 4 ft above floor

PUMP FLOW [corrected] (liters/m): 1.678

RUN TIME (min): 100

AIR VOLUME (liters): 167.8

TOTAL WT. GAIN (mg): 0.03

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 611

SAMPLE DATE: 03/22/88

CORE HOLE: AC-1

LOCATION: BACKGROUND - right side, approximately 8 ft face, approximately 4 ft above floor

PUMP FLOW [corrected] (liters/m): 1.705

RUN TIME (min): 998

AIR VOLUME (liters): 1702

TOTAL WT. GAIN (mg): 0.05

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 612

SAMPLE DATE: 03/23/88

CORE HOLE: AC-1

**LOCATION: Personal Sample (PS)-helper, during
DCT & collar leak**

PUMP FLOW [corrected] (liters/m): 1.684

RUN TIME (min): 102.1

AIR VOLUME (liters): 171.8

TOTAL WT. GAIN (mg): 0.20

QUARTZ (mg): (0.02) LOD

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 613

SAMPLE DATE: 03/25/88

CORE HOLE: AC-1

**LOCATION: Personal Sample (PS)-drilling
consultant**

PUMP FLOW [corrected] (liters/m): 1.63

RUN TIME (min): 65.32

AIR VOLUME (liters): 106.3

TOTAL WT. GAIN (mg): 0.29

QUARTZ (mg): (0.02) LOD

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 614

SAMPLE DATE: 03/25/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-driller

PUMP FLOW [corrected] (liters/m): 1.656

RUN TIME (min): 73

AIR VOLUME (liters): 120.9

TOTAL WT. GAIN (mg): 0.18

QUARTZ (mg): (0.02) LOD

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 615

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-driller

PUMP FLOW [corrected] (liters/m): 1.614

RUN TIME (min): 221.1

AIR VOLUME (liters): 356.9

TOTAL WT. GAIN (mg): 0.18

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 616

SAMPLE DATE: 03/23/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-driller

PUMP FLOW [corrected] (liters/m): 1.67

RUN TIME (min): 76

AIR VOLUME (liters): 126.9

TOTAL WT. GAIN (mg): 0.12

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 619-B

SAMPLE DATE: 03/24/88

CORE HOLE: AC-1

LOCATION: BLIND BLANK - FW samples

PUMP FLOW [corrected] (liters/m): 1.71

RUN TIME (min): 150

AIR VOLUME (liters): 256.5

TOTAL WT. GAIN (mg): -0.02

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITTE (mg): ND

SAMPLE ID: FW 620

SAMPLE DATE: 03/30/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-driller

PUMP FLOW [corrected] (liters/m): 1.646

RUN TIME (min): 167.1

AIR VOLUME (liters): 275.1

TOTAL WT. GAIN (mg): 0.14

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITITE (mg): ND

SAMPLE ID: FW 621

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-investigator

PUMP FLOW [corrected] (liters/m): 1.622

RUN TIME (min): 122

AIR VOLUME (liters): 197.9

TOTAL WT. GAIN (mg): 0.11

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITITE (mg): ND

SAMPLE ID: FW 622

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-drilling
consultant

PUMP FLOW [corrected] (liters/m): 1.646

RUN TIME (min): 131

AIR VOLUME (liters): 215.6

TOTAL WT. GAIN (mg): 0.14

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITITE (mg): ND

SAMPLE ID: FW 623

SAMPLE DATE: 03/30/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-drilling
consultant

PUMP FLOW [corrected] (liters/m): 1.698

RUN TIME (min): 237

AIR VOLUME (liters): 402.4

TOTAL WT. GAIN (mg): 0.13

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITITE (mg): ND

SAMPLE ID: FW 624

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: Personal Sample (PS)-helper (no
weight gain)

PUMP FLOW [corrected] (liters/m): 1.685

RUN TIME (min): 132.9

AIR VOLUME (liters): 223.9

TOTAL WT. GAIN (mg): -0.01

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITITE (mg): ND

SAMPLE ID: FW 625

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: Demo. Drift face between DCT &
collar

PUMP FLOW [corrected] (liters/m): 1.646

RUN TIME (min): 124.3

AIR VOLUME (liters): 204.6

TOTAL WT. GAIN (mg): 0.52

QUARTZ (mg): 0.04

CRISTOBALITE (mg): ND

TRIDYMITITE (mg): ND

SAMPLE ID: FW 626

SAMPLE DATE: 03/30/88

CORE HOLE: AC-1

LOCATION: Demo. Drift left wall above impactor

PUMP FLOW [corrected] (liters/m): 1.684

RUN TIME (min): 340.9

AIR VOLUME (liters): 574.1

TOTAL WT. GAIN (mg): 0.38

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 627

SAMPLE DATE: 03/30/88

CORE HOLE: AC-1

LOCATION: Demo. Drift right wall above impactor

PUMP FLOW [corrected] (liters/m): 1.679

RUN TIME (min): 338.8

AIR VOLUME (liters): 568.9

TOTAL WT. GAIN (mg): 0.11

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 630

SAMPLE DATE: 04/13/88

CORE HOLE: AC-2

LOCATION: BACKGROUND - Laser Drift - On drill hoist chain

PUMP FLOW [corrected] (liters/m): 1.708

RUN TIME (min): 720

AIR VOLUME (liters): 1230

TOTAL WT. GAIN (mg): 0.03

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 631

SAMPLE DATE: 04/14/88

CORE HOLE: AC-2

LOCATION: Laser Drift, right wall in line w/DCT

PUMP FLOW [corrected] (liters/m): 1.685

RUN TIME (min): 349.2

AIR VOLUME (liters): 588.4

TOTAL WT. GAIN (mg): 0.13

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 632

SAMPLE DATE: 04/14/88

CORE HOLE: AC-2

LOCATION: Personal Sample (PS)-driller

PUMP FLOW [corrected] (liters/m): 1.661

RUN TIME (min): 160

AIR VOLUME (liters): 365.8

TOTAL WT. GAIN (mg): 0.15

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 633

SAMPLE DATE: 04/14/88

CORE HOLE: AC-2

LOCATION: 15 ft drill wall, center DCT & wall, approximately 4 ft above floor

PUMP FLOW [corrected] (liters/m): 1.612

RUN TIME (min): 265

AIR VOLUME (liters): 427.2

TOTAL WT. GAIN (mg): 0.10

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 634-B

SAMPLE DATE: 04/19/88

CORE HOLE: AC-2

LOCATION: BLIND BLANK - FW samples

PUMP FLOW [corrected] (liters/m): 0

RUN TIME (min): 0

AIR VOLUME (liters): 324.2

TOTAL WT. GAIN (mg): 0

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID: FW 641

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: Personal Sample (PS)-helper

PUMP FLOW [corrected] (liters/m): 1.66

RUN TIME (min): 379.7

AIR VOLUME (liters): 630.3

TOTAL WT. GAIN (mg): 0.11

QUARTZ (mg): ND

CRISTOBALITE (mg): ND

TRIDYMITE (mg): ND

SAMPLE ID.: AC-1/R7 #3

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: Bulk sample #3 from DCT Bag,
Run 7

QUARTZ (%): 6.8

CRISTOBALITE (%): ND

TRIDYMITE (%): ND

SAMPLE ID.: AC-2/R8-12 #3

SAMPLE DATE: 04/13/88

CORE HOLE: AC-2

LOCATION: Bulk sample #3 from DCT Bag,
Runs 8 - 12

QUARTZ (%): 11.0

CRISTOBALITE (%): ND

TRIDYMITE (%): ND

APPENDIX D-3

FIBER SAMPLE ANALYTICAL DATA

SAMPLE NO.: CE 52

SAMPLE DATE: 03/22/88

CORE HOLE: AC-1

LOCATION: BACKGROUND sample. Positioned on drill.

SAMPLING VOL (liters): 1278

FIBERS COUNTED/100 Optical Fields (fibers): 2

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Uncountable.

SAMPLE NO.: CE 53

SAMPLE DATE: 03/23/88

CORE HOLE: AC-1

LOCATION: Right wall, approximately 3 ft behind impactor, approximately 6 ft from floor.

SAMPLING VOL (liters): 129.1

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Uncountable.

SAMPLE NO.: CE 54

SAMPLE DATE: 03/23/88

CORE HOLE: AC-1

LOCATION: Left wall, approximately 6.5 ft from face.

SAMPLING VOL (liters): 122.7

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Uncountable.

SAMPLE NO.: CE 55

SAMPLE DATE: 03/23/88

CORE HOLE: AC-1

LOCATION: Hanging above drill rig.

SAMPLING VOL (liters): 106.3

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Uncountable.

SAMPLE NO.: CE 75B

SAMPLE DATE: 03/24/88

CORE HOLE: AC-1

LOCATION: BLIND BLANK - CE samples.

SAMPLING VOL (liters): 0

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Filter Blank.

SAMPLE NO.: CE 56

SAMPLE DATE: 03/25/88

CORE HOLE: AC-1

LOCATION: PERSONAL SAMPLE.

SAMPLING VOL (liters): 121.7

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Uncountable.

SAMPLE NO.: CE 57

SAMPLE DATE: 03/25/88

CORE HOLE: AC-1

LOCATION: PERSONAL SAMPLE.

SAMPLING VOL (liters): 147.4

FIBERS COUNTED/100 Optical Fields (fibers): 4

FIBER CONC. (f/cm³): <0.05

ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 50B

SAMPLE DATE: 03/28/88

CORE HOLE: AC-1

LOCATION: BLIND BLANK - CE samples.

SAMPLING VOL (liters): 0

FIBERS COUNTED/100 Optical Fields (fibers): 2

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Filter Blank.

SAMPLE NO.: CE 59

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Left wall, even with drill.
SAMPLING VOL (liters): 109.7

FIBERS COUNTED/100 Optical Fields (fibers): 3
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 60

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Behind drill, to the left.
SAMPLING VOL (liters): 55

FIBERS COUNTED/100 Optical Fields (fibers): 1
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Very Few Particles.

SAMPLE NO.: CE 61

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Right wall near DCT.
SAMPLING VOL (liters): 27.1

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm³): NA
ANALYTICAL COMMENTS: Back-up Separator Paper in Place.

SAMPLE NO.: CE 62

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Between wall and drill.
SAMPLING VOL (liters): 57.3

FIBERS COUNTED/100 Optical Fields (fibers): 7
FIBER CONC. (f/cm³): 0.06
ANALYTICAL COMMENTS: Few Fibers - Deposit Nonfibrous.

SAMPLE NO.: CE 64

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: On face in Demonstration Drift.
SAMPLING VOL (liters): 62.3

FIBERS COUNTED/100 Optical Fields (fibers): 6
FIBER CONC. (f/cm³): 0.05
ANALYTICAL COMMENTS: Few Fibers - Deposit Nonfibrous.

SAMPLE NO.: CE 65

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Between wall and drill rig.
SAMPLING VOL (liters): 43.9

FIBERS COUNTED/100 Optical Fields (fibers): 4
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Few fibers - Deposit Nonfibrous.

SAMPLE NO.: CE 66

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Right wall near DCT.
SAMPLING VOL (liters): 54.2

FIBERS COUNTED/100 Optical Fields (fibers): 4
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Few fibers - Deposit Nonfibrous.

SAMPLE NO.: CE 67

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: At face in Demonstration Drift.
SAMPLING VOL (liters): 31.1

FIBERS COUNTED/100 Optical Fields (fibers): 4
FIBER CONC. (f/cm³): 0.06
ANALYTICAL COMMENTS: Few fibers - Deposit Nonfibrous.

SAMPLE NO.: CE 69

SAMPLE DATE: 03/30/88

CORE HOLE: AC-1

LOCATION: Right wall near impactor at CE sample site.

SAMPLING VOL (liters): 30.2

FIBERS COUNTED/100 Optical Fields (fibers): 3

FIBER CONC. (f/cm³): 0.05

ANALYTICAL COMMENTS: Vehicle Exhaust.

SAMPLE NO.: CE 74

SAMPLE DATE: 03/30/88

CORE HOLE: AC-1

LOCATION: At drill rig between drill and wall.

SAMPLING VOL (liters): 86

FIBERS COUNTED/100 Optical Fields (fibers): 3

FIBER CONC. (f/cm³): <0.05

ANALYTICAL COMMENTS: Vehicle Exhaust.

SAMPLE NO.: CE 58

SAMPLE DATE: 03/31/88

CORE HOLE: AC-1

LOCATION: At drill to left of operator.

SAMPLING VOL (liters): 29.9

FIBERS COUNTED/100 Optical Fields (fibers): 2

FIBER CONC. (f/cm³): <0.05

ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 68

SAMPLE DATE: 03/31/88

CORE HOLE: AC-1

LOCATION: Left wall just behind drill plane.

SAMPLING VOL (liters): 31.1

FIBERS COUNTED/100 Optical Fields (fibers): 4

FIBER CONC. (f/cm³): 0.06

ANALYTICAL COMMENTS: Few fibers - Deposit Nonfibrous.

SAMPLE NO.: CE 45B

SAMPLE DATE: 04/04/88

CORE HOLE: AC-1

LOCATION: BLIND BLANK - CE samples.

SAMPLING VOL (liters): 0

FIBERS COUNTED/100 Optical Fields (fibers): 1

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Filter Blank.

SAMPLE NO.: CE 49B

SAMPLE DATE: 04/04/88

CORE HOLE: AC-1

LOCATION: BLIND BLANK - CE samples.

SAMPLING VOL (liters): 0

FIBERS COUNTED/100 Optical Fields (fibers): 2

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Filter Blank.

SAMPLE NO.: CE 71

SAMPLE DATE: 04/13/88

CORE HOLE: AC-2

LOCATION: BACKGROUND, on Rock bolt, left of drill collar.

SAMPLING VOL (liters): 1436.4

FIBERS COUNTED/100 Optical Fields (fibers): 1

FIBER CONC. (f/cm³): <0.05

ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 72

SAMPLE DATE: 04/14/88

CORE HOLE: AC-2

LOCATION: On wall approximately 5 ft to right of drill collar.

SAMPLING VOL (liters): 58.5

FIBERS COUNTED/100 Optical Fields (fibers): 27

FIBER CONC. (f/cm³): 0.22

ANALYTICAL COMMENTS: Some Fibers - Unusual Morphology.

SAMPLE NO.: CE 1

SAMPLE DATE: 04/14/88
CORE HOLE: AC-2
LOCATION: Hanger between drill and table (in personal area).
SAMPLING VOL (liters): 127.8

FIBERS COUNTED/100 Optical Fields (fibers): 2
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 2

SAMPLE DATE: 04/14/88
CORE HOLE: AC-2
LOCATION: On wall between DCT and drill collar.
SAMPLING VOL (liters): 127.5

FIBERS COUNTED/100 Optical Fields (fibers): 3
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 4

SAMPLE DATE: 04/14/88
CORE HOLE: AC-2
LOCATION: On wall, approximately 5 ft right of drill collar.
SAMPLING VOL (liters): 37

FIBERS COUNTED/100 Optical Fields (fibers): 2
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 6

SAMPLE DATE: 04/14/88
CORE HOLE: AC-2
LOCATION: On wall between DCT and drill collar.
SAMPLING VOL (liters): 127.5

FIBERS COUNTED/100 Optical Fields (fibers): 13
FIBER CONC. (f/cm³): 0.05
ANALYTICAL COMMENTS: Some Fibers - Deposit Light.

SAMPLE NO.: CE 73B

SAMPLE DATE: 04/15/88
CORE HOLE: AC-2
LOCATION: BLIND BLANK - CE samples.
SAMPLING VOL (liters): 0

FIBERS COUNTED/100 Optical Fields (fibers): 2
FIBER CONC. (f/cm³): NA
ANALYTICAL COMMENTS: Filter Blank.

SAMPLE NO.: CE 3

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: On water box in middle of drift.
SAMPLING VOL (liters): 121.4

FIBERS COUNTED/100 Optical Fields (fibers): 3
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Vehicle Exhaust.

SAMPLE NO.: CE 7

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: On DCT.
SAMPLING VOL (liters): 185.5

FIBERS COUNTED/100 Optical Fields (fibers): 2
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 8

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: On DCT.
SAMPLING VOL (liters): 61.8

FIBERS COUNTED/100 Optical Fields (fibers): 1
FIBER CONC. (f/cm³): <0.05
ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 12

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: On wall by impactor, between drill and table.

SAMPLING VOL (liters): 290.8

FIBERS COUNTED/100 Optical Fields (fibers): 2

FIBER CONC. (f/cm³): <0.05

ANALYTICAL COMMENTS: Deposit Nonfibrous.

SAMPLE NO.: CE 13

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: On DCT.

SAMPLING VOL (liters): 123.7

FIBERS COUNTED/100 Optical Fields (fibers): 2

FIBER CONC. (f/cm³): <0.05

**ANALYTICAL COMMENTS: Deposit Nonfibrous,
Vehicle Exhaust.**

SAMPLE NO.: CE 17

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: On water box in middle of drift.

SAMPLING VOL (liters): 121.7

FIBERS COUNTED/100 Optical Fields (fibers): 2

FIBER CONC. (f/cm³): <0.05

ANALYTICAL COMMENTS: Vehicle Exhaust.

SAMPLE NO.: CE 19

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: On wall behind DCT.

SAMPLING VOL (liters): 60.7

FIBERS COUNTED/100 Optical Fields (fibers): 1

FIBER CONC. (f/cm³): <0.05

ANALYTICAL COMMENTS: Deposit Very Light.

SAMPLE NO.: CE 20B

SAMPLE DATE: 04/26/88

CORE HOLE: AC-2

LOCATION: BLIND BLANK - CE samples.

SAMPLING VOL (liters): 0

FIBERS COUNTED/100 Optical Fields (fibers): 1

FIBER CONC. (f/cm³): NA

ANALYTICAL COMMENTS: Filter Blank.

APPENDIX D-4

PIXE SAMPLE ANALYTICAL DATA

SAMPLE NO.: NP 4

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: On DCT

MASS $\mu\text{g}/\text{cm}^2$: 5.887699

FILTER AREA-1 (cm^2): 4.155

FILTER AREA-2 (cm^2): 3.801

AIR VOLUME-1 (m^3): 0.294

AIR VOLUME-2 (m^3): 0.294

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0061	0.019666	0.115787	1.636378	1.496961
SILICON	1.74	0.0038	0.063751	0.375347	5.304649	4.852701
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0029	0.020969	0.123459	1.744803	1.596149
CHLORINE	2.622	0.0025	0.00834	0.049103	0.693956	0.634832
POTASSIUM	3.314	0.0018	0.008698	0.051211	0.723747	0.662085
CALCIUM	3.692	0.0017	0.009648	0.056805	0.802805	0.734408
TITANIUM	4.511	0.0011	0.001593	0.009379	0.13255	0.121257
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0004	0.001098	0.006465	0.091368	0.083583
MANGANESE	5.899	0.0003	0.000509	0.002997	0.042356	0.038747
IRON	6.399	0.0002	0.04169	0.245458	3.468973	3.173421
NICKEL	0	0	0	0	0	0
COPPER	8.041	0.0001	0.000245	0.001442	0.020379	0.018643
ZINC	8.631	0.0001	0.001795	0.010568	0.149354	0.136629
BROMINE	11.924	0.0008	0.321167	1.890935	26.72393	24.44709
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0006	0.000832	0.004899	0.069236	0.063337

SAMPLE NO.: NP 5

MASS $\mu\text{g}/\text{cm}^2$: 4.517624

SAMPLE DATE: 04/19/88

FILTER AREA-1 (cm^2): 4.155

CORE HOLE: AC-2

FILTER AREA-2 (cm^2): 3.801

LOCATION: On DCT front

AIR VOLUME-1 (m^3): 0.105

AIR VOLUME-2 (m^3): 0.105

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0061	0.027435	0.123941	4.904523	4.486664
SILICON	1.74	0.0038	0.032507	0.146854	5.811223	5.316115
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0028	0.00886	0.040026	1.583886	1.448941
CHLORINE	2.622	0.0026	0.006248	0.028226	1.116943	1.021781
POTASSIUM	3.314	0.0018	0.00274	0.012378	0.489815	0.448084
CALCIUM	3.692	0.0018	0.002383	0.010765	0.425986	0.389693
TITANIUM	4.511	0.0012	0.001136	0.005132	0.203081	0.185778
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0004	0.001457	0.006582	0.260459	0.238268
MANGANESE	0	0	0	0	0	0
IRON	6.399	0.0002	0.004755	0.021481	0.850034	0.777612
NICKEL	0	0	0	0	0	0
COPPER	8.041	0.0001	0.000197	0.00089	0.035219	0.032218
ZINC	8.631	0.0002	0.001327	0.005995	0.237231	0.217019
BROMINE	11.924	0.0004	0.410345	1.853784	73.35689	67.10698
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0008	0.000611	0.00276	0.109217	0.099912

SAMPLE NO.: NP 10

SAMPLE DATE: 04/21/88

CORE HOLE: AC-2

LOCATION: On face, between collar (~5 ft) and DCT

MASS $\mu\text{g}/\text{cm}^2$: 5.884412

FILTER AREA-1 (cm^2): 4.155

FILTER AREA-2 (cm^2): 3.801

AIR VOLUME-1 (m^3): 0.1

AIR VOLUME-2 (m^3): 0.1

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0046	0.021166	0.124549	5.175011	4.734108
SILICON	1.74	0.0029	0.066941	0.393908	16.36688	14.97244
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0022	0.014941	0.087919	3.653035	3.341801
CHLORINE	2.622	0.002	0.005845	0.034394	1.429071	1.307316
POTASSIUM	3.314	0.0014	0.009177	0.054001	2.243742	0.052578
CALCIUM	3.692	0.0014	0.009669	0.056896	2.364029	0.162617
TITANIUM	4.511	0.001	0.001325	0.007797	0.323965	0.296364
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0003	0.001226	0.007214	0.299742	0.274204
MANGANESE	5.899	0.0002	0.000497	0.002925	0.121534	0.111179
IRON	6.399	0.0002	0.039697	0.233594	9.705831	8.878908
NICKEL	0	0	0	0	0	0
COPPER	8.041	0.0001	0.000216	0.001271	0.05281	0.048311
ZINC	8.631	0.0001	0.001517	0.008927	0.370917	0.339315
BROMINE	11.924	0.0005	0.32721	1.925438	80.00195	73.1859
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0006	0.000575	0.003384	0.140605	0.128626

SAMPLE NO.: NP 14

MASS $\mu\text{g}/\text{cm}^2$: 10.50574

SAMPLE DATE: 04/21/88

FILTER AREA-1 (cm^2): 4.155

CORE HOLE: AC-2

FILTER AREA-2 (cm^2): 3.801

LOCATION: On DCT front

AIR VOLUME-1 (m^3): 0.44

AIR VOLUME-2 (m^3): 0.44

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0035	0.031256	0.328367	3.100829	2.836643
SILICON	1.74	0.0022	0.139157	1.461947	13.80543	12.62923
PHOSPHORUS	2.014	0.0018	0.001568	0.016473	0.155558	0.142304
SULFUR	2.308	0.0016	0.019957	0.209663	1.979886	1.811202
CHLORINE	2.622	0.0014	0.006211	0.065251	0.616177	0.56368
POTASSIUM	3.314	0.0011	0.02154	0.226294	2.136936	1.954872
CALCIUM	3.692	0.0012	0.018201	0.191215	1.805678	1.651837
TITANIUM	4.511	0.0006	0.0017	0.01786	0.168655	0.154286
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0002	0.000704	0.007396	0.069842	0.063891
MANGANESE	5.899	0.0001	0.001283	0.013479	0.127285	0.11644
IRON	6.399	0.0001	0.078195	0.821496	7.757537	7.096605
NICKEL	7.472	0	0.000064	0.000672	0.006346	0.005805
COPPER	8.041	1	0.000332	0.003488	0.032938	0.030132
ZINC	8.631	0.0001	0.0018	0.01891	0.178571	0.163357
BROMINE	11.924	0.0003	0.177602	1.86584	17.61947	16.11831
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0003	0.000043	0.004517	0.042655	0.039021

SAMPLE NO.: NP 22

SAMPLE DATE: 04/20/88

CORE HOLE: AC-2

LOCATION: On wire (middle of personnel area)

MASS $\mu\text{g}/\text{cm}^2$: 4.653607

FILTER AREA-1 (cm^2): 0

FILTER AREA-2 (cm^2): 3.801

AIR VOLUME-1 (m^3): 0.414

AIR VOLUME-2 (m^3): 0.414

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0091	0.01294	0.060218	0	0.552871
SILICON	1.74	0.0056	0.023478	0.109257	0	1.003106
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.004	0.008888	0.041361	0	0.379742
CHLORINE	2.622	0.0036	0.009182	0.042729	0	0.392302
POTASSIUM	3.314	0.0028	0.002697	0.012551	0	0.115233
CALCIUM	3.692	0.0029	0.004056	0.018875	0	0.173294
TITANIUM	4.511	0.0012	0.000726	0.003379	0	0.031023
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0003	0.002475	0.011518	0	0.105749
MANGANESE	5.899	0.0003	0.000332	0.001545	0	0.014185
IRON	6.399	0.0002	0.014094	0.065588	0	0.602174
NICKEL	7.472	0.0001	0.000067	0.000312	0	0.002865
COPPER	8.041	0.0001	0.000142	0.000661	0	0.006069
ZINC	8.631	0.0001	0.001372	0.006385	0	0.058622
BROMINE	11.924	0.0004	0.418826	1.949052	0	17.89456
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0005	0.000767	0.003569	0	0.032768

SAMPLE NO.: NP 27

SAMPLE DATE: 04/21/88

CORE HOLE: AC-2

LOCATION: On wall between DCT and drill collar

MASS $\mu\text{g}/\text{cm}^2$: 4.600712

FILTER AREA-1 (cm^2): 0

FILTER AREA-2 (cm^2): 3.801

AIR VOLUME-1 (m^3): 0.212

AIR VOLUME-2 (m^3): 0.212

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0093	0.023129	0.106408	0	1.907815
SILICON	1.74	0.0057	0.028947	0.133178	0	2.387781
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0044	0.005996	0.027584	0	0.49456
CHLORINE	2.622	0.0038	0.005696	0.026206	0	0.469854
POTASSIUM	3.314	0.003	0.003893	0.017911	0	0.321131
CALCIUM	3.692	0.003	0.003867	0.017791	0	0.318979
TITANIUM	4.511	0.0012	0.001336	0.006147	0	0.110211
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0003	0.002717	0.0125	0	0.224116
MANGANESE	5.899	0.0003	0.000148	0.000681	0	0.01221
IRON	6.399	0.0002	0.010691	0.04918	0	0.88176
NICKEL	7.472	0.0001	0.000089	0.000409	0	0.007333
COPPER	8.041	0.0001	0.000147	0.000678	0	0.012156
ZINC	8.631	0.0001	0.001279	0.005884	0	0.105496
BROMINE	11.924	0.0005	0.411347	1.892489	0	33.9309
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0005	0.00076	0.003497	0	0.062699

SAMPLE NO.: NP 32B

SAMPLE DATE: 04/28/88

CORE HOLE: AC-2

LOCATION: BLIND BLANK - PIXE sample set

MASS $\mu\text{g}/\text{cm}^2$: 4.146936

FILTER AREA-1 (cm^2): 0

FILTER AREA-2 (cm^2): 3.801

AIR VOLUME-1 (m^3): 0

AIR VOLUME-2 (m^3): 0.232

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	0	0	0	0	0	0
SILICON	1.74	0.0059	0.007166	0.029717	0	0.486872
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0046	0.00796	0.03301	0	1.540823
CHLORINE	2.622	0.0042	0.00676	0.028033	0	0.459282
POTASSIUM	0	0	0	0	0	0
CALCIUM	0	0	0	0	0	0
TITANIUM	4.511	0.0013	0.001035	0.004292	0	0.070319
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0004	0.001306	0.005416	0	0.088734
MANGANESE	0	0	0	0	0	0
IRON	6.399	0.0002	0.000571	0.002368	0	0.038796
NICKEL	0	0	0	0	0	0
COPPER	8.041	0.0001	0.000131	0.000543	0	0.008896
ZINC	8.631	0.0001	0.000628	0.002604	0	0.042663
BROMINE	11.924	0.0005	0.474122	1.966154	0	32.21272
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0006	0.000321	0.001331	0	0.021807

SAMPLE NO.: NP 47B

SAMPLE DATE: 04/12/88

CORE HOLE: AC-2

LOCATION: BLIND BLANK - PIXE sample set

MASS $\mu\text{g}/\text{cm}^2$: 2.181741

FILTER AREA-1 (cm^2): 4.155

FILTER AREA-2 (cm^2): 3.801

AIR VOLUME-1 (m^3): 0.06

AIR VOLUME-2 (m^3): 0.06

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0208	0.052017	0.113488	7.859045	7.16558
SILICON	1.74	0.0131	0.030843	0.067291	4.659902	4.248723
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0096	0.018948	0.04134	2.862795	2.610189
CHLORINE	2.622	0.0087	0.013089	0.028557	1.977572	1.803076
POTASSIUM	0	0	0	0	0	0
CALCIUM	0	0	0	0	0	0
TITANIUM	4.511	0.0037	0.001116	0.002435	0.168624	0.153745
VANADIUM	4.952	0.002	0.000486	0.00106	0.073405	0.066928
CHROMIUM	5.415	0.0011	0.003909	0.008528	0.590564	0.538454
MANGANESE	0	0	0	0	0	0
IRON	6.399	0.0005	0.001499	0.00327	0.226448	0.206466
NICKEL	7.472	0.0004	0.000249	0.000543	0.037603	0.034285
COPPER	8.041	0.0003	0.000312	0.000681	0.047159	0.042998
ZINC	8.631	0.0004	0.002066	0.004507	0.31211	0.28457
BROMINE	11.924	0.0016	0.858455	1.872926	129.7001	118.2557
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	23.174	0.0158	0.0027	0.005891	0.407952	0.371955
ANTIMONY	26.359	0.0305	0.013297	0.029011	2.009012	1.831741
LEAD	10.552	0.002	0.000993	0.002166	0.149996	0.13676

SAMPLE NO.: NP 52

SAMPLE DATE: 03/29/88

CORE HOLE: AC-2

LOCATION: PERSONAL SAMPLE on Investigator

MASS $\mu\text{g}/\text{cm}^2$: 0.547707

FILTER AREA-1 (cm^2): 4.155

FILTER AREA-2 (cm^2): 3.801

AIR VOLUME-1 (m^3): 0.126

AIR VOLUME-2 (m^3): 0.126

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0476	0.12082	0.066174	2.182167	1.999423
SILICON	1.74	0.0395	0.39986	0.219006	7.221984	6.617185
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0308	0.091673	0.05021	1.655735	1.517076
CHLORINE	2.622	0.029	0.029464	0.016138	0.53217	0.487604
POTASSIUM	3.314	0.0208	0.048925	0.026797	0.883663	0.809661
CALCIUM	3.692	0.0209	0.068428	0.037478	1.235882	1.132384
TITANIUM	4.511	0.0124	0.016486	0.009029	0.297742	0.272808
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0039	0.016143	0.008842	0.291575	0.267158
MANGANESE	0	0	0	0	0	0
IRON	6.399	0.0019	0.083229	0.045585	1.50322	1.377334
NICKEL	7.472	0.0012	0.001199	0.000657	0.021665	0.019851
COPPER	8.041	0.0011	0.001151	0.00063	0.020775	0.019035
ZINC	8.631	0.0011	0.004096	0.002243	0.073966	0.067771
BROMINE	11.924	0.004	0.0038	0.002081	0.068623	0.062877
STRONTIUM	14.165	0.0081	0.003632	0.001989	0.06559	0.060097
MOLYBDENUM	17.479	0.0185	0.006523	0.003573	0.117824	0.107957
CADMIUM	0	0	0	0	0	0
ANTIMONY	26.359	0.1053	0.10181	0.055762	1.838818	1.684828
LEAD	10.552	0.0056	0.002749	0.001506	0.049662	0.045503

SAMPLE NO.: NP 55

MASS $\mu\text{g}/\text{cm}^2$: 2.39308

SAMPLE DATE: 03/30/88

FILTER AREA-1 (cm^2): 4.155

CORE HOLE: AC-2

FILTER AREA-2 (cm^2): 3.801

LOCATION: On wall of Extens/Demonstrative curve

AIR VOLUME-1 (m^3): 1

AIR VOLUME-2 (m^3): 1266

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0171	0.044661	0.106877	0.444074	0.000321
SILICON	1.74	0.0107	0.048268	0.115509	5.47994	0.000347
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0078	0.021307	0.050989	0.211859	0.000153
CHLORINE	2.622	0.0073	0.012649	0.03027	0.125772	0.000091
POTASSIUM	0	0	0	0	0	0
CALCIUM	3.692	0.0053	0.006179	0.014787	0.06144	0.000044
TITANIUM	4.511	0.0028	0.002612	0.006251	0.025973	0.000019
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0009	0.005383	0.012882	0.053525	0.000039
MANGANESE	0	0	0	0	0	0
IRON	6.399	0.0005	0.010261	0.024555	0.102026	0.000074
NICKEL	0	0	0	0	0	0
COPPER	8.041	0.0003	0.000208	0.000498	0.002069	0.000001
ZINC	8.631	0.0003	0.00185	0.004427	0.018394	0.000013
BROMINE	11.924	0.0004	0.824721	1.973623	8.200404	0.005926
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	23.174	0.0146	0.006635	0.015878	0.065973	0.000048
ANTIMONY	26.359	0.0239	0.013921	0.033314	0.13842	0.0001
LEAD	10.552	0.0015	0.001346	0.003221	0.013383	0.00001

SAMPLE NO.: NP 56

SAMPLE DATE: 04/19/88

CORE HOLE: AC-2

LOCATION: On face ~6.5 ft Right of collar and 7 ft from DCT

MASS $\mu\text{g}/\text{cm}^2$: 5.136017
 FILTER AREA-1 (cm^2): 0
 FILTER AREA-2 (cm^2): 3.801
 AIR VOLUME-1 (m^3): 0
 AIR VOLUME-2 (m^3): 0.242

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0083	0.020348	0.104508	0	1.641467
SILICON	1.74	0.0051	0.044632	0.229231	0	3.600442
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0037	0.009088	0.046676	0	0.733122
CHLORINE	2.622	0.0034	0.00653	0.033538	0	0.526768
POTASSIUM	3.314	0.0027	0.006687	0.034345	0	0.539444
CALCIUM	3.692	0.0026	0.005266	0.027046	0	0.424801
TITANIUM	4.511	0.0011	0.001213	0.00623	0	0.097852
VANADIUM	0	0	0	0	0	0
CHROMIUM	5.415	0.0003	0.001874	0.009625	0	0.151176
MANGANESE	5.899	0.0002	0.00032	0.001644	0	0.025822
IRON	6.399	0.0002	0.015428	0.079238	0	1.244561
NICKEL	7.472	0.0001	0.000072	0.00037	0	0.005811
COPPER	8.041	0.0001	0.000179	0.000919	0	0.014434
ZINC	8.631	0.0001	0.001116	0.005732	0	0.09003
BROMINE	11.924	0.0004	0.38664	1.98579	0	31.19003
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	0	0	0	0	0	0
ANTIMONY	0	0	0	0	0	0
LEAD	10.552	0.0005	0.000607	0.003118	0	0.048973

SAMPLE NO.: NP 59

MASS $\mu\text{g}/\text{cm}^2$: 2.762536
FILTER AREA-1 (cm^2): 4.155
FILTER AREA-2 (cm^2): 3.801
AIR VOLUME-1 (m^3): 1
AIR VOLUME-2 (m^3): 0.061

SAMPLE DATE: 03/30/88

CORE HOLE: AC-1

LOCATION: Left wall (~8 ft from face) even with drill

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT	ELEMENTAL CONC.	ELEMENTAL		
				MASS $\mu\text{g}/\text{cm}^2$	MASS/VOL-1 $\mu\text{g}/\text{m}^3$	MASS/VOL-2 $\mu\text{g}/\text{m}^3$
ALUMINUM	1.487	0.0146	0.056961	0.157357	0.653818	9.805147
SILICON	1.74	0.009	0.153926	0.425226	1.766814	26.49646
PHOSPHORUS	0	0	0	0	0	0
SULFUR	2.308	0.0069	0.010648	0.029415	0.122219	1.832892
CHLORINE	2.622	0.0064	0.00957	0.026437	0.109846	1.547329
POTASSIUM	3.314	0.0048	0.016722	0.046195	0.19194	2.878479
CALCIUM	3.692	0.0046	0.005069	0.014003	0.058182	0.872548
TITANIUM	4.511	0.0025	0.003357	0.009274	0.038533	0.577877
VANADIUM	4.952	0.0014	0.000299	0.000826	0.003432	0.051469
CHROMIUM	5.415	0.0008	0.005316	0.014686	0.06102	0.915106
MANGANESE	0	0	0	0	0	0
IRON	6.399	0.0004	0.013924	0.038466	0.159826	2.396873
NICKEL	7.472	0.0002	0.000144	0.000398	0.001654	0.0248
COPPER	8.041	0.0003	0.000326	0.000901	0.003744	0.056143
ZINC	8.631	0.0003	0.001747	0.004826	0.020052	0.300715
BROMINE	11.924	0.0013	0.697734	1.927515	8.008825	120.1063
STRONTIUM	0	0	0	0	0	0
MOLYBDENUM	0	0	0	0	0	0
CADMIUM	23.174	0.0127	0.010751	0.0297	0.123404	1.850651
ANTIMONY	26.359	0.0217	0.012866	0.035543	0.147681	2.214737
LEAD	10.552	0.0013	0.000641	0.001771	0.007359	0.110354

SAMPLE NO.: AC-1/R7 #1

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: BULK SAMPLE #1 from DCT Bag for Run 7

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT 95% CONFIDENCE	CONCENTRATION MASS	ERROR ±
OXYGEN			49.542%	0.609%
SODIUM	1.041	0.195%	3.205%	1.028%
MAGNESIUM	1.254	836.6 ppm	0.193%	0.143%
ALUMINUM	1.487	446.4 ppm	6.952%	0.483%
SILICON	1.74	324.5 ppm	32.47%	2.140%
CHLORINE	2.622	188.7 ppm	256.8 ppm	118.9 ppm
POTASSIUM	3.314	170.8 ppm	4.331%	0.288%
CALCIUM	3.692	425.9 ppm	0.199%	0.021%
TITANIUM	4.511	67.9 ppm	0.168%	0.12%
MANGANESE	5.899	12.45 ppm	0.143%	0.010%
IRON	6.399	18.68 ppm	2.648%	0.174%
NICKEL	7.472	5.93 ppm	7.62 ppm	2.53 ppm
COPPER	8.041	5.46 ppm	33.63 ppm	3.78 ppm
ZINC	8.631	5.81 ppm	205.2 ppm	14.65 ppm
GALLIUM	9.243	4.97 ppm	18.31 ppm	2.9 ppm
RUBIDIUM	13.395	8.96 ppm	162.6 ppm	14.89 ppm
STRONTIUM	14.165	9.95 ppm	16.58 ppm	5.13 ppm
YTTRIUM	14.958	28.05 ppm	61.36 ppm	11.68 ppm
ZIRCONIUM	15.775	31.21 ppm	607.8 ppm	48.01 ppm
MOLYBDENUM	0	0	0	0
TUNGSTEN	8.398	30.45 ppm	88.39 ppm	10.29 ppm
LEAD	10.552	11.93 ppm	44.11 ppm	7.0 ppm

SAMPLE NO.: AC-1/R7 #1

SAMPLE DATE: 04/13/88

CORE HOLE: AC-1

LOCATION: BULK SAMPLE #1 from DCT Bag for Runs 8-12

ELEMENTS	ENERGY (KEV)	DETECT. LIMIT 95% CONFIDENCE	CONCENTRATION MASS	ERROR ±
OXYGEN			45.304%	0.707%
SODIUM	1.041	0.212%	3.242%	1.188%
MAGNESIUM	1.254	905.2 ppm	0.211%	0.198%
ALUMINUM	1.487	491.5 ppm	7.375%	0.516%
SILICON	1.74	352.2 ppm	35.76%	2.356%
CHLORINE	2.622	221.4 ppm	342.1 ppm	146.3 ppm
POTASSIUM	3.314	218.8 ppm	5.057%	0.337%
CALCIUM	3.692	468.6 ppm	0.127%	0.018%
TITANIUM	4.511	67.68 ppm	0.165%	0.012%
MANGANESE	5.899	12.1 ppm	0.146%	0.01%
IRON	6.399	18.53 ppm	2.463%	0.162%
NICKEL	7.472	5.69 ppm	4.39 ppm	2.34 ppm
COPPER	8.041	5.20 ppm	14.35 ppm	2.65 ppm
ZINC	8.631	5.23 ppm	157.5 ppm	11.47 ppm
GALLIUM	9.243	4.975 ppm	22.36 ppm	3.04 ppm
RUBIDIUM	13.395	10.22 ppm	153.4 ppm	14.01 ppm
STRONTIUM	14.165	11.57 ppm	12.06 ppm	4.49 ppm
YTTRIUM	14.958	26.31 ppm	70.27 ppm	11.64 ppm
ZIRCONIUM	15.775	28.1 ppm	607 ppm	47.35 ppm
MOLYBDENUM	17.479	59.65 ppm	29.32 ppm	13.92 ppm
TUNGSTEN	8.398	26.3 ppm	67.16 ppm	8.93 ppm
LEAD	10.552	12.73 ppm	32.23 ppm	6.12 ppm

APPENDIX D-5
SEM/EDX SAMPLES

SAMPLE NO: NP 27

SAMPLE DATE: 04/21/88
CORE HOLE: AC-2
LOCATION: On wall between DCT and drill collar.
RUN TIME (m): 104
MASS ($\mu\text{g}/\text{m}^3$): 4.600712
AIR VOLUME (m^3): 0.212

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 22

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: On wire (middle of personnel area).
RUN TIME (m): 209.5
MASS ($\mu\text{g}/\text{m}^3$): 4.653607
AIR VOL (m^3): 0.414

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 56

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On face approximately 6.5 ft right of collar approximately 7 ft from DCT.
RUN TIME (m): 120
MASS ($\mu\text{g}/\text{m}^3$): 5.136017
AIR VOLUME (m^3): 0

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 32B

SAMPLE DATE: 04/28/88
CORE HOLE: AC-2
LOCATION: BLIND BLANK - PIXE sample set.
RUN TIME (m): 0
MASS ($\mu\text{g}/\text{m}^3$): 4.146936
AIR VOL (m^3): 0.232

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENT: No Fibers Detected.

SAMPLE NO: NP 10

SAMPLE DATE: 04/21/88
CORE HOLE: AC-2
LOCATION: On face, between collar (5) and DCT.
RUN TIME (m): 282
MASS ($\mu\text{g}/\text{m}^3$): 5.884412
AIR VOL (m^3): 0.1

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 59

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Left wall (approximately 8 ft from face) even with Drill.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 2.762536
AIR VOL (m^3): 0.061

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 55

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: On wall of Extensiometer/
Demonstration curve.
RUN TIME (m): 68.5
MASS ($\mu\text{g}/\text{m}^3$): 2.39308
AIR VOL (m^3): 1.266

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 47B

SAMPLE DATE: 04/12/8
CORE HOLE: AC-2
LOCATION: Blank sent with set for PIXE analysis.
RUN TIME (m): 60.2
MASS ($\mu\text{g}/\text{m}^3$): 2.181741
AIR VOL (m^3): 0.06

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 4

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: On DCT.
RUN TIME (m): 152
MASS ($\mu\text{g}/\text{m}^3$): .887699
AIR VOL (m^3): 0.294

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 5

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On DCT front.
RUN TIME (m): 60
MASS ($\mu\text{g}/\text{m}^3$ g/ m^3): 4.517624
AIR VOL (m^3): 0.105

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 14

SAMPLE DATE: 04/21/88
CORE HOLE: AC-2
LOCATION: On DCT front.
RUN TIME (m): 293.4
MASS ($\mu\text{g}/\text{m}^3$): 10.50574
AIR VOL (m^3): 0.44

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 52

SAMPLE DATE: 03/29/88
CORE HOLE: AC-1
LOCATION: Personal sample on investigator.
RUN TIME (m): 60
MASS ($\mu\text{g}/\text{m}^3$): 0.547707
AIR VOL (m^3): 0.126

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 49B

SAMPLE DATE: 04/08/88
CORE HOLE: AC-1
LOCATION: BLIND BLANK - NP sample set.
RUN TIME (m): 50
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.106

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 71

SAMPLE DATE: 03/22/88
CORE HOLE: AC-1
LOCATION: BACKGROUND-Demonstration Drift.
RUN TIME (m): 100
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.2294

FIBERS COUNTED/100 Optical Fields (fibers): .0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 72

SAMPLE DATE: 03/23/88
CORE HOLE: AC-1
LOCATION: ACI location, left side Demonstration Drift.
RUN TIME (m): 81
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1861

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 73

SAMPLE DATE: 03/23/88
CORE HOLE: AC-1
LOCATION: Right ACI location, Demonstration Drift.
RUN TIME (m): 72
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1317

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 74

SAMPLE DATE: 03/25/88
CORE HOLE: AC-1
LOCATION: Personal sample on investigator.
RUN TIME (m): 64.7
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1148

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 75

SAMPLE DATE: 03/25/88
CORE HOLE: AC-1
LOCATION: Personal sample on investigator.
RUN TIME (m): 68.7
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1514

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected

SAMPLE NO: NP 48B

SAMPLE DATE: 04/08/88
CORE HOLE: AC-1
LOCATION: BLIND BLANK
RUN TIME (m): 45
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0923

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 51

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: ON DCT.
RUN TIME (m): 15
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0305

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 53

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Right side Demonstration Drift,
even with drill.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.061

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 54

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: Personal sample on investigator.
RUN TIME (m): 50
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0968

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO. NP 57

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: On DCT.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.061

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 63

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: On DCT.
RUN TIME (m): 15
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0305

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 68

SAMPLE DATE: 03/30/88
CORE HOLE: AC-1
LOCATION: On wall of ExtensimeterA
Demonstration Curve.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.055

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 50

SAMPLE DATE: 04/13/88
CORE HOLE: AC-2
LOCATION: BACKGROUND.
RUN TIME (m): 720
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 1.4508

FIBERS COUNTED/100 Optical Fields (fibers):
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 58B

SAMPLE DATE: 04/26/88
CORE HOLE: AC-1
LOCATION: BLANK - NP sample set.
RUN TIME (m): 0
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 64

SAMPLE DATE: 04/14/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 70.7
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1395

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 7

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 60
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1228

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 6

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0614

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 9

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On front of DCT.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0526

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 12

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0614

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 16

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: Personal sample on investigator.
RUN TIME (m): 63
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1316

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 17

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0526

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 19

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0584

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected

SAMPLE NO: NP 24

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: Back wall.
RUN TIME (m): 101
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.2138

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 26

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 60
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1023

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 28

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 60
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1023

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 29

SAMPLE DATE: 04/20/88
CORE HOLE: AC-2
LOCATION: At DCT.
RUN TIME (m): 102
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1963

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 33B

SAMPLE DATE: 04/26/88
CORE HOLE: AC-2
LOCATION: BLANK - NP sample set.
RUN TIME (m): 0
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 34

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: Wall behind DCT.
RUN TIME (m): 45
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0877

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 35

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: Wall behind DCT.
RUN TIME (m): 34
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0662

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 40B

SAMPLE DATE: 04/26/88
CORE HOLE: AC-2
LOCATION: BLANK - NP sample set.
RUN TIME (m): 0
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 69

SAMPLE DATE: 03/30/88
CORE HOLE: AC-2
LOCATION: On DCT (removed from set/
contaminated).
RUN TIME (m): 60
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.1052

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 61

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: Between DCT and drill collar.
RUN TIME (m): 120
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.242

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 62

SAMPLE DATE: 04/18/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0604

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 66

SAMPLE DATE: 04/19/88
CORE HOLE: AC-2
LOCATION: On DCT.
RUN TIME (m): 27
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0474

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 67

SAMPLE DATE: 04/18/88
CORE HOLE: AC-2
LOCATION: On water box.
RUN TIME (m): 30
MASS ($\mu\text{g}/\text{m}^3$): 0
AIR VOL (m^3): 0.0604

FIBERS COUNTED/100 Optical Fields (fibers): 0
FIBER CONC. (f/cm^3): 0
ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 1

SAMPLE DATE: 04/14/88

CORE HOLE: AC-2

LOCATION: On DCT.

RUN TIME (m): 377

MASS ($\mu\text{g}/\text{m}^3$): 0.000135

AIR VOL (m^3): 0

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm^3): 0

ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE NO: NP 2

SAMPLE DATE: 04/14/88

CORE HOLE: AC-2

LOCATION: On DCT.

RUN TIME (m): 362.9

MASS ($\mu\text{g}/\text{m}^3$): 0.000026

AIR VOL (m^3): 0.82

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm^3): 0

ANALYTICAL COMMENTS: No Fibers Detected.

BULK SAMPLE FIBER ANALYSIS BY SEM/EDX

SAMPLE ID: AC-1/R-7 #2

SAMPLE DATE: 03/29/88

CORE HOLE: AC-1

LOCATION: BULK SAMPLE #2/DCT BAG Run 7.

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm^3): 0

ANALYTICAL COMMENTS: No Fibers Detected.

SAMPLE ID.: AC-2/R 8-12 #2

SAMPLE DATE: 04/13/88

CORE HOLE: AC-2

**LOCATION: BULK SAMPLE #2/DCT BAG
Runs 8-12.**

FIBERS COUNTED/100 Optical Fields (fibers): 0

FIBER CONC. (f/cm^3): 0

ANALYTICAL COMMENTS: No Fibers Detected.

Figure D5-1. SEM Photomicrograph (1000x) and EDX Spectra for Bulk AC-1 Run #7 (2).

Figure D5-2. SEM Photomicrograph (1000x) and EDX Spectra for Bulk AC-2 Run #3 (2).

APPENDIX D-6

CASCADE IMPACTOR DATA

DM FILTER SET: DM-01A

SAMPLE DATE: 03/29/88

IMPACTOR ID: ACI-099

CORE HOLE: AC-1

LOCATION: Right wall, approximately 12 ft from Demonstration Drift face

RUN TIME (min): 248

PRE-SEPARATOR	0.000735	0.735
STAGE 0	0.00067	0.67
STAGE 1	0.001043	1.043
STAGE 2	0.000681	0.681
STAGE 3	0.001364	1.364
STAGE 4	0.001444	1.444
STAGE 5	0.001211	1.211
STAGE 6	0.000839	0.839
STAGE 7	0.000617	0.617
FINAL	0.001094	1.094

TOTAL WEIGHT GAIN (g): 0.009698 (mg): 9.698

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 1.866

STANDARD DEVIATION: 3.67

IMPACTOR CONCENTRATION (mg/m^3): 1.28

DM FILTER SET: DM-02A

SAMPLE DATE: 03/29/88

IMPACTOR ID: ACI-934

CORE HOLE: AC-1

LOCATION: Left wall, approximately 12 ft from Demonstration Drift face

RUN TIME (min): 248

PRE-SEPARATOR	0.000322	0.322
STAGE 0	0.000551	0.551
STAGE 1	0.000708	0.708
STAGE 2	0.000387	0.387
STAGE 3	0.000473	0.473
STAGE 4	0.000406	0.406
STAGE 5	0.000377	0.377
STAGE 6	0.000289	0.289
STAGE 7	0.000373	0.373
FINAL	0.001281	1.281

TOTAL WEIGHT GAIN (g): 0.005167 (mg): 5.167

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 1.52

STANDARD DEVIATION: 6.73

IMPACTOR CONCENTRATION (mg/m^3): 0.69

DM FILTER SET: DM-03A

SAMPLE DATE: 03/24/88

IMPACTOR ID: ACI-931

CORE HOLE: AC-1

LOCATION: (Negative weights for all but final stage, unusable data)

RUN TIME (min): 120

PRE-SEPARATOR	0	0
STAGE 0	0	0
STAGE 1	0	0
STAGE 2	0	0
STAGE 3	0	0
STAGE 4	0	0
STAGE 5	0	0
STAGE 6	0	0
STAGE 7	0	0
FINAL	0.000391	0.391

TOTAL WEIGHT GAIN (g): 0 (mg): 0

MASS MEDIAN AERODYNAMIC DIAMETER (μm):

STANDARD DEVIATION: 0

IMPACTOR CONCENTRATION (mg/m^3):

DM FILTER SET: DM-04A

SAMPLE DATE: 03/25/88

IMPACTOR ID: ACI- 899

CORE HOLE: AC-1

LOCATION: Left impactor position (12 ft from Demonstration Drift face)

RUN TIME (min): 75

PRE-SEPARATOR	0.000932	0.932
STAGE 0	0.001045	1.045
STAGE 1	0.00127	1.27
STAGE 2	0.00054	0.54
STAGE 3	0.001115	1.115
STAGE 4	0.001024	1.024
STAGE 5	0.000961	0.961
STAGE 6	0.000069	0.069
STAGE 7	-0.00012	-0.119
FINAL	0.000196	0.196

TOTAL WEIGHT GAIN (g): 0.007033 (mg): 7.033

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 3.834

STANDARD DEVIATION: 3.07

IMPACTOR CONCENTRATION (mg/m^3): 2.99

DM FILTER SET: DM-05A

SAMPLE DATE: 03/23/88

IMPACTOR ID: ACI-1001

CORE HOLE: AC-1

LOCATION: Right-side Demonstration Drift, approximately 12 ft from face

RUN TIME (min): 95

PRE-SEPARATOR	0.000004	0.004
STAGE 0	0.000773	0.773
STAGE 1	0.000549	0.549
STAGE 2	0.000725	0.725
STAGE 3	0.002333	2.333
STAGE 4	0.001998	1.998
STAGE 5	0.001484	1.484
STAGE 6	0.000897	0.897
STAGE 7	0.000238	0.238
FINAL	0.000493	0.493

TOTAL WEIGHT GAIN (g): 0.009494 (mg): 9.494

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 2.481

STANDARD DEVIATION: 2.536

IMPACTOR CONCENTRATION (mg/m^3): 3.53

DM FILTER SET: DM-06A

SAMPLE DATE: 03/23/88

IMPACTOR ID: ACI-892

CORE HOLE: AC-1

LOCATION: Left-side Demonstration Drift, approximately 12 ft from face

RUN TIME (min): 95

PRE-SEPARATOR	0.003085	3.085
STAGE 0	0.00345	3.45
STAGE 1	0.003826	3.826
STAGE 2	0.00155	1.55
STAGE 3	0.00366	3.66
STAGE 4	0.00308	3.08
STAGE 5	0.002391	2.391
STAGE 6	0.000744	0.744
STAGE 7	0.000283	0.283
FINAL	0.000656	0.656

TOTAL WEIGHT GAIN (g): 0.022725 (mg): 22.725

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 3.847

STANDARD DEVIATION: 2.93

IMPACTOR CONCENTRATION (mg/m^3): 7.31

DM FILTER SET: DM-07A

SAMPLE DATE: 03/24/88

IMPACTOR ID: ACI-935

CORE HOLE: AC-1

LOCATION: BACKGROUND-Demonstration Drift (Muckers recently in main tunnel)

RUN TIME (min): 120

PRE-SEPARATOR	0.000337	0.337
STAGE 0	0.000195	0.195
STAGE 1	0.000192	0.192
STAGE 2	0.000108	0.108
STAGE 3	0.000174	0.174
STAGE 4	0.000093	0.093
STAGE 5	0.000051	0.051
STAGE 6	0.000016	0.016
STAGE 7	0.00008	0.08
FINAL	0.00043	0.43

TOTAL WEIGHT GAIN (g): 0.001676 (mg): 1.676

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 1.65

STANDARD DEVIATION: 8.32

IMPACTOR CONCENTRATION (mg/m^3): 0.39

DM FILTER SET: DM-08A

SAMPLE DATE: 03/24/88

IMPACTOR ID: ACI-1002

CORE HOLE: AC-1

LOCATION: BACKGROUND-Demonstration Drift (Muckers recently in main tunnel)

RUN TIME (min): 75

PRE-SEPARATOR	0	0
STAGE 0	0.000498	0.498
STAGE 1	0.000655	0.655
STAGE 2	0.00035	0.35
STAGE 3	0.000565	0.565
STAGE 4	0.000582	0.582
STAGE 5	0.000525	0.525
STAGE 6	0.0001	0.1
STAGE 7	0.000012	0.012
FINAL	0.000418	0.418

TOTAL WEIGHT GAIN (g): 0.003705 (mg): 3.705

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 2.92

STANDARD DEVIATION: 3.82

IMPACTOR CONCENTRATION (mg/m^3): 1.75

DM FILTER SET: DM-09A

SAMPLE DATE: 04/19/88

IMPACTOR ID: ACI-892

CORE HOLE: AC-2

LOCATION: (Negative weights for stages 2-7, UNUSABLE DATA)

RUN TIME (min): 105

PRE-SEPARATOR	0.000515	0.515
STAGE 0	0.000526	0.526
STAGE 1	0.000236	0.236
STAGE 2	0	0
STAGE 3	0	0
STAGE 4	0	0
STAGE 5	0	0
STAGE 6	0	0
STAGE 7	0	0
FINAL	0.000213	0.213

TOTAL WEIGHT GAIN (g): 0 (mg): 0

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 0

STANDARD DEVIATION: 0

IMPACTOR CONCENTRATION (mg/m^3): 0

DM FILTER SET: DM-10A

SAMPLE DATE: 04/14/88

IMPACTOR ID: ACI-1002

CORE HOLE: AC-2

LOCATION: Center of Laser Drift, approximately 15 ft from face

RUN TIME (min): 189

PRE-SEPARATOR	0.000603	0.603
STAGE 0	0.000339	0.339
STAGE 1	0.000332	0.332
STAGE 2	0.000213	0.213
STAGE 3	0.000181	0.181
STAGE 4	0.00016	0.16
STAGE 5	0.000215	0.215
STAGE 6	0.000283	0.283
STAGE 7	0.000261	0.261
FINAL	0.000845	0.845

TOTAL WEIGHT GAIN (g): 0.003432 (mg): 3.432

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 1.14

STANDARD DEVIATION: 8.41

IMPACTOR CONCENTRATION (mg/m^3): .53

DM FILTER SET: DM-12A

SAMPLE DATE: 04/19/88

IMPACTOR ID: ACI-899

CORE HOLE: AC-2

LOCATION: (Negative weights for stages 1-7, UNUSABLE DATA)

RUN TIME (min): 105

PRE-SEPARATOR	0.00025	0.25
STAGE 0	0.000006	0.006
STAGE 1	0	0
STAGE 2	0	0
STAGE 3	0	0
STAGE 4	0	0
STAGE 5	0	0
STAGE 6	0	0
STAGE 7	0	0
FINAL	0.000247	0.247

TOTAL WEIGHT GAIN (g): 0 (mg): 0

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 0

STANDARD DEVIATION: 0

IMPACTOR CONCENTRATION (mg/m^3): 0

DM FILTER SET DM-13A

SAMPLE DATE: 04/20/88

IMPACTOR ID: ACI-1001

CORE HOLE: AC-2

LOCATION: Wall opposite core hole, approximately 20 ft face between
table and drill

RUN TIME (min): 256

PRE-SEPARATOR	0.000489	0.489
STAGE 0	0.000522	0.522
STAGE 1	0.000559	0.559
STAGE 2	0.000427	0.427
STAGE 3	0.000499	0.499
STAGE 4	0.000463	0.463
STAGE 5	0.000395	0.395
STAGE 6	0.000363	0.363
STAGE 7	0.000427	0.427
FINAL	0.001159	1.159

TOTAL WEIGHT GAIN (g): 0.005303 (mg): 5.303

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 1.47

STANDARD DEVIATION: 6.06

IMPACTOR CONCENTRATION (mg/m^3): .66

DM FILTER SET: DM-14A

SAMPLE DATE: 04/20/88

IMPACTOR ID: ACI-931

CORE HOLE: AC-2

LOCATION: Between Laser core hole and DCT, near wall

RUN TIME (min): 256

PRE-SEPARATOR	0.000709	0.709
STAGE 0	0.000465	0.465
STAGE 1	0.000431	0.431
STAGE 2	0.000347	0.347
STAGE 3	0.000445	0.445
STAGE 4	0.00043	0.43
STAGE 5	0.000388	0.388
STAGE 6	0.000425	0.425
STAGE 7	0.000395	0.395
FINAL	0.001318	1.318

TOTAL WEIGHT GAIN (g): 0.005353 (mg): 5.353

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 1.16

STANDARD DEVIATION: 6.51

IMPACTOR CONCENTRATION (mg/m^3): .55

DM FILTER SET: DM-15A

SAMPLE DATE: 04/21/88

IMPACTOR ID: ACI-1002

CORE HOLE: AC-2

LOCATION: Center of Laser Drift, approximately 15 ft from face

RUN TIME (min): 192

PRE-SEPARATOR	0.0005	0.5
STAGE 0	0.001052	1.052
STAGE 1	0.00027	0.27
STAGE 2	0.00018	0.18
STAGE 3	0.000205	0.205
STAGE 4	0.000188	0.188
STAGE 5	0.000256	0.256
STAGE 6	0.000192	0.192
STAGE 7	0.000286	0.286
FINAL	0.00037	0.37

TOTAL WEIGHT GAIN (g): 0.003499 (mg): 3.499

MASS MEDIAN AERODYNAMIC DIAMETER (μm): 0.965

STANDARD DEVIATION: 9.86

IMPACTOR CONCENTRATION (mg/m^3): .55

APPENDIX E
NOTEBOOKS AND LOGBOOKS

Data in this report can be found in the following notebooks and logbook.

NOTEBOOKS

TWS-HSE5-07-87-006

TWS-HSE5-12-87-007

TWS-HSE5-12-87-008

TWS-HSE5-12-87-009

TWS-HSE5-12-87-010

LOGBOOKS

TWS-HSE5-06-88-001

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