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CHARACTERIZATION OF EMISSIONS FROM PLUTONIUM-URANIUM OXIDE FUEL FABRICATION

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CHARACTERIZATION OF EMISSIONS FROM PLUTONIUM-URANIUM OXIDE FUEL FABRICATION

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FOREWORD

Protection of the environment requires effective regulatory actions which are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach which transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound integrated monitoring data base through multidisciplinary, multimedia programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment

- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report describes efforts to develop optimized monitoring techniques for measuring plutonium emissions from a mixed oxide fuel fabricating facility. This report should be useful in the design of monitoring systems for similar types of nuclear facilities. The users who should find this report of value are the various regulatory agencies involved in standards setting and compliance monitoring such as the Nuclear Regulatory Commission, U.S. Environmental Protection Agency, U.S. Energy Research and Development Administration, and the State and local agencies. Further information on this research may be obtained from the Methods Development and Analytical Support Branch of this Laboratory.

George B. Morgan
Director
Environmental Monitoring and Support Laboratory
Las Vegas

ABSTRACT

To develop accurate techniques for monitoring plutonium emissions from plutonium-uranium oxide fuel fabrication facilities, knowledge of the appropriate physical and chemical properties of the released plutonium are necessary. In-stack, standard hi-vol, and special ultra-high volume air samplers were used to collect particulate samples at the Babcock and Wilcox mixed oxide facility in Parks Township, Pennsylvania.

The number of radioactive particles emitted, the particles sizes, and plutonium and uranium isotopic content were determined. These characteristics are used to propose an appropriate monitoring technique for plutonium for facilities of this type.

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LIST OF FIGURES AND TABLES

LIST OF ABBREVIATIONS

Abbreviations

μm = micrometer
aCi = attocurie (10^{-18} = atto)
Ar = argon
BCL = Battelle Columbus Laboratory
cm = centimeter
cm^2 = square centimeters
cm/s = centimeters per second
Ci = curie
Ci/g = curies per gram
Ci/m^3 = curies per cubic meter
DOP = dioctylphthalate
dpm = disintegrations per minute
EMP = electron microprobe
fCi = femtocurie (10^{-15} = femto)
$FeSO_x$ = iron sulfates and sulfites
FT = fission tracks
ft^3 = cubic feet
g = gram
h = hour
H_2 = hydrogen
H_2O = water
HEDL = Hanford Engineering and Development Laboratory
HEPA = high efficiency particulate air (filter)
kg = kilogram
km = kilometer
l = liter
l/min = liters per minute
m = meter
m/min = meter per minute
m^2 = square meters
m^3 = cubic meters
m^3/h = cubic meters per hour
m^3/min = cubic meters per minute
min = minute
mm = millimeter
m/s = meters per second
N_2 = nitrogen
NaCl = sodium chloride (salt)
nCi = nanocurie (10^{-9} = nano)
ng = nanogram
NMD = Nuclear Materials Development
NRC = Nuclear Regulatory Commission
O = oxygen
pCi = picocurie (10^{-12} = pico)
pCi/g = picocurie per gram
Pu = plutonium
PuO_2 = plutonium dioxide
PuO_x = Plutonium oxides
QA = Quality Assurance
s = second
SEM = scanning electron microscope
SiO_x = silicon oxides
TEM = transmission electron microscope
TiO_x = titanium oxides
U = uranium
UO_2 = uranium dioxide
UO_x = uranium oxides

LIST OF SYMBOLS

Symbols

a	=	acceleration due to gravity
C_1	=	percentage of cation number 1
C_2	=	percentage of cation number 2
C_3	=	percentage of cation number 3
d	=	apparent particle diameter micrometers
d_a	=	aerodynamic diameter of particle, micrometers
D	=	inside stack diameter, meters
H	=	stack height, meters
H_e	=	effective stack height, meters
l	=	length, micrometers
n_d	=	index of refraction
P_1	=	particle density, grams per cubic centimeter
P_2	=	air density, grams per cubic centimeter
Q	=	emission rate, particles per second and/or particles per cubic meter; flow rate, m^3/min
r	=	distance from center of sampling tube to stack wall
t	=	thickness, micrometers
T_a	=	ambient temperature, °Kelvin
T_s	=	temperature of stack gas, °Kelvin
U	=	time averaged wind velocity at the height, H, meters per second
V	=	stack gas velocity, meters per second
ω	=	width, micrometers
x	=	downwind distance, meters
y	=	crosswind distance, meters
a	=	vertical distance, meters
σ_y	=	standard deviation of the time averaged plume concentration distributed in the crosswind direction
σ_z	=	standard deviation of the time averaged plume concentration distributed in the vertical direction
ρ	=	density, grams per cubic centimeter
ρ_1	=	density of cation number 1
ρ_2	=	density of cation number 2
ρ_3	=	density of cation number 3
n	=	viscosity of air, poise
χ	=	ground-level concentration, picocuries per cubic meter and/or particles per cubic meter

ACKNOWLEDGMENTS

The authors wish to thank the management of Babcock and Wilcox, especially Mr. Grant LaPier and Mr. David Ortz, for allowing the U.S. Environmental Protection Agency (EPA) to conduct this study at the Babcock and Wilcox mixed oxide fuel fabrication facility and for their assistance in providing support in changing air filters and in providing meteorological data. The authors would also like to thank the Hanford Engineering and Development Laboratory, Westinghouse Corporation, particularly Mr. Robert Smith, for providing use of their exhaust stack sampling ports.

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INTRODUCTION

The objective of this research is to develop techniques for monitoring plutonium emissions from mixed oxide fuel fabrication facilities. Appropriate monitoring techniques and procedures for particulate plutonium emissions are dependent upon a number of factors; among the most important are the physical (size, shape, density, specific activity) and chemical properties of these particulates. Additional factors which must be considered are the effects of aging and climatic conditioning of individual particles containing plutonium after their release into the environment. These factors led to a requirement for sampling at and in the environs of a plutonium-uranium oxide fuel fabrication facility. At the inception of this research there were only two facilities in the United States fabricating mixed plutonium-uranium oxide fuels: Babcock and Wilcox, located in Pennsylvania, and Kerr-McGee, located in Oklahoma. Each of these facilities had established a prototype production line (using different chemical processes) for fabricating fuel for a breeder reactor.

It was decided that the Babcock and Wilcox facility should be sampled first because an intensive investigation by the Nuclear Regulatory Commission (NRC) and certain other governmental bodies was being conducted at the Kerr-McGee facility which precluded any sampling effort in the time frame allocated to this research effort.

The Babcock and Wilcox mixed oxide facility, hereafter referred to as the Plant, is one of three facilities located on 59 acres (23.9 hectare) of land approximately 5 kilometers (km) northeast of Apollo, Pennsylvania. The other two facilities are the Metals Complex and the Nuclear Materials Development (NMD) Type II Plant. Specialty metals (but no nuclear materials) are handled at the Metals Complex, and highly enriched uranium is processed in the NMD Type II Plant.

Principal operations of the Plant include a glove box line for the fabrication of finished rods, or pins, of mixed oxide pellets (plutonium dioxide mixed with uranium dioxide), and a scrap recovery line that produces purified plutonium nitrate solution from scrap materials. Plutonium nitrate from the scrap recovery line is ultimately shipped from the Plant.

Five basic steps are used to produce finished fuel rods. Plutonium dioxide powder undergoes several physical preparatory steps, and then is blended with uranium dioxide. This mixed oxide powder is formed into high-density pellets via a conventional pelletizing procedure. Finally, the peletized mixed-oxide fuel is loaded into rods which, in turn, are welded, inspected, washed, and loaded for shipment. A recycle line also exists, whereby rejected pellets and/or powder can be worked back into the mixed oxide line. The process is outlined in Figure 1.

Plutonium-bearing scrap, either from outside customers or from the mixed oxide operations, is dissolved in a nitric acid/hydrofluoric acid mixture. The resultant plutonium nitrate solution is purified by ion exchange columns, concentrated, collected in 10-liter (l) bottles, and stored until ready for shipment.

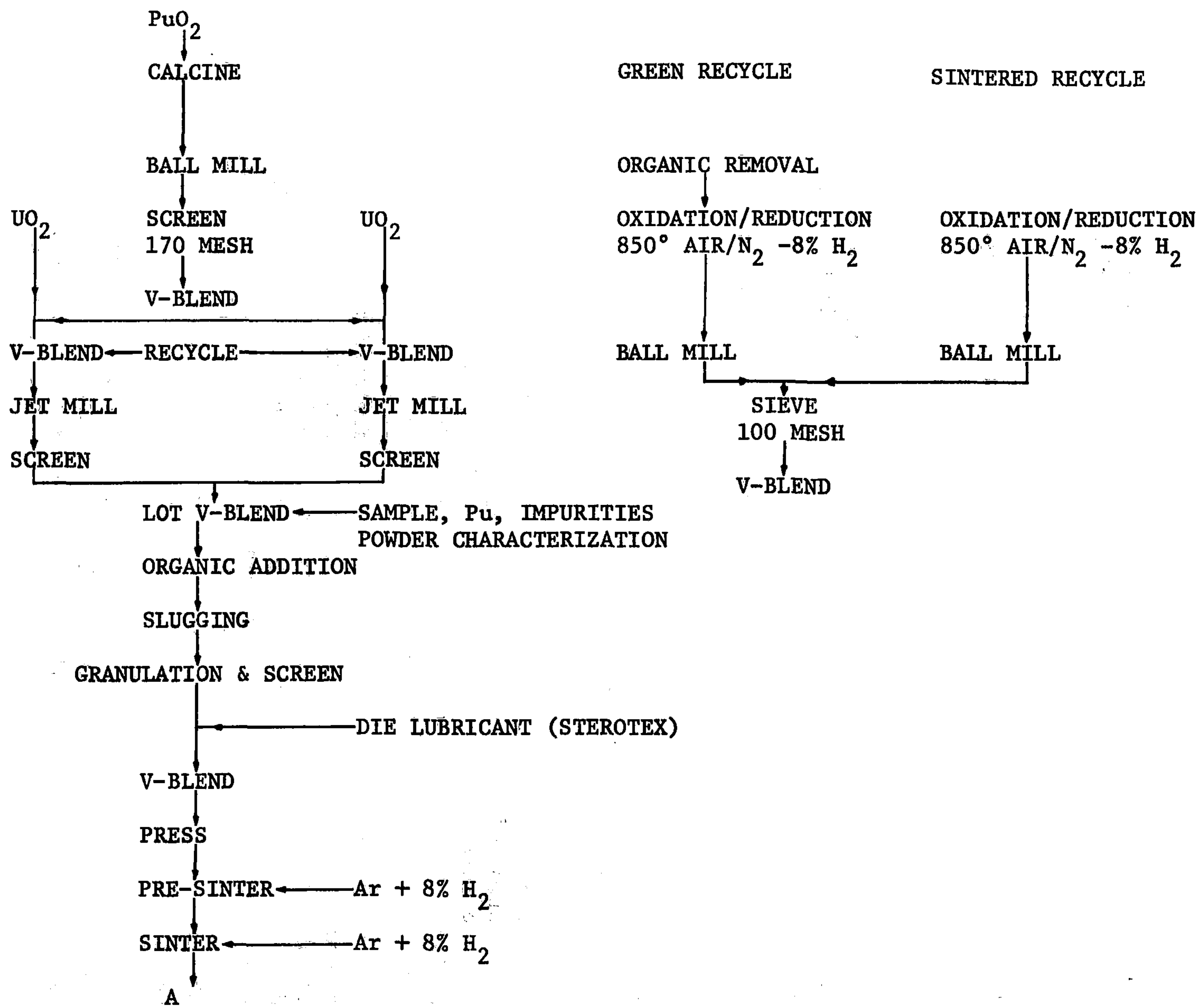


Figure 1. Babcock and Wilcox process flow diagram for fuel fabrication.

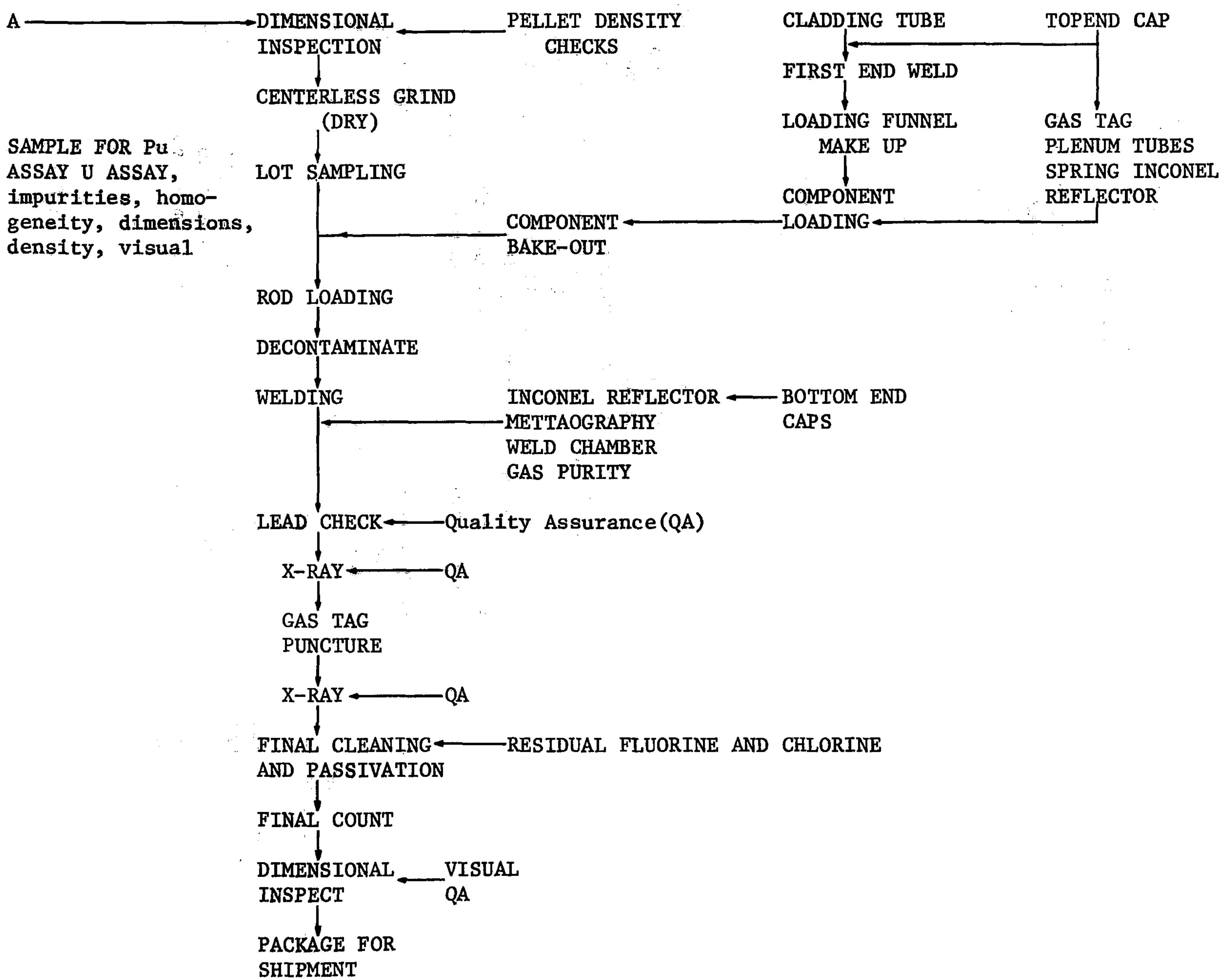


Figure 1. Babcock and Wilcox process flow diagram for fuel fabrication. (continued).

The exhaust emissions from glove boxes (after initial high efficiency particulate air (HEPA) filtration), hoods, etc., which are used in the preparation of the fuel pins as well as emissions from an analytical laboratory, cafeteria, and office area are all passed through prefilters and final HEPA filters (Filter No. 7W-60NL-N2N2 manufactured by Flanders Filters, Inc.*) before exhaustion into the atmosphere through a stack with an inside diameter of 0.46 meter (m) at a velocity of 401 meters per minute (m/min). The Hanford Engineering and Development Laboratory (HEDL), Westinghouse, Inc., and Babcock and Wilcox had established sampling stations in the stack. HEDL and Babcock and Wilcox engineers had determined stack velocities, sampling points, and flow rates for isokinetic sampling both upstream and downstream relative to the final HEPA filter banks by a hot-wire anemometer technique. The emissions from processing the plutonium-bearing scrap are not exhausted through this stack.

CONCLUSION

The following conclusions concerning the character of the plutonium-uranium stack emissions from a typical mixed oxide fuel fabrication facility can be made from this research:

1. Approximately 4.5 nanocuries (nCi) of plutonium-239 was emitted into the atmosphere per kilogram (kg) of plutonium fabricated into mixed oxide fuel. This is equivalent to 0.15 nCi per fuel pin fabricated. The plutonium-239 was being emitted into the atmosphere in the form of submicron particles with an aerodynamic mean diameter of 0.2 micrometer (μm). Approximately 300,000 particles were emitted into the atmosphere per kilogram (kg) of fuel fabricated or 10,000 particles per fuel pin fabricated. The average activity of each particle emitted was 15.1 femtocurie (fCi). These particles have been identified individually and as occlusions and inclusions in host particles of feldspars, flyash, organic or carbonaceous materials. The chemical form of the individual particles was plutonium-uranium oxide.

2. Plutonium-239 was being emitted into the environment, although in quantities too small to be detected by standard air monitoring techniques for collection and gross alpha analysis of air samples. In addition, the amount of uranium found in the environmental air samples tended to mask the small amount of plutonium present when only gross alpha measurements were made.

3. Due to extraneous materials on stack sampling filters, particle penetration into the filter, and isotope composition, direct alpha counting of stack sampling filters may substantially underestimate the amount of plutonium emitted into the environment. In this case, plutonium emissions were estimated more than 60 percent low.

*This filter shows a retentivity of 99.97 percent by standard DOP (dioctylphthalate) test.

4. Soil samples taken in the environs of the Plant indicated plutonium-238 and/or -239 in concentrations ranging from less than 0.003 picocuries per gram (pCi/g) to 0.3 pCi/g. These variable and relatively high levels preclude soil sampling and analysis as an applicable monitoring technique.

RECOMMENDATIONS

The results of this study indicate that plutonium emissions from this type of facility should be determined by sampling directly at the source. The source can be considered as some point after the final stack filters and before exhaustion into the atmosphere. Environmental air sampling, using samplers capable of minimum sampling rates of 500 cubic meters per hour (m^3/h), should be used as a check on the stack monitoring program.

Sampling programs near new sources of possible actinide pollution must commence well in advance of establishment of any such sources. The prime considerations here are:

a. A thorough study of existing actinides in the environment must be made prior to the commencement of plant operation. The types of actinide present, the isotopic composition and the amount present must be determined.

b. Typical meteorological conditions must be well established.

c. Realistic dispersion calculations, based on plant engineering design and meteorological predictions, should be used to determine sampling sites for maximum probability of pollutant collection.

d. The collection devices and medium used for stack monitoring must be chosen to provide optimum sampling conditions (location in stack, flow rates).

e. Basic isotopic information is required to establish standard analytical techniques for monitoring of routine samples. Therefore, periodic, detailed analysis of particulate pollutants must be made to establish any variations in isotopic composition or change in prefilter and final filter efficiencies.

METHODOLOGY

SAMPLING

Stack Sampling

The stack used to exhaust particulate matter from the preparation of fuel pins was sampled using the setup shown in Figure 2. Figure 3 shows the sample-port geometry. The stack from the scrap processing area was not sampled because it was not in operation during the sampling period. In brief, 47-millimeter (mm) diameter Millipore type AA filters backed with Microsorban type 99/97 filters were exposed isokinetically to the stack emissions through sampling tubes at flow rates of 19.8 liters/min (l/min) and 21.2 liters/min upstream and downstream of the HEPA filters, respectively. These samplers were run continuously for the 86-day period from 5/15/75 to 8/9/75. The Millipore filters have a pore diameter of approximately 0.8 micrometer. Microsorban filter material has a retentivity greater than 99 percent for particles of diameter greater than or equal to 0.3 micrometers.

The filters were removed by Babcock and Wilcox personnel after appropriate instruction. Fuel fabrication operations were conducted for 51 days of the 86-day sampling period (the Plant was not in operation on weekends or on May 29 or August 5). During this 51-day production period, 103.8 kilograms of plutonium (524.3 kilograms of mixed oxide fuel) and 3,034 fuel pins were produced. The composition of the fuel, ratio of plutonium-239 to uranium-238, for May and June was 24.2 percent and from July to August was 19.8 percent.

Environmental Air Sampling

The first phase of the environmental air sampling program was conducted over the period from 5/14/75 to 8/14/75. Air samplers using 100-mm Microsorban type 99/97 material and sampling at an average rate of 1.8 m^3/h were operated at several locations in the environs of the Plant by Babcock and Wilcox personnel. Air sampling locations are shown in Figure 4. Appendix A contains a table of sampling data. Meteorological data indicated that the prevalent winds were to the north-northeast approximately 37 percent of the time during the sampling period. This information was used to determine air sampling locations. Two samplers were located downwind of the stack; one was about 100 meters from the stack while the second was about 900 meters further downwind. A third sampler was located on the site of the cylinder storage area. A fourth sampler, located 8 kilometers crosswind to the southeast and denoted as station 5, served as a background sampling location. Typical sampling times were 500 hours.

The second phase of the environmental sampling program used a massive volume air sampler located near the cylinder storage area. The flow rate through this sampler was approximately 1600 m^3/h. The particle collection was by impaction and electrostatic precipitation. The sampler fractionated particulates into three size ranges: 1) less than 1.7 micrometers, 2) 1.7 to 3.5 micrometers, and 3) 3.5 to 20 micrometers. Aside from the obvious advantage of

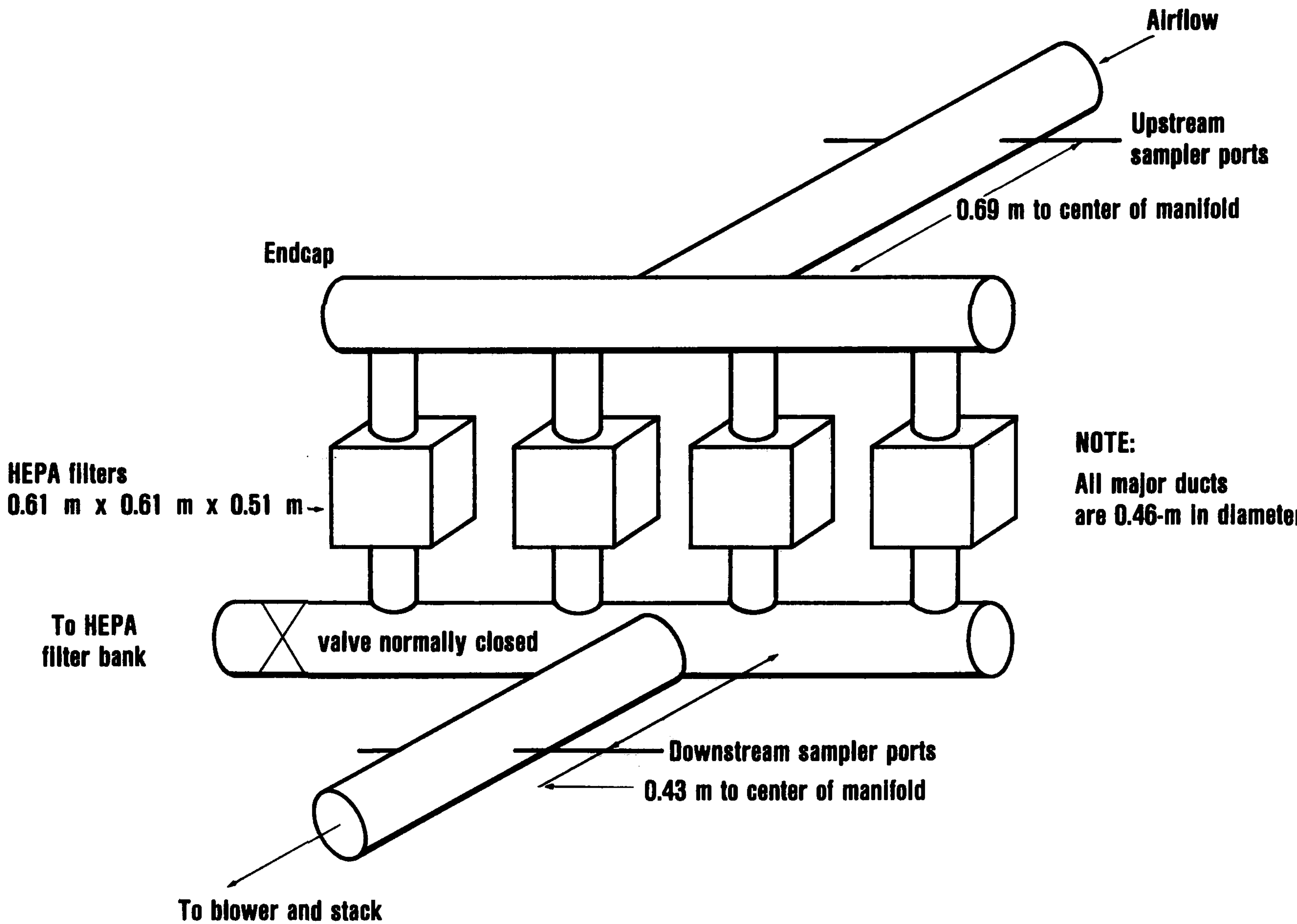
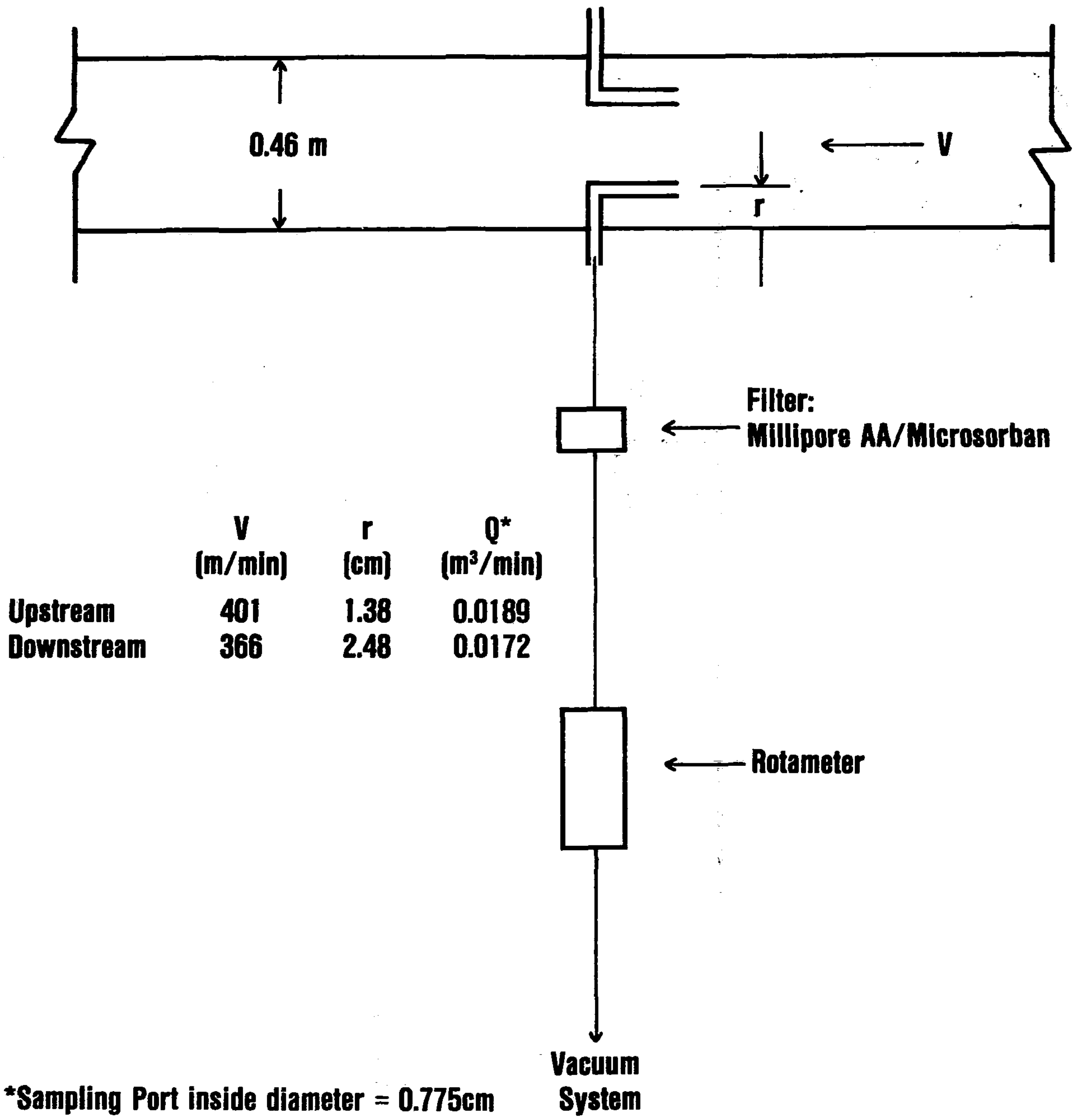


Figure 2. Stack and high efficiency particulate air filter arrangement.



	V (m/min)	r (cm)	Q* (m³/min)
Upstream	401	1.38	0.0189
Downstream	366	2.48	0.0172

*Sampling Port inside diameter = 0.775cm

Figure 3. Stack sample port geometry.

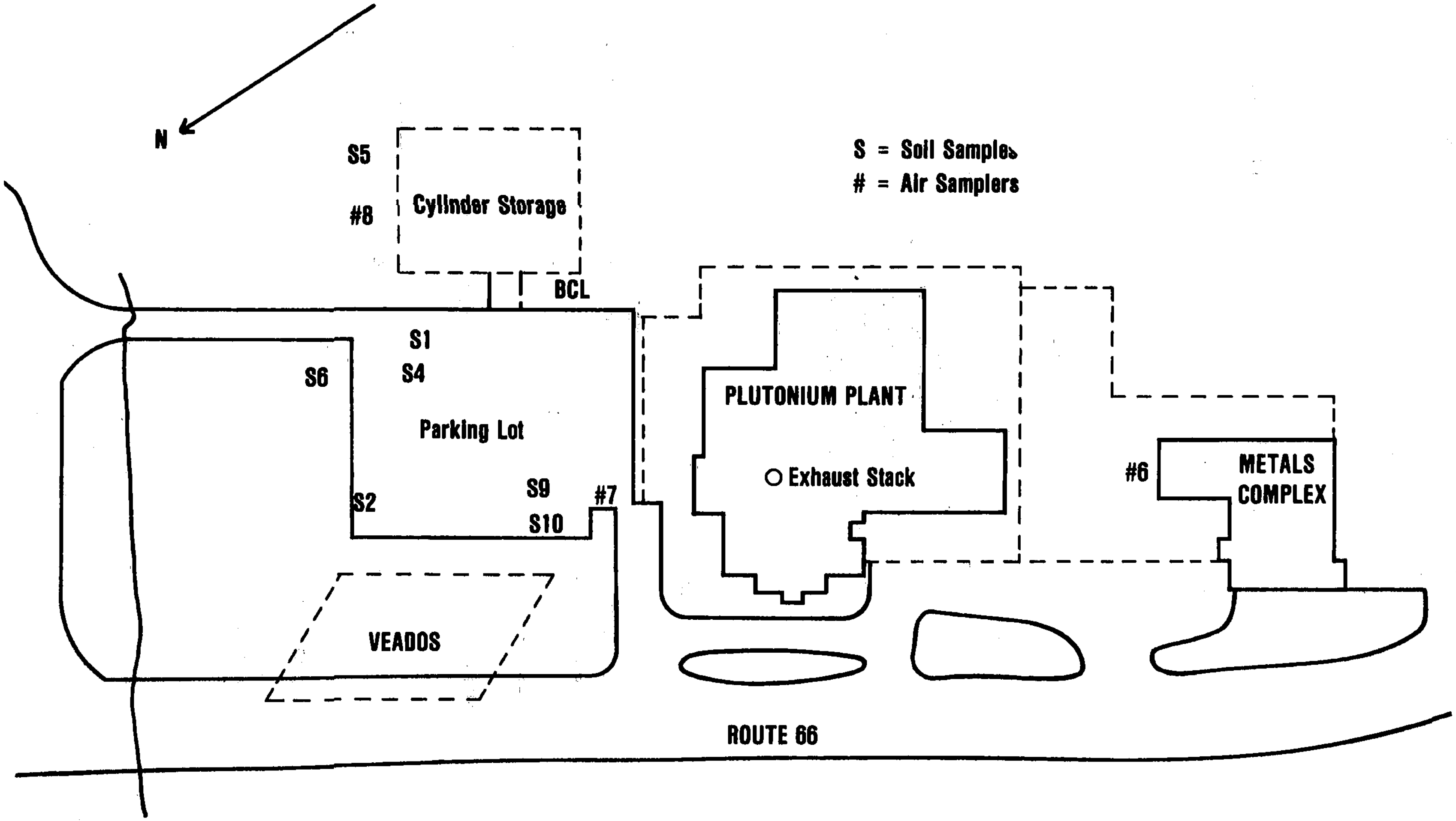


Figure 4. Air and soil sampling locations.

the high sampling rate, the particulates were collected free from any filter matrix and in gram quantities (typical for a 7-day sampling period). This sampler was operated for the 7-day period from 10/22/75 to 10/29/75. The Plant was not operating during this period.

Soil Sampling

Soil samples were taken from several locations in the environs of the Plant. The locations where the soil samples were taken are shown in Figure 4. A topographic map of the general area is shown in Appendix B. A method developed by Johnson et al. (1975) was used for collecting the soil samples. Johnson's method requires 4 square meters (m^2) of surface soil to be swept and collected, however, this method was developed for desert and other relatively arid and vegetation-free areas. The land area surrounding the Plant was covered with grasses and commercial farm crops, thus a very limited area was available for sampling via the Johnson technique. Soil was collected from a drainage ditch near the Plant cylinder storage area, near the northeast fence area, and from runoff silt deposited in the parking lot. Several other small areas were sampled near the Plant; however, in these cases it was not possible to sweep the full 4 m^2 area. Soil samples were also obtained from three upwind locations as well as two locations further downwind. The soils were subsequently sieved and the 150-micrometer fraction was used for alpha spectrometry analysis. The results of all soil analyses are shown in Appendix C.

ANALYSIS

Stack and Environmental Air Samples

A portion of each stack and air sample was solubilized and analyzed by mass spectrometry for isotopes of plutonium and uranium. Another portion of each stack and air sample was taken for particle analysis. Particle analysis was performed in two steps: (a) identification of radioactive particles, and (b) detailed physical and chemical analysis of selected radioactive particles.

a. Identification of Radioactive Particles--

This portion of the analysis consists of autoradiography by photographic and/or track-etch techniques after neutron irradiation of the filter to determine the total number of fissionable particles present per unit sample area and the distribution of such particles according to activity levels. (Becker 1969, Fleischer 1963, McCrone 1973).

b. Detailed Physical and Chemical Characterization--

A portion of the sample was chosen and particles were separated by chemical or physical means designed to preserve the integrity of any contained particles. Individual particles were examined to provide, in as much detail as possible, the level of alpha activity per particle and an estimate of the size ranges of the particles. Several particles in each size range were then chosen for further study. Size and shape estimations and photographs were made by optical or electron microscopy as appropriate to particle size. The gross elemental composition of certain of these particles was determined by electron microprobe analysis. Finally, mass spectrometric analysis was used to determine isotopic composition of the plutonium or uranium present on or in the particle. Analysis of non-fissionable particles was identical to that of fissionable particles except that track-etch studies were not done.

ANALYTICAL RESULTS OF STACK SAMPLE AND CHARACTERIZATION OF THE EMISIONS ENTERING THE ENVIRONMENT

The sample taken downstream of the final HEPA filter (sample 43) had a gross alpha count of 190 disintegrations per minute (dpm) and the sample taken upstream of the final HEPA filter (sample 44) had a gross alpha count of 1.2×10^6 dpm (these measurements were made by Babcock and Wilcox using an alpha counter on the unprocessed samples and represents their standard analysis technique). No further analyses of sample 44 were attempted because of the high activity. The information below was obtained from sample 43.

FISSIONABLE PARTICLE CHARACTERIZATION

A variety of representative particles on sample 43 were characterized by optical and electron microscopy. A significant number of these contained small particles of PuO_x-UO_x attached to host particles containing aluminum, silicon, iron, and oxygen. These host particles are either flyash or naturally occurring feldspars. In most instances the PuO_x-UO_x inclusions were too small to obtain any physical characteristics. Other PuO_x-UO_x particles were associated with organic or carbonaceous material. The latter was most probably of biological origin (i.e., vegetative plant tissue).

Particle Selection

A total of 140 fissionable particles was optically characterized. These included host particles that contained one or more fissionable inclusions or occlusions. An attempt was made to optically characterize a representative number of particles with less than 1000 fission tracks. A summary of the optical measurements is presented in Appendix D-2.

TABLE 1. NUMBER OF PARTICLES CHARACTERIZED IN EACH FISSION TRACK GROUP

Fission Track Range	Number of Particles Characterized
1 - 16	21
17 - 32	20
33 - 64	20
65 - 128	21
129 - 256	27
256 - 1000	24
>1000	7
TOTAL	140

Particle Size

The particle sizes were determined using an optical microscope. An apparent diameter was calculated, using maximum dimensions, by the following equation:

$$d = (l \times w \times t)^{1/3} \tag{1}$$

Where the thickness could not be determined, it was estimated as one-half width. In Appendix D-2 some sizes are recorded as zero because these particles were less than 2 µm and thus too small to adequately characterize. A particle size distribution of the 140 particles characterized in Appendix D-2 is presented in Figure 5. The median equivalent diameter, that diameter for which 50 percent of the particles measured are less than the stated size, was determined graphically as shown in Figure 5. The median equivalent diameter was 1.75 µm.

Particle Density

The particle densities, ρ, were calculated from the following equation (Larsen and Berman 1934):

$$\frac{n_d - 1}{d} = \rho \tag{2}$$

When the compound contains several cations, ρ becomes

$$\rho_1 C_1 + \rho_2 C_2 + \rho_3 C_3 . \ . \ . \ . \ . \tag{3}$$

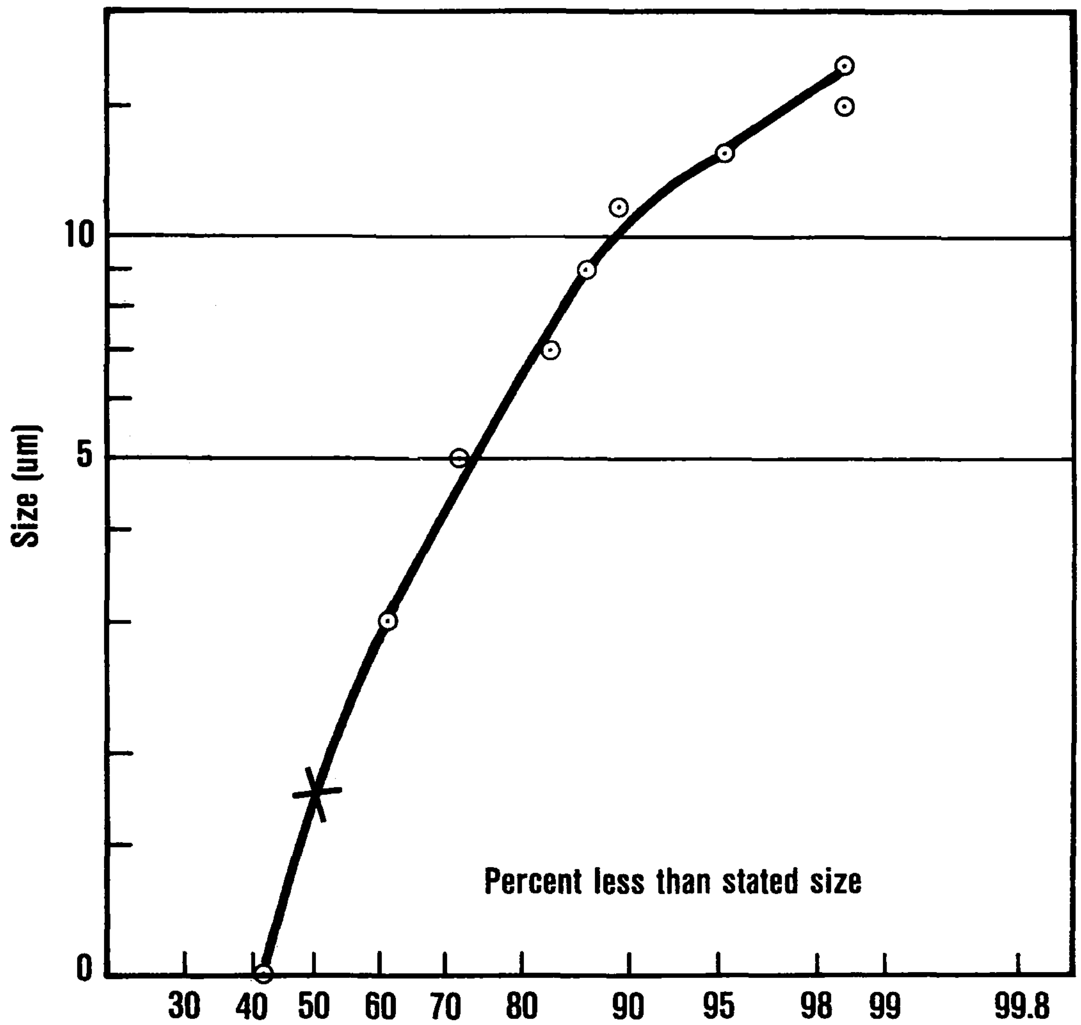


Figure 5. Size distribution of the fissionable particles.

The elemental analysis determined by the electron microprobe (EMP) was used as each C value. The ρ values were obtained from handbook tables cited in Larsen and Berman (1934). Generally, the refractive index used was 1.52, however, some indices were determined optically. No refractive index greater than 1.66 was determined optically.

The density of the particle was difficult to calculate in those instances where the particle contained more than one optical portion. In those cases, and particularly where oxides of iron, uranium, or plutonium were observed, the density was estimated. Densities ranged from 1.0 to greater than 7.2 grams per cubic centimeter (g/cm^3). The density of all particles analyzed is given in Appendix D-2.

Electron Microprobe Analyses

The particles were analyzed using an Applied Research Laboratory's electron microprobe (EMP). Generally, the major consituents of the nonfissionable particles analyzed were iron, aluminum, oxygen, and silicon. The fissionable particles usually contained U, Pu, and O. The results are presented in Appendix D-3. Some of the particles were photomicrographed on the scanning (SEM) or transmission electron microscope (TEM).

Mass Spectrometric Analysis

The isotopic values of plutonium were determined by first using a low filament temperature for ionization. The uranium isotopic values were then determined using a higher filament temperature. Uranium-234 concentrations were generally less than 0.007 percent, uranium-236 was not detectable in most cases; any difference was assumed to be uranium-238. For the plutonium isotopes present, plutonium-240 was approximately 11 percent, plutonium-241 approximately 1.5 percent, plutonium-242 approximately 0.2 percent, and plutonium-239 approximately 86 percent. A complete listing of the plutonium and uranium isotopic values is presented in Appendices D-4 and D-5, respectively. Appendix G contains various photomicrographs of selected particles.

NONFISSIONABLE PARTICLES

Optical Microscopy

Representative particulates selected from sample 43 were examined using a polarizing microscope. Over 95 percent of the particulates consisted of resinous vegetation material, carbon and unburned coal, and coal flyash including black, brown, and clear flyash spheres. Trace materials (less than 1 percent) including oil soot, paint particulates, metal fragments, pollens, fungal spores, corn starch, insect parts, salt (NaCl), feldspars, calcite, nylon, rutile (TiO_2) and asbestos were noted.

Electron Microprobe (EMP)

A small portion of the particulates was also examined using the EMP. A large portion (greater than 25 percent) of the material consisted of carbonaceous or organic material. A significant number (10-20 percent) of oxidized stainless steel particles was found in poorly defined form, possibly a hydrated corrosion product. Other particles identified included SiO_x, feldspars, aluminum silicates (some as flyash), gypsum, TiO_x, dolomite and $FeSO_x$.

GROSS PLUTONIUM EMISSIONS

An estimation of the total plutonium entering the environment was made using fission track, gross alpha and mass spectrometry data.

Gross Plutonium Emissions Estimated from Fission Track Data

An estimation of total plutonium entering the environment from fission track data from individual particles was obtained using the following information:

a. The plutonium-oxide to uranium-oxide ratios of fissionable particles as analyzed by EMP varied from 0 to 0.96.

b. Isotopically, the uranium was usually natural (0.72 percent uranium-235).

c. Greater than 99 percent of the fission tracks observed were calculated to originate from the plutonium portion of any mixed oxide particle observed in this study (Hayden 1974, Nathans et al. 1974).

The fission track data from one-half of sample 43 and the above data yield an estimate of the plutonium activity obtained as shown in Table 2.

Since the total dpm calculated in Table 2 was for half the sample, it is estimated that the total filter had 2 × 29.25 = 58.5 dpm of plutonium. The resultant estimation of plutonium activity for the total sample is 88.9 dpm when the calculations are made using the maximum number of tracks in each group (i.e., 16 tracks in the 3-16 track group).

TABLE 2. CALCULATION OF PLUTONIUM ACTIVITY FROM FISSION TRACK DATA FROM HALF OF SAMPLE 43

Fission Track Star Range (FT)	Median Value (FT)	Number of Stars Observed	Total Fission Tracks	pg of ^{239}Pu	dpm of ^{239}Pu	dpm/particle ($\times 10^{-3}$)
3 - 16	10	991	9910	5.83	1.00	1.0
17 - 32	25	1397	34925	20.54	3.50	2.5
33 - 64	49	1240	60760	35.74	6.07	4.9
65 - 128	97	527	51119	30.07	5.11	9.7
129 - 256	196	196	37828	22.25	3.79	190.0
256 - 1000	628	77	48356	28.44	4.83	620.0
>1000*	4500*	11	49500	29.12	4.95	4500.0
TOTAL		4439 stars			29.25 dpm	

*Assuming maximum star as 10,000 tracks

Total emission calculations were made as follows:

Stack diameter = 0.46 m

Area = 0.17 m^2

Exit velocity = 401 m/min

Stack emission rate, Q = 0.17 m^2 × 401 m/min = 68.1 m^3/min

Stack sampler rate = 19.82 liter/min = 0.0198 m^3/min

Therefore, total emission rate = 68.1/0.0198 = 3439 times the sampler rate.

Assuming sample 43 contains 58.5 dpm plutonium (from above) and that the sample was taken isokinetically, then the total plutonium particulate alpha activity emitted from the stack during the sampling period was 58.5 × 3439 = 201,200 dpm or 2.0 × 10^5 dpm/2.22 × 10^3 dpm/nCi = 90.1 nCi. Since the sampling period was 86 days, this represents 1.05 nCi of plutonium emitted per day using the median value from Table 2 or 1.60 nCi using the maximum value.

Gross Plutonium Emissions Estimated from Gross Alpha Count

The data from gross alpha counting by Babcock and Wilcox were also used to calculate the gross plutonium-239 emitted from the stack. The calculation was as follows:

The gross alpha count on sample 43 was 190 dpm. Therefore, 190 × 3439 = 6.5 × 10^5 or 293 nCi emitted in 86 days or 3.41 nCi/day.

Gross Plutonium Emissions Estimated from Mass Spectrometry Data

The total nanograms (ng) of plutonium on the sample, as determined by mass spectrometry analysis of one-quarter of the sample, was 1.78 nanograms. Adjusting for the contribution of plutonium-240, there was 170 dpm/ng of total plutonium. Therefore, the plutonium disintegration rate of this filter was 170 × 1.78 = 303 dpm = 136 pCi or 1.58 pCi/day. The total effluent was 3439 × 1.58 = 5.43 nCi/day or 9.2 nCi/workday. Of the three techniques used to calculate plutonium emissions, the latter would be expected to provide the most accurate information. The number of plutonium particles in the Plant emissions per day can be calculated as follows: From Table 2, 4500 particles per half sample or 9,000 particles were found in the 86-day sample. Since the volume ratio (stack/sample) was 3439, the stack particles emission rate is then (9000/86) × 3439 = 3.6 × 10^5 particles per sample day or 6.07 × 10^5 particles per workday (7 particles/s). As calculated above, 136 pCi in 9,000 particles was emitted, implying an average activity of 15.1 fCi/particle.

Given the plutonium-239 emission rate of 5.43 nCi of gross plutonium per sampling day and 3.6 × 10^5 particles per sampling day, we can summarize the emitted plutonium-239 in the following manner: (following page)

TABLE 3. PLUTONIUM-239 EMISSION SUMMARY

	Per Work Day	Per Sampling Day	Per kg of Fuel Fabricated	Per Fuel Pin
Total (nCi)	9.20	5.43	4.51	0.15
Particulate	6.07×10^5	3.6×10^5	2.99×10^5	1.02×10^4

The aerodynamic size of the emitted particles can be calculated as follows:

Particles larger than about a micrometer in diameter settle in air at velocities approximated by Stokes' Law (U.S. DHEW, 1969)

$$V = a \times d^2(P_1 - P_2)/18\eta \quad (4)$$

The expression is true only for spheres. An upper limit to its applicability is set when a certain settling velocity is reached and the particle generates a significant wake. The lower limit is reached when the particles become small, around 1 µm, so air resistance is no longer continuous but is rather the result of individual collisions with air molecules. Under these conditions the particles "slip" between molecules and Stokes' equation underestimates their falling velocity.

In the case of nonspherical particles, substitution of V, a, P_1, P_2, and η in the above equation leads to a fictitious diameter, d_a, which is known as the 'aerodynamic' diameter.

If the density, P_1, is unknown, it may arbitrarily be assigned a value of 1 g/cm³. In this case d is no longer Stokes' diameter but rather the "reduced sedimentation diameter." An example is: 1-µm sphere of lead or $PuO_2 - UO_2$ (50:50) with a density of 11 g/cm³ has a reduced sedimentation diameter of ≈3.3 µm. The settling velocity is now increased from 2×10^{-2} cm/s to 2×10^{-1} cm/s. Conversely, a large (greater than 6 µm) host particle with a density of 2 to 3 g/cm³ with a 1-µm PuO_x-UO_x inclusion has its "reduced sedimentation diameter" altered by 5 percent; therefore, there is no noticeable change in the settling velocity.

A calculation was made to determine the equivalent particle size of the PuO_x-UO_x particles found in sample 43. This equivalent particle size is based upon the fission track distribution and is presented in Table 4; the data from Table 4 are plotted in Figure 6. The median equivalent diameter (Figure 6) is near 0.2 µm. This is significant in that half of the equivalent diameter particles of PuO_x-UO_x may be a pulmonary hazard if these particles exist in a free, unattached state.

TABLE 4. EQUIVALENT SIZE OF PuO_x-UO_x PARTICLES FROM SAMPLE 43

Fission Star Range (Tracks)	Tracks (Avg.)	Equivalent Particle Size (μm)	Number of Particles	Percent of Total	Cumulative Percent
3 - 16	10	0.14	991	22.3	22.3
17 - 32	25	0.19	1397	31.5	53.8
33 - 64	25	0.24	1240	27.9	81.7
65 - 128	97	0.29	527	11.9	93.6
129 - 255	193	0.37	196	4.4	98.0
256 - 1000	628	0.54	77	1.7	99.7
>1000	4500*	1.05	11	0.2	99.9
TOTALS			4439	99.9	

*Assuming maximum star as 10,000 tracks

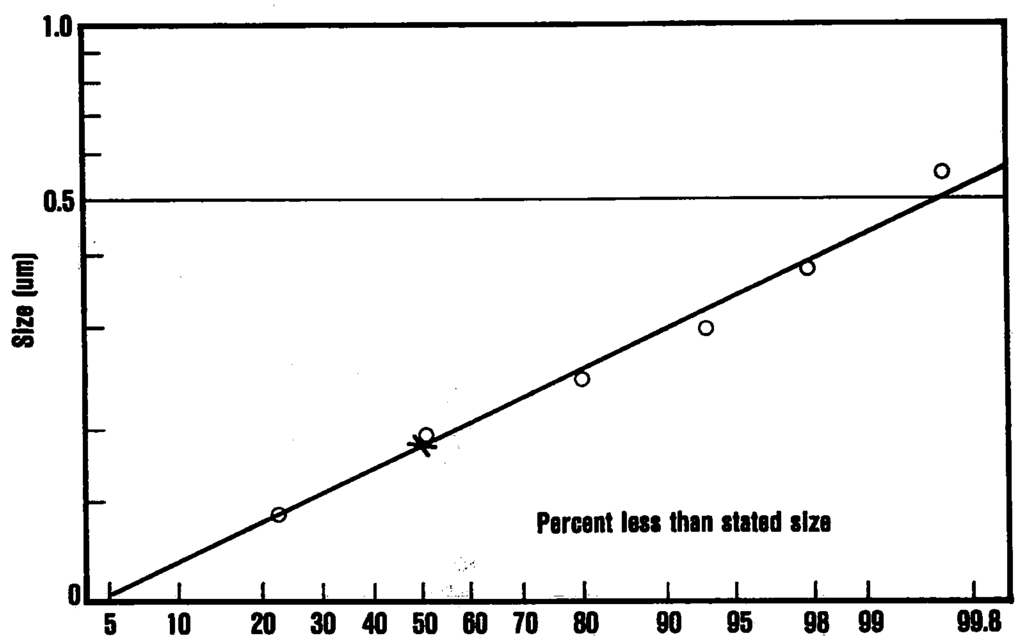


Figure 6. Equivalent size of PuO_x—UO_x particles from sample 43 based upon tracks.

RESULTS OF ENVIRONMENTAL AIR ANALYSIS

PARTICLE CHARACTERIZATION

Examination of a large number of particles from environmental air samples has shown the presence of various isotopes of uranium; however, no plutonium particles were found. The uranium isotopes and their percentages are listed in Appendix F.

GROSS ACTINIDE ANALYSIS

Appendix E-1 contains results of gross analysis by mass spectrometric techniques for six environmental air samples. The total grams of uranium per filter is one the order of 10^{-7} and is predominately uranium-235 and uranium-238. The total grams of plutonium per filter ranges from less than 10^{-12} to 2×10^{-12} with isotopic compositions of plutonium-239 in the 50 to 80 isotope-percent range and plutonium-240 in the 0 to 27 isotope-percent range. Plutonium-241 was present in one sample at 23 isotope-percent. The specific activity of plutonium-239 is 6.13×10^{-2} Ci/g. The average activity collected, assuming 1×10^{-12}g of plutonium at an 80 percent concentration for the 239 isotope, is $(6.13 \times 10^{-2}\text{Ci/g}) \times (0.80) = (4.9 \times 10^{-14}\ \text{Ci}) = 49$ fCi. Sampling times ran from 137 to 676 hours. The average sample collection time was 500 hours at a rate of 1.8 m^3/h.

Therefore, for an average sampled air volume of $500 \times 1.8 = 900\ m^3$, the average ground-level concentration of plutonium was:

$$4.9 \times 10^{-14}\ \text{curies}/900\ m^3 = 5.4 \times 10^{-17}\ \text{Ci}/m^3 = 54\ \text{aCi}/m^3$$

Appendix E-2 contains gross levels of various uranium and plutonium isotopes as a function of size fraction.

REQUIREMENTS FOR MONITORING

The establishment of an environmental sampling methodology is dependent upon knowledge of the pollutant concentration in the surrounding area. A major source of pollutant entry into the environment from the Plant is assumed to be the exhaust stack utilized for the production of finished fuel rods. Estimations of the stack plume concentration at ground level are dependent upon a number of factors.

These factors can be classed under three general headings, and are:

1. Process factors

   - Emission rate
   - Temperature of emission products
   - Form of emission products, i.e., dust, fumes, mist, spray, etc.

- Concentration of emission products
- Particle size distribution and terminal velocity
- Agglomerating characteristics
- Chemical properties

2. Source factors

- Stack height
- Stack diameter and exit configuration
- Stack velocity
- Relationship of stack to surroundings

3. Meteorological factors

- Wind speed and direction
- Temperature and humidity
- Atmospheric stability
- Topographic effects

The basic formula for plume dispersions assumes a Gaussian diffusion model (Turner 1970). This model is described by

$$\chi(x,y,z,H) = \frac{Q}{2\pi\sigma_y\sigma_z U} \exp\left[-1/2\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-1/2\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-1/2\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \quad (5)$$

Equation (5) has found widespread acceptance even though more exotic models have been developed. The critical factors of this model are the standard deviations of plume concentration, σ_y and σ_z. These factors are dependent upon atmospheric turbulence and most commonly based on the Pasquill typing scheme (Pasquill 1961) and are classed from "very unstable" to "very stable". The general acceptance of this typing scheme has caused considerable effort to be expended in the development of usable formulation of the deviation paramaters (Smith 1951; Turner 1964; Briggs 1969). The values recently developed by Briggs (1974) as quoted by Gifford (1976) are used for calculations of emissions from the Babcock and Wilcox stack. These parameters are shown in Table 5.

TABLE 5. ATMOSPHERIC TURBULENCE PARAMETERS

Pasquill Type	σ_y (m)	σ_z (m)
A	$0.22x(1 + 0.0001x)^{-\frac{1}{2}}$	$0.20x$
B	$0.16x(1 + 0.0001x)^{-\frac{1}{2}}$	$0.12x$
C	$0.11x(1 + 0.0001x)^{-\frac{1}{2}}$	$0.08x(1 + 0.0002x)^{-\frac{1}{2}}$
D	$0.08x(1 + 0.0001x)^{-\frac{1}{2}}$	$0.06x(1 + 0.0015x)^{-\frac{1}{2}}$
E	$0.06x(1 + 0.0001x)^{-\frac{1}{2}}$	$0.03x(1 + 0.0003x)^{-1}$
F	$0.04x(1 + 0.0001x)^{-\frac{1}{2}}$	$0.016x(1+ 0.0003x)^{-1}$

Note: Values quoted are for open country conditions with $10^2 < x < 10^4$m.

The key to the stability types is given in Table 6.

TABLE 6. KEY TO ATMOSPHERIC STABILITY CATEGORIES (Pasquill 1961)

Surface Wind Speed (at 10 m), m/s	Day			Night	
	Incoming Solar Radiation			Thinly Overcast of	
	Strong	Moderate	Slight	$\geq$4/8 Low Cloud	$\leq$3/8 Cloud
<2	A	A, B	B	--	--
2 to 3	A, B	B	C	E	F
3 to 5	B	B, C	C	D	E
5 to 6	C	C, D	D	D	D
>6	C	D	D	D	D

Note: The neutral class, D, should be assumed for overcast conditions during day or night.

The meteorological conditions observed at the Plant location during the months of May to August limits the consideration of stability classes to A, B and D.

The major concern here is the prediction of maximum plume concentration values and locations of the maximums. The involvement of the σ's with x and the multiplicity of exponential functions of χ make this procedure complex for the general case. The diffusion equation is reduced in complexity by restricting calculations to ground level (z = 0) and along the plume centerline (y = 0). When this is done, equation (5) reduces to

$$\chi(x, 0, 0, H) = \frac{Q}{\pi\sigma_y\sigma_z U} \exp\left[-\tfrac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (6)$$

The variation of σ_y is related through the square root function of x for all classes of stability. Rather than perform the differentiation of equation (5) and performing the hand calculation, it is much simpler to allow a computer to calculate values of $\chi(x)$ and to plot equation (6) for the various stability classes.

Figure 7 shows a plot of downwind ground-level concentrations for the plume. The calculation is based on the following assumptions:

1. The stack gas exit velocity was constant at 6.68 meters per second (m/s).
2. The temperature of emission products was the same as ambient temperature.
3. The particulate emission products had an effective diameter of less than 20 μm.

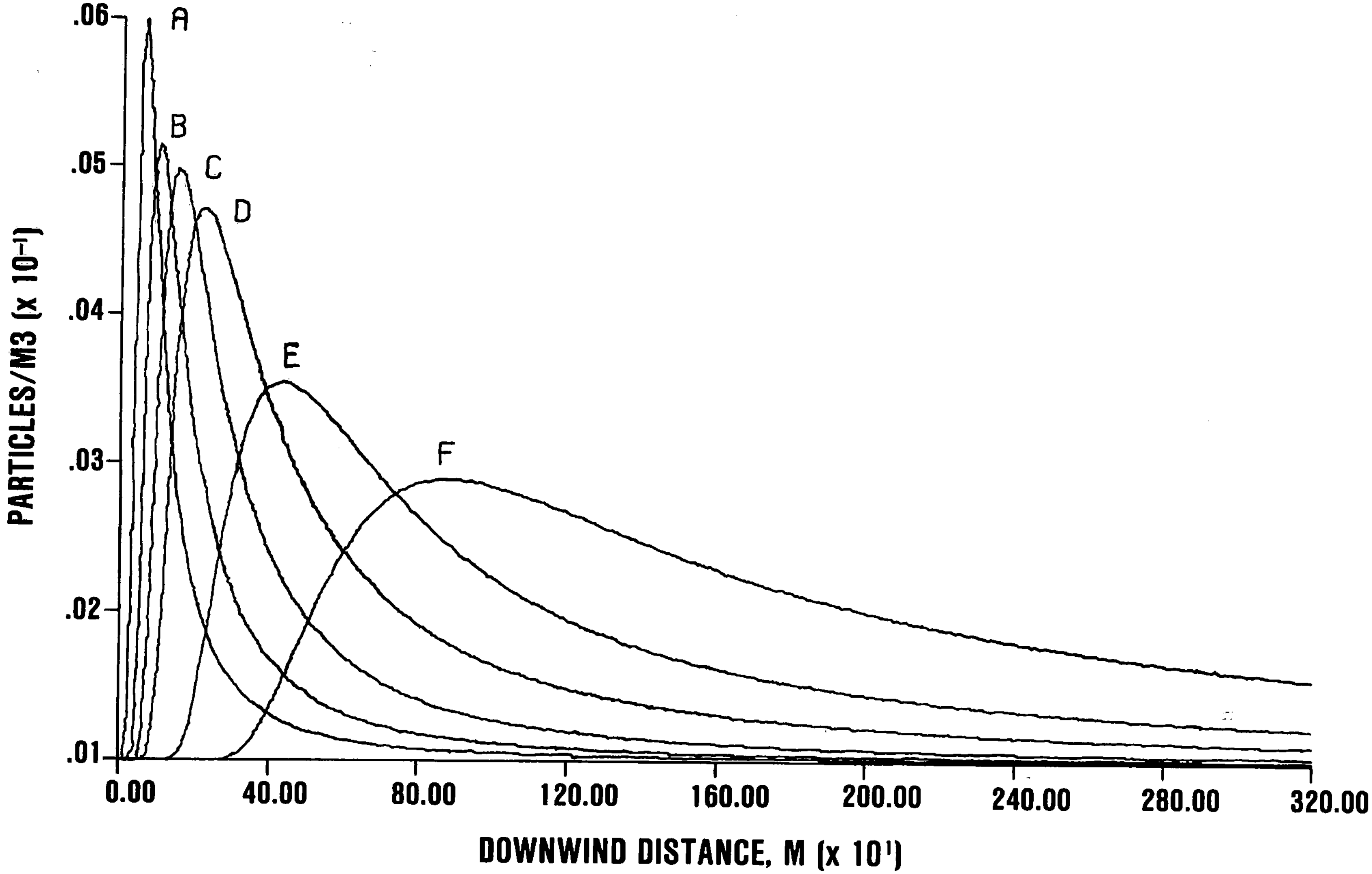


Figure 7. Predicted ground-level plume concentration

4. The stack height was 10.7 m.
5. The stack diameter was 0.46 m.
6. The wind speed averaged 1.6 m/s* over the months of May-August.
7. The wind direction was constant during the calculation period.
8. The effects of surrounding building and topography were considered negligible.
9. No corrections made for humidity and temperature variations.
10. The particle emission rate was 7 particles/s.
11. The effective stack height was 15.6 m.
12. The turbulence values were those shown in Table 5.
13. The plume was nonbuoyant with neither washout nor dilution.

The effective stack height, H_e, used for the calculation is as follows (Briggs 1969):

$$H = H_e + 1.5 \left(\frac{T_a \; V^2 \; D^2}{U \; T_s \; 4} \right)^{\frac{1}{3}} \left(\frac{a}{T_a} \right)^{-\frac{1}{6}} \tag{7}$$

Table 7 is a tabulation of stability class and the resulting values of maximum concentrations and distances as calculated from equation (6).

TABLE 7. GROUND-LEVEL PLUME CONCENTRATIONS FROM DISPERSION MODEL

Stability Class	x_{max} (m)	χ_{max} (particles/m³ × 10^{-3})	χ_{max} (pCi/m³ × 10^{-5})
A	60	6.1	9.2
B	90	5.1	7.7
C	140	4.9	7.4
D	200	4.5	6.8
E	400	3.1	4.7
F	825	2.2	3.3

Note: $\sigma_y(x)$ and $\sigma_z(x)$ values for x<100 m are linear extrapolations of the values quoted in Table 5.

Air Volume Requirements

The total volume of air to be sampled in order to measure a minimum detectable activity† of 0.1 pCi for plutonium-239, using an approximate value for the smallest χ_{max}, is:

*The quality of the measurements is suspect due to location of meteorological instrumentation with respect to the stack location and surrounding buildings.

†Generally accepted for total dissolution isotopic analysis by alpha spectrometer.

Volume = 0.1 pCi/4.0 x 10^{-5} pCi/m^3 = 2500 m^3

An additional factor of wind variation raises this minimum value. Due to variation in wind directions at the Plant, the samples were downwind of the stack approximately 37 percent of the time. Therefore, the minimum volume of the sampled air calculated by the preceding equation would have to be multiplied by 1/0.37 to account for wind variation. This gives a minimum quantity of 6,760 m^3 of air which must be sampled to measure minimum detectable activity. If we make the assumption that the plume width is typically 22.5 degrees (Briggs 1974), and also, that the wind pattern is uniformly distributed around the other 15 compass points during the remaining 63 percent of the time, we can see that for sampling points at other locations it would be necessary to collect approximately 59,500 m^3 of air to reach the minimum detectable levels for plutonium.

It should be noted that the simplifying assumptions used in the basic concentration calculation are applicable only for an ideal source and tend to maximize the concentrations. Real conditions as they pertain to fabrication processes and individual sources, as well as environmental and meteorological factors (washout, dilution, terrain, building, etc.), would tend to further reduce ground-level concentrations. For instance, Figures 8a and 8b are plots of the basic diffusion equation of Figure 7 with variations in the parameters of windspeed and crosswind distance, respectively; the variation parameter in these figures increases in value in the positive direction of the third axis. From these figures, it can be seen that any or all of these factors can reduce the ground-level concentration at downwind distances.

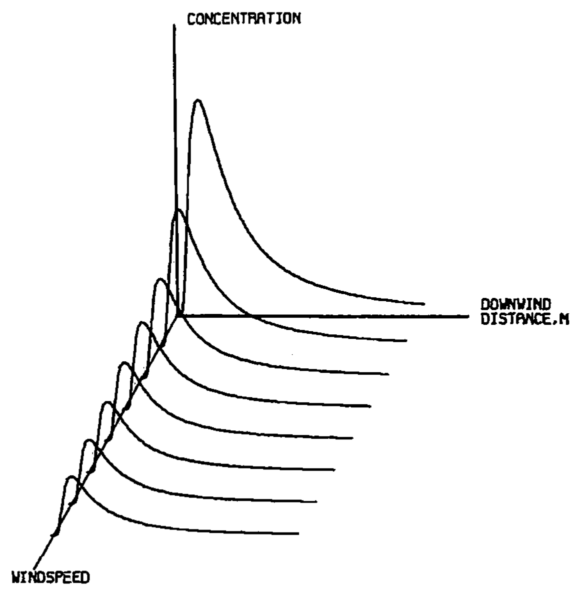


Figure 8a. Plume concentration versus variable windspeed, relative values.

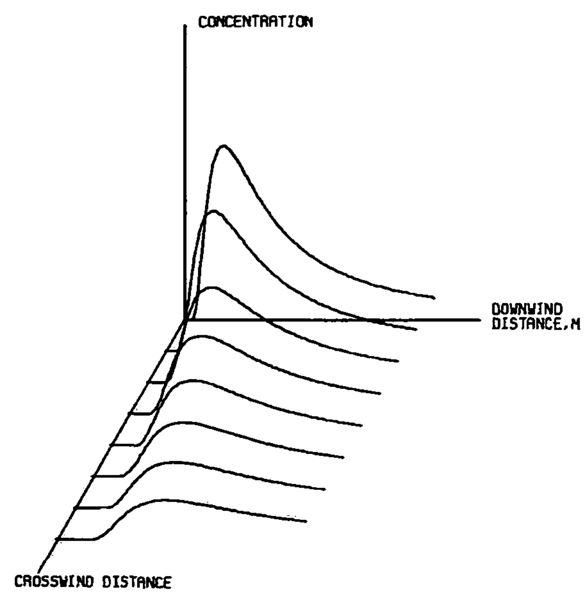


Figure 8b. Plume concentration versus variable crosswind distance, relative values.

Pasquill (1974) and Weber (1976) report an error analysis of the diffusion equation. The results of errors introduced by uncertainties in H, σ_y and σ_z (Briggs' error analysis on Table 5 values is not available) have led them to predict a net root-mean-square error of 49 percent.

A variety of air samplers using some form of filter material as a collections medium are available. Such samplers typically operate in the 0.14 to 2.24 m^3/min (5 to 80 ft^3/min) range. With this type of sampler, minimum sampling times vary from 2 to 31 days for an 'in-plume' sample of the required 6,760 m^3 of air. A realistic sampling period of 24 hours would require a sampler rate of 280 m^3/h.

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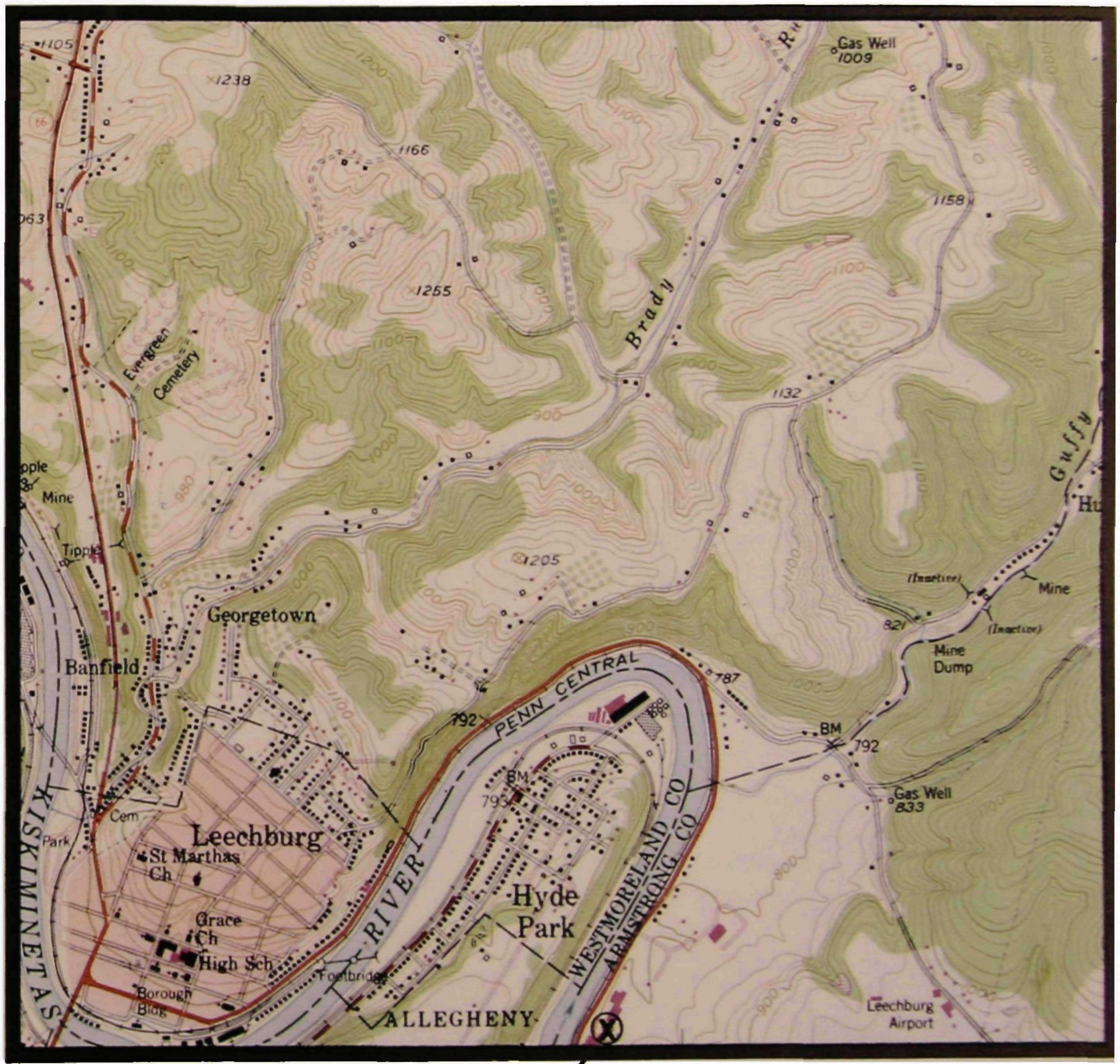
APPENDIX A. ENVIRONMENTAL SAMPLER DATA.

Sample No.	Sampling Dates (Start & Stop)	Run Time (hrs.)	Babcock & Wilcox Locations (See Fig. 4)
41	05/14/75 - 06/02/75	457	7
42	05/14/75 - 05/23/75	216	8
45	05/15/75 - 05/20/75	109	V
46	05/15/75 - 05/15/75	3	5
47	05/20/75 - 06/20/75	320	V
48	05/23/75 - 05/30/75	137	5
49	05/29/75 - 06/26/75	676	8
50	06/02/75 - 06/26/75	674	7
51	06/02/75 - 06/26/75	675	5
52	06/09/75 - 06/26/75	478	5
53	05/30/75 - 06/09/75	191	5
54	06/26/75 - 07/18/75	529	V
55	06/26/75 - 07/18/75	529	7
56	06/26/75 - 07/18/75	529	8
57	06/26/75 - 07/18/75	532	5
58	07/18/75 - 08/04/75	410	Metals
59	07/18/75 - 08/04/75	410	7
60	07/18/75 - 08/04/75	409	8
61	07/18/75 - 08/04/75	404	5
62	10/22/75 - 10/29/75	165	BCL

APPENDIX B. USGS TOPOGRAPHIC MAP OF LEECHBURG, PA. AREA.



Babcock and Wilcox Plant

Scale: 1" = 0.62 km

APPENDIX C. RESULTS OF PLUTONIUM-238 AND -239 ANALYSES OF SOIL SAMPLES.

Sample Number	Total Dry Weight (g)	pCi/g	
		^{238}Pu	^{239}Pu
NUMEC #1-1	9.91	0.02 ± 0.017	0.157 ± 0.020
NUMEC #1-2	10.001	0.009 ± 0.004	0.29 ± 0.035
NUMEC #2-1	9.996	0.016 ± 0.007	0.064 ± 0.015
NUMEC #2-2	9.973	0.003	0.025 ± 0.001
NUMEC #4-1	9.981	0.014	0.229 ± 0.075
NUMEC #4-2	10.001	0.024 ± 0.006	0.518 ± 0.050
NUMEC #5-1	3.966	0.043 ± 0.023	0.156 ± 0.048
NUMEC #5-2	3.949	0.005	0.180 ± 0.033
NUMEC #6-1	4.983	0.026 ± 0.008	0.006
NUMEC #6-2	4.975	0.012 ± 0.008	0.002
NUMEC #7-1	4.998	0.018 ± 0.008	0.006
NUMEC #7-2	4.917	2.12 ± 0.20	0.008 ± 0.006
NUMEC #8-1	4.996	0.120 ± 0.024	0.008 ± 0.006
NUMEC #8-2	4.991	2.28 ± 0.180	0.12
NUMEC #9-1	5.411	0.007	0.004
NUMEC #9-2	4.600	0.276 ± 0.041	0.020 ± 0.009

APPENDIX D. RESULTS OF INDIVIDUAL PARTICLE ANALYSIS; STACK SAMPLE.

CONTENTS

APPENDIX D-1. TERMINOLOGY DEFINITIONS AND CROSS REFERENCE

Heading	Description
Identification (I.D.)	The 3-digit number associated with the sample number is the particle number. When two particles are shown, this means that the two separate particles indicated were attached to each other.
Color	Transmitted color observed with an optical microscope.
MCC	Particle Classification Code 1 Needles or rods 2 Flat 4 High Index (n_D>1.52) 8 Birefringent 16 Colored 32 Opaque A single particle is optically characterized using the above 6-digit code. The binary numbers above the blocks are used additive to describe a particle. Example: Code = 28. The particle is colored and birefringent and has a high refractive index; 16+8+4 = 28. A code of 100 means no morphology measurements were made.
Tracks	This is the number of fission tracks recorded in Lexan with a 9 x 10^{14} neutron x volume x time thermal neutron fluence. One picogram of ^{239}Pu produces approximately 1700 tracks. Where 1001 tracks are indicated this means greater than 1000 tracks.

APPENDIX D-1. TERMINOLOGY DEFINITIONS AND CROSS REFERENCE (continued)

Size	Optical measurements in micrometers. Size = (length x width x thickness)$^{1/3}$ where thickness is arbitrarily assigned a value of one-half the width when it cannot be determined.
Weight	Values shown are in equivalent femtograms of plutonium as calculated from the number of fission tracks observed. One should recognize that in most cases, no plutonium was observed.
Comments	This represents the best possible identification of the particle based on an evaluation of all of the measurements made on that particle.
P_1	Density of particle from refraction estimates.
Isotopic Distribution of Uranium	The values and their corresponding standard deviations shown are in isotope-percent for the nuclide indicated. No ^{233}U was observed in any of the particles. Missing information indicates that the number of counts collected was too low to make an isotopic measurement.
Isotopic Distribution of Plutonium	Same as for uranium except the isotopes indicated are plutonium. A search was made for plutonium in all of the particles analyzed by mass spectrometry; only those which had positive indications of plutonium are listed in these tables. Plutonium-238 was not measured because of the ^{238}U interference.
Elemental Concentrations	The weight percent of the elements indicated as measured by the electron microprobe. The elements are all assumed to be oxides, i.e., the oxygen values are calculated--not measured. Those elements without a weight % indicated are all <1% concentration.

TABLE D-1. CROSS REFERENCE BETWEEN SAMPLE NUMBER AND SAMPLE LOCATION.

EPA No.	Location	
41	Restaurant	7
42	Drum Storage	8
45	Veados Home	V
46	Gum Corner	5
47	Veados Home	V
48	Gum Corner	5
49	Drum Storage	8
49 Top*	Drum Storage	8
50	Restaurant	7
51	Veados Home	V
52	Gum Corner	5
53	Gum Corner	5
54	Veados Home	V
55	Restaurant	7
56	Drum Storage	8
57	Gum Corner	5
43	Stack Downstream	
44	Stack Upstream	
58	Metals Building	6
59	Restaurant	7
60	Drum Storage	8
61	Gum Corner	5
BCL 62-1 3.5-15 μm	Drum Storage	8
BCL 62-2 1.7-3.5 μm	Drum Storage	8
BCL 62-3 <1.7 μm	Drum Storage	8

*Sample split into two parts.

APPENDIX D-2. OPTICAL MEASUREMENTS OF PARTICLES: STACK SAMPLE.

IDENTIFICATION	COLOR		MCC	TRACKS	SIZE	WEIGHT	COMMENTS
EPA 43 201		OPAQUE	48	0.	14.9	0	WOX
EPA 43 202		OPAQUE	48	0.	11.0	0	ZN METAL
EPA 43 203		OPAQUE	48	0.	21.1	0	ZN METAL
EPA 43 204	BROWN	ORANGE	21	0.	6.6	0	FE2O3 LOST
EPA 43 205		BROWN	28	0.	8.5	0	
EPA 43 206		GREEN	100	600.	0.	352	PU PRESENT
EPA 43 501		YELLOW	28	175.	2.6	102	
EPA 43 502			100	50.	0.	29	PU PRESENT
EPA 43 503			100	40.	0.	23	
EPA 43 504		OPAQUE	32	200.	1.0	117	UOX + PUOX
EPA 43 505		OPAQUE	32	175.	1.0	102	UOX + PUOX
EPA 43 506		OPAQUE	32	200.	1.0	117	SIOX
EPA 43 507		OPAQUE	32	375.	1.0	220	UOX + PUOX
EPA 43 508		OPAQUE	32	275.	1.0	161	UOX + PUOX
EPA 43 509		OPAQUE	32	200.	1.0	117	LOST ON TEM
EPA 43 510		OPAQUE	32	200.	1.0	117	LOST ON TEM
EPA 43 511	BROWN	YELLOW	100	1001.	1.6	> 588	LOST ON TEM
EPA 43 512A513		NO COLOR	0	0.	11.4	0	SIOX
EPA 43 513B512		BROWN	20	1001.	1.0	> 588	
EPA 43 514A515		YELLOW	16	0.	15.2	0	
EPA 43 515B514	YELLOW	ORANGE	16	450.	2.2	264	UOX + PUOX
EPA 43 516A517		NO COLOR	0	0.	13.5	0	
EPA 43 517B516		ORANGE	16	175.	2.4	102	UOX + PUOX
EPA 43 518			100	150.	0.	88	PU PRESENT
EPA 43 519		YELLOW	16	175.	5.0	102	PU PRESENT
EPA 43 520A521	YELLOW	ORANGE	16	0.	15.5	0	FEOX
EPA 43 521B520			100	300.	0.	176	UOX + PUOX
EPA 43 522		ORANGE	16	300.	3.2	176	
EPA 43 523A524	YELLOW	ORANGE	16	0.	6.2	0	
EPA 43 524B523			100	500.	0.	294	UOX + PUOX
EPA 43 525			100	80.	0.	47	5 ALPHA TRACKS
EPA 43 526		ORANGE	16	800.	1.8	470	STAINLESS STEEL -OX
EPA 43 527		ORANGE	100	400.	0.	235	LOST
EPA 43 528			100	300.	1.0	176	UOX + PUOX
EPA 43 529A530	BROWN	ORANGE	16	0.	13.0	0	ALSIOX
EPA 43 530B529			100	280.	0.	164	UOX + PUOX
EPA 43 531A532	YELLOW	ORANGE	16	0.	7.5	0	
EPA 43 532B531			100	200.	0.	117	
EPA 43 533		YELLOW	20	350.	1.5	205	
EPA 43 534A539	YELLOW	ORANGE	16	0.	13.5	0	
EPA 43 535A536	YELLOW	ORANGE	24	0.	12.8	0	
EPA 43 536B535			100	150.	0.	88	
EPA 43 537A538	YELLOW	ORANGE	16	0.	3.8	0	
EPA 43 538B537			100	150.	0.	88	UOX + PUOX
EPA 43 539B534			100	150.	0.	88	UOX + PUOX
EPA 43 540A541		YELLOW	16	0.	10.5	0	SIOX
EPA 43 541B540			100	23.	0.	13	
EPA 43 542A543		YELLOW	16	0.	11.8	0	
EPA 43 543B542			100	150.	0.	88	UOX + PUOX
EPA 43 544			100	23.	0.	13	PU PRESENT
EPA 43 545A546		YELLOW	16	0.	4.8	0	TUNGSTEN
EPA 43 546B545			100	45.	0.	26	
EPA 43 547		ORANGE	20	32.	5.4	18	PU PRESENT
EPA 43 548A549		YELLOW	16	0.	6.6	0	
EPA 43 549B548			100	14.	0.	8	
EPA 43 550A551	BROWN	YELLOW	16	0.	4.2	0	
EPA 43 551B550			100	50.	0.	29	
EPA 43 552A553		YELLOW	16	0.	14.8	0	SIOX
EPA 43 553B552			100	55.	0.	32	UOX + PUOX
EPA 43 554	BROWN	ORANGE	16	250.	5.0	147	STAINLESS STEEL-OX
EPA 43 555	YELLOW	ORANGE	16	16.	17.0	9	SIOX
EPA 43 556	BROWN	ORANGE	16	32.	7.0	18	LOST
EPA 43 557A558	ORANGE	YELLOW	16	0.	11.5	0	
EPA 43 558B557			100	19.	0.	11	
EPA 43 559A560	ORANGE	YELLOW	16	0.	30.4	0	
EPA 43 560B559			100	25.	0.	14	PU PRESENT
EPA 43 561A590		OPAQUE	32	0.	7.2	0	
EPA 43 562	ORANGE	YELLOW	16	27.	7.5	15	LOST
EPA 43 563A564	ORANGE	YELLOW	16	0.	16.5	0	
EPA 43 564B563			100	40.	0.	23	PU PRESENT
EPA 43 565	YELLOW	ORANGE	16	16.	16.5	9	ORGANIC
EPA 43 566		YELLOW	16	16.	11.5	9	
EPA 43 567A568	YELLOW	ORANGE	16	0.	18.0	0	SIOX
EPA 43 568B567			100	40.	0.	23	PU PRESENT
EPA 43 569A570	YELLOW	ORANGE	16	0.	10.0	0	
EPA 43 570B569			100	13.	0.	7	PU PRESENT
EPA 43 571A572	YELLOW	ORANGE	16	0.	4.3	0	TUNGSTEN
EPA 43 572B571			100	40.	0.	23	
EPA 43 573A574		YELLOW	16	0.	6.6	0	
EPA 43 574B573			100	30.	0.	17	PU PRESENT

IDENTIFICATION	COLOR		VCC	TRACKS	SIZE	WEIGHT	COMMENTS
EPA 43 575		YELLOW	100	150.	6.0	88	
EPA 43 576A577	ORANGE	YELLOW	16	0.	14.5	0	STAINLESS STEEL-OX
EPA 43 577B576			100	70.	0.	41	PU PRESENT
EPA 43 578A579	YELLOW	ORANGE	16	0.	5.3	0	
EPA 43 579B578			100	80.	0.	47	PU PRESENT
EPA 43 580			100	16.	0.	9	PU PRESENT
EPA 43 581			100	60.	0.	35	
EPA 43 582			100	80.	0.	47	
EPA 43 583			100	70.	0.	41	PU PRESENT
EPA 43 584		OPAQUE	32	100.	3.4	58	
EPA 43 585			100	14.	0.	8	
EPA 43 586			100	70.	0.	41	
EPA 43 587A588	YELLOW	ORANGE	16	0.	3.5	0	STAINLESS STEEL-OX
EPA 43 588B587			100	120.	0.	70	PU PRESENT
EPA 43 589			100	32.	0.	18	PU PRESENT
EPA 43 590B561			100	50.	0.	29	UOX + PUOX
EPA 43 701			100	1001.	0.	> 588	PU PRESENT
EPA 43 702			100	350.	0.	205	PU PRESENT
EPA 43 703			100	500.	0.	294	PU PRESENT
EPA 43 704			100	1001.	0.	> 588	PU PRESENT
EPA 43 705	BROWN	ORANGE	28	150.	8.0	88	SIOX
EPA 43 706		YELLOW	28	95.	3.7	55	SIOX
EPA 43 707		YELLOW	28	275.	5.5	161	ORGANIC
EPA 43 708C715	BROWN	ORANGE	28	400.	4.0	235	ALSIOX
EPA 43 709	BROWN	YELLOW	28	200.	10.0	117	ORGANIC
EPA 43 710		YELLOW	28	85.	5.5	50	PU PRESENT
EPA 43 711		YELLOW	28	55.	3.5	32	ORGANIC
EPA 43 712A724		YELLOW	28	0.	2.7	0	
EPA 43 713	ORANGE	YELLOW	28	300.	3.5	176	PU PRESENT
EPA 43 714	GREEN	BROWN	28	1001.	1.5	> 588	LOST
EPA 43 715E708	BROWN	ORANGE	28	400.	2.0	235	FEOX
EPA 43 716E708		YELLOW	28	400.	3.5	235	SIOX
EPA 43 717E708		YELLOW	28	400.	0.	235	UOX
EPA 43 718		BROWN	20	150.	12.0	88	PU PRESENT
EPA 43 719		BROWN	20	180.	6.5	105	ORGANIC
EPA 43 720A723	YELLOW	ORANGE	20	1001.	7.5	> 588	STAINLESS STEEL
EPA 43 721	YELLOW	ORANGE	28	375.	14.0	220	PU PRESENT
EPA 43 722		BROWN	20	400.	8.0	235	PU PRESENT
EPA 43 723B720	YELLOW	ORANGE	20	1001.	0.	> 588	PUOX + UOX
EPA 43 724B712		YELLOW	28	200.	0.	117	PUOX + UOX
EPA 43 725D733	BROWN	ORANGE	20	130.	3.7	76	
EPA 43 726	BROWN	YELLOW	24	275.	8.0	161	
EPA 43 727		BROWN	20	175.	2.8	102	
EPA 43 728D729	BROWN	ORANGE	28	350.	4.0	205	
EPA 43 729E728	BROWN	ORANGE	100	0.	0.	0	
EPA 43 730E729	BROWN	ORANGE	100	0.	0.	0	
EPA 43 731E728	BROWN	ORANGE	100	0.	0.	0	
EPA 43 732E728	BROWN	ORANGE	100	0.	0.	0	
EPA 43 733E725	BROWN	ORANGE	100	0.	0.	0	
EPA 43 734E725	BROWN	ORANGE	100	0.	0.	0	
EPA 43 735	YELLOW	BROWN	28	47.	14.0	27	
EPA 43 736	YELLOW	BROWN	28	42.	9.5	24	PU PRESENT
EPA 43 737	YELLOW	BROWN	28	85.	8.0	50	PU PRESENT
EPA 43 738		YELLOW	24	96.	6.5	56	SIOX
EPA 43 739	YELLOW	BROWN	28	27.	13.5	15	PU PRESENT
EPA 43 740	BROWN	YELLOW	28	17.	7.0	10	ORGANIC
EPA 43 741		YELLOW	100	6.	5.3	3	
EPA 43 742	ORANGE	YELLOW	28	120.	3.7	70	PU PRESENT
EPA 43 743	ORANGE	BROWN	28	13.	19.0	7	
EPA 43 744D748	ORANGE	BROWN	28	0.	4.0	0	LOST
EPA 43 745		BROWN	100	1.	5.0	0	
EPA 43 746	BROWN	YELLOW	28	13.	5.5	7	
EPA 43 747	ORANGE	BROWN	28	14.	3.7	8	ORGANIC
EPA 43 748E744	ORANGE	BROWN	28	9.	1.7	5	STAINLESS STEEL -OX
EPA 43 749			100	14.	0.	8	PU PRESENT
EPA 43 750	BROWN	YELLOW	28	240.	10.5	141	PU PRESENT
EPA 43 751A798	BROWN	ORANGE	28	0.	2.5	0	FEOX
EPA 43 752	BROWN	YELLOW	28	80.	7.5	47	PU PRESENT
EPA 43 753	BROWN	ORANGE	28	225.	4.8	132	PU PRESENT
EPA 43 754		YELLOW	28	29.	5.5	17	FE,ALSIOX
EPA 43 755D786	ORANGE	BROWN	28	14.	8.0	8	ORGANIC
EPA 43 756			100	120.	0.	70	PU PRESENT
EPA 43 757D783	ORANGE	YELLOW	28	60.	4.7	35	ORGANIC
EPA 43 758	BROWN	ORANGE	28	72.	7.5	42	PU PRESENT
EPA 43 759			100	60.	0.	35	PU PRESENT
EPA 43 760		YELLOW	28	51.	5.0	30	PU PRESENT
EPA 43 761	BROWN	ORANGE	28	120.	5.3	70	LOST
EPA 43 762	BROWN	ORANGE	28	160.	1.7	94	LOST
EPA 43 763			100	15.	0.	8	PU PRESENT
EPA 43 764			100	30.	0.	17	PU PRESENT

APPENDIX D-2. OPTICAL MEASUREMENTS OF PARTICLES: STACK SAMPLE. (concluded)

OPTICAL MEASUREMENTS

IDENTIFICATION	COLOR		MCC	TRACKS	SIZE	WEIGHT	COMMENTS
EPA 43 765	BROWN	YELLOW	24	110.	7.0	64	PU PRESENT
EPA 43 766			100	70.	0.	41	
EPA 43 767			100	45.	0.	26	PU PRESENT
EPA 43 768		YELLOW	24	17.	6.0	10	ORGANIC
EPA 43 769			100	22.	0.	12	
EPA 43 770		YELLOW	24	62.	5.2	36	PU PRESENT
EPA 43 771			100	29.	0.	17	
EPA 43 772	BROWN	YELLOW	28	40.	7.5	23	PU PRESENT
EPA 43 773	BROWN	ORANGE	28	44.	8.0	25	STAINLESS STEEL-OX
EPA 43 774			100	12.	0.	7	PU PRESENT
EPA 43 775		YELLOW	24	10.	6.0	5	QUARTZ
EPA 43 776	ORANGE	YELLOW	28	29.	9.0	17	PU PRESENT
EPA 43 777A739	YELLOW	ORANGE	28	0.	3.7	0	FEOX
EPA 43 778			100	31.	0.	18	PU PRESENT
EPA 43 779	ORANGE	YELLOW	28	19.	9.5	11	PU PRESENT
EPA 43 780	ORANGE	BROWN	28	32.	4.5	16	PU PRESENT
EPA 43 781			100	13.	0.	7	PU PRESENT
EPA 43 782	ORANGE	YELLOW	28	13.	9.0	7	PU PRESENT
EPA 43 783E757	BROWN	ORANGE	28	0.	4.5	0	STAINLESS STEEL-OX
EPA 43 784E757	ORANGE	YELLOW	100	0.	0.	0	ORGANIC
EPA 43 785E757	ORANGE	YELLOW	100	0.	0.	0	ORGANIC
EPA 43 786E755	ORANGE	BROWN	28	14.	0.	8	ORGANIC
EPA 43 787		BROWN	24	120.	7.2	70	ORGANIC
EPA 43 788B751			100	95.	0.	55	UOX + PUOX
EPA 43 789B777			100	135.	0.	79	UOX + PUOX

APPENDIX D-3. PARTICLE CONSTITUTION BY ELECTRON MICROPROBE, STACK SAMPLE.

IDENTIFICATION	ELEMENTAL CONCENTRATION WT.%	ELEMENTS < 1.Ø%
EPA 43 2Ø1	W78,O21	
EPA 43 2Ø2	ZN9Ø,O9	FE
EPA 43 2Ø3	ZN95,O3.3,P1.7	
EPA 43 2Ø5	O48,SI23,FE13,AL8.7,S2.2, MG1.8,NA1.4,PB1.2,P1.Ø	
EPA 43 5Ø1	O51,SI36,AL7,FE4.7,K1.1	TI
EPA 43 5Ø4	U5Ø,PU38,O12	
EPA 43 5Ø5	U5Ø,PU38,O12	
EPA 43 5Ø6	SI47,O53	
EPA 43 5Ø7	U5Ø,PU38,O12	
EPA 43 5Ø8	U5Ø,PU38,O12	
EPA 43 512	SI53,O46	FE
EPA 43 514	O49,SI29,K1Ø,AL8,FE4.5	NA,CA,CR,MG,NI
EPA 43 515	U43,PU4Ø,O17	
EPA 43 516	O49,SI33,AL9,NA8	FE
EPA 43 517	U43,PU4Ø,O17	
EPA 43 519	O5Ø,SI27,AL16,FE5,K2.Ø	MG,TI,CA
EPA 43 52Ø	FE56,O33,CR4.2,SI3.7,NI2.3	
EPA 43 521	U43,PU4Ø,O17	
EPA 43 522	FE52,O32,CR1Ø,N3.9,MN1.5	SI,S,NA,CL
EPA 43 523	FE47,O39,SI8,CR2.9,AL2.1	TI,CA,NA
EPA 43 524	U56,PU27,O17	
EPA 43 526	FE49,CR15,NI5,O3Ø,MN1	
EPA 43 528	U55,PU3Ø,O15	
EPA 43 54Ø	O52,SI44,FE1.8,AL1.Ø	K
EPA 43 542	O51,SI3Ø,FE9,AL4.6,K2.6,NA2.Ø	
EPA 43 543	U51,PU32,O17	
EPA 43 545	W99	
EPA 43 547	O39,FE29,SI24,AL6,K3.3,NA2.3, NI2.Ø,CL1.4	P
EPA 43 548	O46,SI2Ø,AL18,FE9,NA3.2,K1.4	
EPA 43 55Ø	O47,SI28,K13,AL9,FE2.5	NA
EPA 43 552	O53,SI43,CL1.8,NA1.3	FE
EPA 43 553	U52,PU31,O17	
EPA 43 554	FE5Ø,O3Ø,CR9,NI6,CL1.7,S1.Ø	NA
EPA 43 555	O53,SI46	FE,AL,P,MG,W
EPA 43 557	O4Ø,FE31,SI17,CR3.9,AL3.4, NI1.5,S1.1	NA
EPA 43 559	O47,SI21,FE14,AL9,S4.4,NA1.Ø	MG,P,TI

APPENCIX D-3. PARTICLE CONSTITUTION BY ELECTRON MICROPROBE, STACK SAMPLE. (continued)

IDENTIFICATION	ELEMENTAL CONCENTRATION WT.%	ELEMENTS < 1.Ø%
EPA 43 561	O43,FE22,SI18,K4.9,AL4.3, S2.4,CR1.9,NI1.4,NA1.1	
EPA 43 563	FE42,O37,SI12,CR2.Ø,AL1.7, K1.6	P,NI,S,NA
EPA 43 565	C83,O5,FE7.6,SI2.2,CR1.Ø	K,NI,AL,TI,SN, P,S,CL,NA
EPA 43 566	TI39,O39,FE17,SI3.4	AL,K
EPA 43 567	O53,SI47	FE
EPA 43 569	O41,FE33,SI21,CR2.Ø,NI1.Ø	S,AL,CL,MN
EPA 43 571	W99	FE,AL
EPA 43 573	O45,SI29,FE19,K1.1	CR,NI,P,NA,AL, CA,S
EPA 43 575	O48,SI29,AL1Ø,FE7,TI3.Ø	K,CA
EPA 43 576	FE4Ø,O33,CR12,NI6,SI5,P1.Ø	MN,S
EPA 43 578	FE48,O33,SI4.2,CR3.7,NI2.2, NA1.7,CL1.6,S1.2,K1.2,CU1.Ø	MN,TI
EPA 43 584	O45,SI32,K21,FE1.1	
EPA 43 587	FE43,O32,CR11,NI5,TI3.2,SI1.8, S1.2	
EPA 43 59Ø	U53,PU3Ø,O17	
EPA 43 7Ø5	O52,SI43,FE3.9	
EPA 43 7Ø6	O53,SI46	AL
EPA 43 7Ø7	C83,O11,AL3.4,SI2.6	V,MG
EPA 43 7Ø8	O5Ø,SI26,AL22,FE1.1	MG
EPA 43 7Ø9	C72,O21,SI4,FE1.4,AL1.Ø	P
EPA 43 71Ø	O51,SI36,AL11,NA2.3	K
EPA 43 711	C92,O7	SI,NA,P,CL
EPA 43 712	O52,SI41,AL5,FE1.1	
EPA 43 713	U59,O22,SI19	AL
EPA 43 715	FE67,O32	SI
EPA 43 716	O54,SI43,AL2.4	NA
EPA 43 717	U83,O17	
EPA 43 718	O5Ø,SI29,FE1Ø,AL9,S1.8	K,CA,MG
EPA 43 719	C95,SI3.5,O1.4	FE,K,AL
EPA 43 72Ø	FE5Ø,O33,CR1Ø,NI3.4,S1.Ø	CL,SI,MN
EPA 43 721	O45,SI27,FE2Ø,AL3.3,CR1.7, K1.2	NI,TI,P
EPA 43 722	O5Ø,SI29,AL12,K6,FE2.2	GA,MG
EPA 43 723	PU65,U23,O12	
EPA 43 724	PU43,U41,O15	

APPENDIX D-3. PARTICLE CONSTITUTION BY ELECTRON MICROPROBE, STACK SAMPLE. (concluded)

IDENTIFICATION	ELEMENTAL CONCENTRATION WT.%	ELEMENTS < 1.Ø%
EPA 43 735	O41,FE37,SI11,AL5,P3.6,K2.2	NA,S,CR,CA,PB
EPA 43 736	O45,SI16,TI13,AL12,FE1Ø,K2.5, NA1.7	
EPA 43 737	O51,SI34,AL8,FE5,K1.5	P,NI
EPA 43 738	SI42,O53,FE5	AL
EPA 43 739	O47,SI22,AL16,FE8,K5	NA
EPA 43 74Ø	C98,O1.8	FE,P,NA,S
EPA 43 741	O49,SI29,AL13,FE7,MG1.6	TI,K
EPA 43 743	O44,FE25,SI19,AL8,CR2.Ø,K1.8	P,NI,S,MG,TI
EPA 43 745	FE49,O35,SI8,CA3.5,AL1.7, MN1.5	P,MG,K
EPA 43 747	C99	FE,O
EPA 43 748	FE47,CR13,O35,NI5	MN
EPA 43 75Ø	O45,SI2Ø,AL16,FE9,K8	MG
EPA 43 751	FE65,O32	SI,AL
EPA 43 752	O46,SI25,FE13,AL9,K2.4,NI1.4, CR1.2,NA1.1	
EPA 43 753	O49,SI23,AL21,FE6,K1.6	
EPA 43 754	O48,SI25,AL18,FE7	
EPA 43 755	C99	FE,AL,SI
EPA 43 757	C99	
EPA 43 758	O45,FE2Ø,SI2Ø,AL1Ø,K2.Ø,CR1.Ø	
EPA 43 76Ø	O47,SI31,FE12,AL4.7,K2.5	
EPA 43 765	O45,SI28,FE2Ø,AL2.1	
EPA 43 768	C99	FE,SI,TI
EPA 43 77Ø	O47,MO18,SI14,S12,CU6,TI2.9	
EPA 43 772	O4Ø,FE28,SI16,CR5,AL4.5,NI3.Ø, K2.6	
EPA 43 773	FE46,O32,CR18,NI4.1	
EPA 43 775	O53,SI44,FE1.9	AL,K
EPA 43 776	FE47,O37,SI1Ø,K4.9	
EPA 43 777	FE65,O3Ø,CL5	S
EPA 43 779	O38,FE35,SI1Ø,CR4.1,NA3.2, K2.2,AL2.Ø,P1.8,S1.6,NI1.4	
EPA 43 78Ø	FE45,O34,CR9,SI7,NI3.Ø	MN,S
EPA 43 782	O49,SI33,K11,AL5,NA1.9	FE
EPA 43 783	FE49,O33,CR8,SI3.8,NI3.2, AL1.1	
EPA 43 784	C99	
EPA 43 785	C99	
EPA 43 786	C99	
EPA 43 787	C96,O2.1,SI1.5	CA
EPA 43 788	U46,PU37,O17	
EPA 43 789	U46,PU37,O17	

APPENDIX D-4. MASS SPECTROMETRY RESULTS FOR PLUTONIUM.

	ISOTOPIC DISTRIBUTION OF PLUTONIUM							
IDENTIFICATION	%240	+SD	%241	+SD	%242	+SD	%239	+SD
EPA 43 206	11.490	0.043	1.416	0.010	0.200	0.003	86.894	0.047
EPA 43 502	11.433	0.054	1.348	0.012	0.217	0.004	87.003	0.057
EPA 43 504	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 505	11.719	0.047	1.358	0.010	0.215	0.003	86.708	0.050
EPA 43 507	11.670	0.062	1.453	0.015	0.211	0.004	86.666	0.066
EPA 43 508	11.400	0.250	1.764	0.071	0.299	0.028	86.536	0.262
EPA 43 513	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 515	11.780	0.077	1.473	0.019	0.210	0.006	86.538	0.081
EPA 43 516	12.381	0.074	1.865	0.020	0.226	0.005	85.528	0.079
EPA 43 518	10.858	0.260	1.426	0.066	0.208	0.021	87.507	0.270
EPA 43 519	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 521	11.240	0.062	1.374	0.015	0.221	0.005	87.165	0.065
EPA 43 523	11.743	0.056	1.357	0.013	0.215	0.004	86.685	0.059
EPA 43 543	11.268	0.050	1.450	0.012	0.222	0.003	87.060	0.053
EPA 43 544	11.349	0.192	1.396	0.048	0.221	0.017	87.035	0.199
EPA 43 547	11.301	0.135	1.427	0.034	0.236	0.012	87.037	0.140
EPA 43 551	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 554	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 560	11.527	0.259	2.363	0.087	0.751	0.047	85.359	0.280
EPA 43 564	10.589	0.099	1.536	0.026	0.200	0.008	87.675	0.103
EPA 43 565	11.309	0.123	1.461	0.031	0.243	0.011	86.987	0.128
EPA 43 568	11.546	0.113	1.518	0.029	0.218	0.009	86.718	0.118
EPA 43 570	11.167	0.167	1.487	0.043	0.224	0.014	87.123	0.174
EPA 43 574	11.922	0.099	1.337	0.023	0.224	0.008	86.518	0.102
EPA 43 577	11.819	0.075	1.215	0.016	0.224	0.006	86.742	0.078
EPA 43 579	10.942	0.072	1.439	0.018	0.225	0.006	87.393	0.076
EPA 43 580	11.374	0.095	1.404	0.023	0.233	0.008	86.990	0.099
EPA 43 583	11.816	0.124	1.483	0.031	0.207	0.010	86.494	0.129
EPA 43 588	11.726	0.073	1.335	0.017	0.226	0.006	86.713	0.077
EPA 43 589	12.319	0.228	1.250	0.051	0.200	0.017	86.232	0.234
EPA 43 590	11.544	0.080	1.499	0.020	0.210	0.006	86.747	0.084
EPA 43 701	11.463	0.049	1.427	0.011	0.220	0.003	86.891	0.052
EPA 43 702	11.517	0.053	1.426	0.012	0.211	0.004	86.847	0.056
EPA 43 703	11.990	0.075	1.356	0.017	0.207	0.005	86.443	0.079
EPA 43 704	11.071	0.054	1.504	0.013	0.222	0.004	87.203	0.057
EPA 43 705	11.939	0.069	1.359	0.016	0.219	0.005	86.482	0.072
EPA 43 706	11.192	0.070	1.557	0.018	0.191	0.005	87.060	0.074
EPA 43 708	11.517	0.044	1.423	0.010	0.210	0.003	86.850	0.048
EPA 43 709	11.443	0.053	1.579	0.013	0.211	0.004	86.767	0.056
EPA 43 710	11.266	0.064	1.420	0.016	0.208	0.005	87.107	0.065
EPA 43 712	11.789	0.054	1.422	0.013	0.208	0.004	86.582	0.057

APPENDIX D-4. MASS SPECTROMETRY RESULTS FOR PLUTONIUM. (concluded)

				ISOTOPIC DISTRIBUTION OF PLUTONIUM						
IDENTIFICATION			%240	+SD	%241	+SD	%242	+SD	%239	+SD
EPA	43	713	11.055	0.167	1.557	0.044	0.209	0.014	87.179	0.174
EPA	43	718	11.681	0.071	1.383	0.017	0.212	0.005	86.724	0.075
EPA	43	719	10.852	0.136	1.571	0.037	0.231	0.012	87.346	0.143
EPA	43	720	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	43	721	11.281	0.071	1.457	0.017	0.217	0.005	87.044	0.074
EPA	43	722	12.519	0.296	1.386	0.070	0.224	0.024	85.871	0.305
EPA	43	723	10.942	0.038	1.473	0.009	0.220	0.002	87.365	0.042
EPA	43	736	11.211	0.132	1.466	0.034	0.214	0.011	87.109	0.137
EPA	43	737	12.415	0.079	1.247	0.017	0.205	0.006	86.133	0.082
EPA	43	738	11.523	0.078	1.446	0.019	0.215	0.006	86.816	0.082
EPA	43	739	11.859	0.153	1.499	0.039	0.236	0.014	86.406	0.160
EPA	43	742	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	43	743	11.062	0.252	1.347	0.062	0.214	0.020	87.376	0.260
EPA	43	747	12.100	0.203	1.509	0.051	0.243	0.018	86.149	0.211
EPA	43	749	11.887	0.152	1.383	0.037	0.209	0.013	86.521	0.157
EPA	43	750	11.992	0.069	1.301	0.016	0.193	0.005	86.514	0.072
EPA	43	752	11.494	0.052	1.366	0.012	0.202	0.003	86.938	0.056
EPA	43	753	11.782	0.165	1.360	0.040	0.225	0.014	86.632	0.171
EPA	43	755	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	43	756	11.607	0.086	1.356	0.020	0.226	0.007	86.811	0.090
EPA	43	757	11.713	0.193	1.621	0.051	0.207	0.016	86.459	0.201
EPA	43	758	11.932	0.068	1.388	0.016	0.213	0.005	86.467	0.071
EPA	43	759	11.855	0.066	1.456	0.016	0.210	0.005	86.479	0.070
EPA	43	760	11.354	0.088	1.408	0.022	0.206	0.007	87.031	0.092
EPA	43	763	11.485	0.138	1.462	0.035	0.246	0.012	86.807	0.144
EPA	43	764	12.073	0.170	1.387	0.041	0.214	0.014	86.327	0.176
EPA	43	765	11.972	0.086	1.254	0.019	0.214	0.006	86.559	0.089
EPA	43	767	11.787	0.147	1.338	0.035	0.232	0.012	86.642	0.152
EPA	43	768	11.308	0.214	1.349	0.052	0.238	0.019	87.105	0.222
EPA	43	770	11.782	0.145	1.380	0.035	0.241	0.012	86.597	0.150
EPA	43	772	11.668	0.085	1.411	0.020	0.195	0.006	86.726	0.088
EPA	43	773	12.373	0.279	1.376	0.067	0.214	0.025	86.037	0.289
EPA	43	774	11.599	0.194	1.471	0.050	0.285	0.020	86.645	0.203
EPA	43	776	11.590	0.208	1.330	0.050	0.217	0.017	86.864	0.215
EPA	43	778	11.651	0.112	1.377	0.027	0.229	0.009	86.743	0.116
EPA	43	779	12.271	0.170	1.526	0.042	0.211	0.013	85.991	0.176
EPA	43	780	12.630	0.166	1.135	0.035	0.239	0.013	85.996	0.171
EPA	43	781	11.690	0.142	1.364	0.034	0.235	0.013	86.710	0.147
EPA	43	782	11.215	0.268	1.156	0.062	0.237	0.025	87.392	0.277
EPA	43	783	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	43	784	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	43	785	11.627	0.085	1.539	0.021	0.212	0.007	86.621	0.089
EPA	43	788	11.627	0.069	1.426	0.016	0.206	0.005	86.741	0.072
EPA	43	789	10.847	0.092	1.529	0.024	0.271	0.008	87.353	0.096

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APPENDIX D-5. MASS SPECTROMETRY RESULTS FOR URANIUM

	ISOTOPIC DISTRIBUTION OF URANIUM							
IDENTIFICATION	%234	+SD	%235	+SD	%236	+SD	%238	+SD
EPA 43 206	0.005	0.000	0.703	0.009	0.001	0.000	99.291	0.009
EPA 43 501	0.	0.	3.588	0.101	0.	0.	96.412	0.115
EPA 43 502	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 503	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 504	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 505	0.	0.	0.721	0.009	0.	0.	99.279	0.010
EPA 43 506	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 507	0.005	0.000	0.719	0.008	0.	0.	99.276	0.008
EPA 43 508	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 513	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 515	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 516	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 518	0.011	0.001	1.199	0.015	0.	0.	98.790	0.015
EPA 43 519	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 521	0.005	0.000	0.735	0.007	0.	0.	99.260	0.007
EPA 43 522	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 523	0.006	0.001	0.735	0.010	0.	0.	99.259	0.010
EPA 43 525	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 526	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 528	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 533	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 541	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 543	0.	0.	0.744	0.017	0.	0.	99.256	0.017
EPA 43 544	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 546	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 547	0.	0.	0.605	0.020	0.	0.	99.395	0.022
EPA 43 549	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 551	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 553	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 554	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 555	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 558	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 560	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 564	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 565	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 566	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 568	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 570	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 572	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 574	0.	0.	0.794	0.024	0.	0.	99.206	0.025
EPA 43 575	0.	0.	0.	0.	0.	0.	00.000	0.

	ISOTOPIC DISTRIBUTION OF URANIUM							
IDENTIFICATION	%234	+SD	%235	+SD	%236	+SD	%238	+SD
EPA 43 577	0.	0.	0.705	0.016	0.	0.	99.295	0.016
EPA 43 579	0.	0.	0.714	0.015	0.	0.	99.286	0.015
EPA 43 580	0.	0.	0.727	0.021	0.	0.	99.273	0.022
EPA 43 581	0.	0.	0.721	0.013	0.	0.	99.279	0.013
EPA 43 582	0.005	0.001	0.732	0.008	0.	0.	99.263	0.009
EPA 43 583	0.	0.	0.735	0.013	0.	0.	99.265	0.014
EPA 43 584	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 585	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 586	0.	0.	0.711	0.013	0.	0.	99.289	0.014
EPA 43 588	0.	0.	0.672	0.015	0.	0.	99.328	0.015
EPA 43 589	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 590	0.	0.	0.733	0.015	0.	0.	99.267	0.015
EPA 43 701	0.005	0.000	0.725	0.008	0.	0.	99.271	0.008
EPA 43 702	0.	0.	0.754	0.014	0.	0.	99.246	0.015
EPA 43 703	0.	0.	0.728	0.014	0.	0.	99.272	0.014
EPA 43 704	0.005	0.000	0.728	0.008	0.	0.	99.267	0.008
EPA 43 705	0.005	0.000	0.708	0.010	0.001	0.000	99.285	0.010
EPA 43 706	0.007	0.001	0.727	0.015	0.	0.	99.266	0.015
EPA 43 707	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 708	0.005	0.000	0.730	0.008	0.	0.	99.264	0.008
EPA 43 709	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 710	0.006	0.001	0.710	0.012	0.	0.	99.285	0.012
EPA 43 711	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 712	0.005	0.001	0.708	0.012	0.	0.	99.286	0.012
EPA 43 713	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 718	0.	0.	1.083	0.023	0.	0.	98.917	0.023
EPA 43 719	0.	0.	0.832	0.020	0.	0.	99.168	0.020
EPA 43 720	0.	0.	3.914	0.104	0.	0.	96.086	0.105
EPA 43 721	0.362	0.004	35.587	0.098	0.078	0.002	63.974	0.099
EPA 43 723	0.	0.	0.691	0.015	0.006	0.001	99.303	0.016
EPA 43 735	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 736	0.	0.	0.742	0.020	0.	0.	99.258	0.021
EPA 43 737	0.	0.	0.728	0.015	0.	0.	99.272	0.015
EPA 43 738	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 739	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 740	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 741	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 742	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 743	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 745	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 746	0.	0.	0.	0.	0.	0.	00.000	0.

APPENDIX D-5. MASS SPECTROMETRY RESULTS FOR URANIUM. (concluded)

	ISOTOPIC DISTRIBUTION OF URANIUM							
IDENTIFICATION	%234	+SD	%235	+SD	%236	+SD	%238	+SD
EPA 43 747	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 748	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 749	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 750	0.	0.	0.698	0.017	0.	0.	99.302	0.017
EPA 43 752	0.	0.	0.701	0.021	0.	0.	99.299	0.021
EPA 43 753	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 754	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 755	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 756	0.	0.	0.696	0.016	0.	0.	99.304	0.016
EPA 43 757	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 758	0.	0.	0.720	0.015	0.	0.	99.280	0.016
EPA 43 759	0.	0.	0.741	0.022	0.	0.	99.259	0.023
EPA 43 760	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 763	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 764	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 765	0.	0.	0.713	0.017	0.	0.	99.287	0.017
EPA 43 766	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 767	0.	0.	0.710	0.021	0.	0.	99.290	0.021
EPA 43 768	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 769	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 770	0.	0.	0.688	0.017	0.	0.	99.312	0.017
EPA 43 771	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 772	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 773	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 774	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 775	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 776	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 778	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 779	0.	0.	0.660	0.021	0.	0.	99.340	0.022
EPA 43 780	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 781	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 782	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 783	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 784	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 785	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 786	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 787	0.	0.	0.	0.	0.	0.	00.000	0.
EPA 43 788	0.	0.	0.754	0.017	0.	0.	99.246	0.017
EPA 43 789	0.	0.	0.	0.	0.	0.	00.000	0.

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APPENDIX E-1. RESULTS OF GROSS ANALYSIS OF ENVIRONMENTAL SAMPLES.

Gross analysis of environmental air samples to date gives the following values of collected actinides as determined by mass spectrometry.

Sample No.	Plutonium	Uranium
49	$<5.8 \times 10^{-13}$ g/sample	4.47×10^{-7} g/sample
50	$<1.1 \times 10^{-12}$ g/sample	2.86×10^{-7} g/sample
51	$<2.4 \times 10^{-12}$ g/sample	*
52	$<7.6 \times 10^{-13}$ g/sample	3.59×10^{-7} g/sample
55	$<1.0 \times 10^{-12}$ g/sample	*
62-1	48.0×10^{-12} g/g particulate	4.9×10^{-6} g/g particulate
62-2	92.0×10^{-12} g/g particulate	4.6×10^{-6} g/g particulate
62-3	67.0×10^{-12} g/g particulate	2.7×10^{-6} g/g particulate

*Below minimum detectable level

APPENDIX E-2. GROSS ISOTOPE LEVELS FROM MASSIVE AIR SAMPLES.*

Isotope	Sample 62-1 0.2624 g total weight 3.5-20 μm size range		Sample 62-2 0.2131 g total weight 1.7-3.5 μm size range		Sample 62-3 1.1523 g total weight <1.7 μm size range		Specific Activity (Ci/g)
	Concentration (μCi/ml)	Percent of Total Wt.	Concentration (μCi/ml)	Percent of Total Wt.	Concentration (μCi/ml)	Percent of Total Wt.	
^{239}Pu	2.61×10^{-18}	86.8	3.98×10^{-18}	84.9	1.59×10^{-17}	86.4	6.14×10^{-2}
^{240}Pu	1.31×10^{-18}	11.8	2.10×10^{-18}	12.1	8.10×10^{-18}	11.8	2.27×10^{-1}
^{241}Pu	7.75×10^{-17}	1.4	2.59×10^{-16}	3.0	6.13×10^{-16}	1.8	1.13×10^{2}
^{234}U	8.22×10^{-18}	0.0266	2.29×10^{-18}	0.0333	3.16×10^{-17}	0.0422	6.19×10^{-3}
^{235}U	2.86×10^{-19}	2.69	7.38×10^{-19}	3.09	1.10×10^{-18}	4.12	2.14×10^{-6}
^{236}U	1.71×10^{-20}	0.0054	2.39×10^{-20}	0.0099	7.36×10^{-20}	0.0097	6.34×10^{-5}

*Data reduced from gross values tabulated in Appendix E-1.

APPENDIX F-1. OPTICAL MEASUREMENTS: ENVIRONMENTAL AIR SAMPLES.

IDENTIFICATION	COLOR		MCC	TRACKS	SIZE	COMMENTS
EPA 41 101			100	200.	0.	
EPA 41 102			100	5000.	0.	
EPA 41 103			100	300.	0.	
EPA 41 104			100	450.	0.	
EPA 41 105			100	150.	0.	
EPA 41 106		YELLOW	16	700.	1.6	
EPA 41 107			100	830.	0.	
EPA 41 108		YELLOW	16	150.	0.	
EPA 41 109		GREEN	16	2800.	1.0	
EPA 41 110			100	3000.	0.	
EPA 41 111			100	2700.	0.	
EPA 41 112			100	1000.	0.	
EPA 41 113			100	3000.	0.	
EPA 41 114			100	4000.	0.	
EPA 41 115			100	3500.	0.	LOST
EPA 41 201		NO COLOR	10	0.	15.5	GYPSUM
EPA 41 202		NO COLOR	10	0.	12.0	GYPSUM
EPA 41 203		NO COLOR	8	0.	7.5	GYPSUM
EPA 41 501A502		YELLOW	20	50.	2.3	UOX
EPA 41 502B501			100	0.	0.	
EPA 41 503			100	40.	0.	
EPA 41 504		OPAQUE	32	30.	9.0	
EPA 41 505		YELLOW	16	30.	5.0	
EPA 41 506			100	25.	0.	
EPA 41 507			100	35.	0.	
EPA 41 508			100	35.	0.	
EPA 41 509		YELLOW	24	40.	15.6	ZIRCON
EPA 41 510		ORANGE	20	40.	2.1	FEOX
EPA 41 511A512		OPAQUE	32	0.	5.0	
EPA 41 512B511		ORANGE	20	24.	2.0	
EPA 42 201		NO COLOR	8	0.	13.0	KFESI308
EPA 42 501		YELLOW	17	90.	19.5	ORGANIC
EPA 42 502	ORANGE	YELLOW	24	40.	19.5	LOST
EPA 42 503A504		YELLOW	17	0.	2.7	ORGANIC
EPA 42 504B503			100	60.	0.	
EPA 42 505C509			100	0.	0.	
EPA 42 506A507		YELLOW	16	0.	2.5	
EPA 42 507B506			100	35.	0.	
EPA 42 508			100	20.	0.	
EPA 42 509E505		YELLOW	16	45.	35.0	ORGANIC
EPA 42 510E505		YELLOW	16	45.	13.0	ORGANIC
EPA 42 701A704	BROWN	YELLOW	28	0.	7.0	ORGANIC
EPA 42 702	YELLOW	BROWN	28	50.	18.0	
EPA 42 703	BROWN	YELLOW	28	45.	4.3	ORGANIC
EPA 42 704B701			100	18.	0.	
EPA 50 701	BROWN	YELLOW	28	38.	5.2	
EPA 50 702	BROWN	YELLOW	28	130.	10.0	FEOX
EPA 50 703	BROWN	YELLOW	23	175.	2.8	NBOX
EPA 50 704			100	10.	0.	
EPA 50 705			100	17.	0.	
EPA 50 706	BROWN	YELLOW	28	350.	2.5	
EPA 50 707			100	25.	0.	
EPA 50 708			100	16.	0.	
EPA 50 709			100	14.	0.	
EPA 50 710A716	BROWN	YELLOW	28	0.	5.0	

APPENDIX F-1. OPTICAL MEASUREMENTS: ENVIRONMENTAL AIR SAMPLES. (continued)

IDENTIFICATION	COLOR		MCC	TRACKS	SIZE	COMMENTS
EPA 50 711			100	42.	0.	
EPA 50 712	YELLOW	BROWN	20	160.	6.8	
EPA 50 713	BROWN	YELLOW	28	20.	5.8	
EPA 50 714	BROWN	YELLOW	28	26.	8.0	
EPA 50 715		YELLOW	28	42.	9.0	LOST
EPA 50 716B710			100	22.	0.	UOX
EPA 54 201A202		GREEN	100	50.	3.7	
EPA 54 202B201		OPAQUE	32	50.	1.2	
EPA 54 203		OPAQUE	48	50.	9.6	CARBON
EPA 54 204D205		GREY	20	0.	6.8	
EPA 54 205E204			100	140.	0.	UOX
EPA 55 101A102	YELLOW	BROWN	24	0.	5.6	
EPA 55 102B101		BROWN	20	1001.	1.8	UOX
EPA 55 103	GREEN	YELLOW	28	1001.	6.5	NBOX+ UOX
EPA 55 104	GREEN	ORANGE	28	1001.	6.5	
EPA 55 105			100	1001.	0.	
EPA 55 106			100	1001.	0.	
EPA 55 107			100	1001.	0.	
EPA 55 108			100	1001.	0.	
EPA 55 109			100	1001.	0.	
EPA 55 110	ORANGE	YELLOW	28	1001.	4.8	
EPA 55 201			100	300.	0.	
EPA 55 202			100	400.	0.	
EPA 55 203			100	500.	0.	
EPA 55 204		OPAQUE	32	500.	1.9	ORGANIC
EPA 55 205		GREY	24	100.	6.5	
EPA 55 206		OPAQUE	32	150.	1.0	
EPA 55 207			100	350.	0.	
EPA 55 208A209	BROWN	ORANGE	28	0.	7.5	
EPA 55 209B208		OPAQUE	32	190.	1.3	
EPA 55 210C211		BROWN	100	350.	26.6	
EPA 55 211E210		OPAQUE	32	175.	4.8	LOST
EPA 55 212			100	175.	0.	
EPA 55 213	GREY	GREEN	24	200.	2.1	
EPA 55 214		OPAQUE	32	250.	1.3	LOST
EPA 55 215E210	YELLOW	BROWN	24	175.	21.8	U308
EPA 55 701	YELLOW	BROWN	22	9999.	7.0	U02
EPA 55 702	YELLOW	BROWN	22	9999.	11.0	U02
EPA 55 703		BROWN	28	9999.	4.7	FES2, (PYRITE)
EPA 56 201			100	400.	0.	
EPA 56 202			100	300.	0.	
EPA 56 203			100	300.	0.	
EPA 56 204		OPAQUE	32	150.	1.6	
EPA 56 205	GREY	GREEN	16	250.	3.7	
EPA 56 206		OPAQUE	32	125.	6.8	LOST
EPA 56 207		OPAQUE	32	125.	1.9	
EPA 56 208		OPAQUE	32	200.	2.3	UOX
EPA 56 209		RED	28	400.	2.3	
EPA 56 210		BROWN	29	250.	28.0	ORGANIC
EPA 56 211*		OPAQUE	32	140.	1.8	
EPA 56 212		OPAQUE	32	225.	4.8	LOST
EPA 56 213			100	125.	0.	
EPA 56 214		OPAQUE	50	150.	4.3	U03
EPA 56 215	ORANGE	BROWN	28	300.	4.2	LOST
EPA 57 201		OPAQUE	48	0.	15.0	
EPA 57 203		OPAQUE	48	0.	10.0	ORGANIC
EPA 57 204		RED	28	0.	10.2	FE203
EPA 57 205		NO COLOR	8	0.	32.0	GYPSUM
EPA 57 206		NO COLOR	8	0.	17.5	GYPSUM LOST

APPENDIX F-1. OPTICAL MEASUREMENTS: ENVIRONMENTAL AIR SAMPLES. (continued)

IDENTIFICATION			COLOR		MCC	TRACKS	SIZE	COMMENTS
EPA	57	207C209	YELLOW	BROWN	17	0.	7.0	CARBON
EPA	57	208C210		BROWN	20	0.	28.0	CARBON
EPA	57	209E207		OPAQUE	32	0.	4.3	
EPA	57	210E208			100	0.	0.	UOX
EPA	57	211E208			100	0.	0.	UOX
EPA	58	201	BROWN	GREY	24	0.	22.0	LOST
EPA	58	202		NO COLOR	8	0.	35.0	
EPA	58	203		NO COLOR	9	0.	9.8	GYPSUM LOST
EPA	58	204		OPAQUE	32	1001.	9.6	
EPA	58	205		OPAQUE	32	100.	3.4	
EPA	58	206		OPAQUE	32	100.	2.8	
EPA	58	207		BROWN	28	80.	1.8	
EPA	58	208		GREY	24	125.	4.1	
EPA	58	209		OPAQUE	32	125.	1.5	
EPA	58	210		OPAQUE	32	140.	3.8	UOX
EPA	58	211	BROWN	ORANGE	28	1000.	5.8	FEOX
EPA	58	212		OPAQUE	32	300.	3.0	ZROX
EPA	58	213		RED	28	200.	3.2	UOX
EPA	58	214		OPAQUE	32	350.	6.1	U308 + U02 LOST
EPA	58	215		OPAQUE	32	150.	4.2	UOX
EPA	58	216		OPAQUE	32	200.	3.6	UOX
EPA	58	217D218		OPAQUE	32	1001.	11.8	
EPA	58	218E217		OPAQUE	32	750.	5.0	
EPA	58	219			100	45.	0.	
EPA	58	220		OPAQUE	32	100.	21.0	
EPA	58	221		OPAQUE	32	40.	0.	
EPA	58	222		OPAQUE	32	65.	0.	
EPA	58	223		OPAQUE	32	42.	0.	
EPA	58	224		OPAQUE	32	1001.	17.5	LOST
EPA	58	225		OPAQUE	32	110.	1.8	UOX + NBOX
EPA	58	226D227		OPAQUE	32	1001.	18.2	
EPA	58	227E226		OPAQUE	48	600.	9.8	U03
EPA	58	228		BROWN	28	1001.	10.8	U02
EPA	58	229	ORANGE	BROWN	28	150.	5.5	U02
EPA	58	230	RED	ORANGE	28	1001.	1.1	
EPA	58	231		OPAQUE	48	300.	4.8	U03
EPA	58	232E217		OPAQUE	32	1000.	6.8	U02 + U308
EPA	58	233E226		OPAQUE	48	500.	8.4	U03
EPA	59	201		OPAQUE	32	500.	5.9	
EPA	59	202D203	RED	BROWN	28	0.	7.8	
EPA	59	203E202		OPAQUE	100	0.	1.4	LOST
EPA	59	204E202		OPAQUE	100	0.	2.9	LOST
EPA	59	205		OPAQUE	32	1001.	1.6	UOX + NBOX
EPA	59	206A213		ORANGE	28	0.	1.3	ALSIOX
EPA	59	207		OPAQUE	48	150.	4.5	U02
EPA	59	208	ORANGE	GREY	16	90.	1.4	UOX
EPA	59	209	ORANGE	GREY	16	120.	1.8	UOX
EPA	59	210	ORANGE	BROWN	20	500.	4.8	LOST
EPA	59	211			100	125.	0.	
EPA	59	212			100	200.	0.	
EPA	59	213B206			100	1000.	0.	UOX
EPA	59	214			100	250.	0.	
EPA	59	215			100	45.	0.	
EPA	59	216		OPAQUE	32	125.	1.3	
EPA	59	217			100	100.	0.	
EPA	59	218A219		NO COLOR	16	125.	11.2	ORGANIC
EPA	59	219B218		OPAQUE	32	125.	1.2	
EPA	59	220A221		NO COLOR	0	125.	7.5	SIOX
EPA	59	221B220		NO COLOR	8	125.	2.0	
EPA	59	222A228		GREY	24	0.	3.4	ORGANIC
EPA	59	223A224		NO COLOR	16	0.	13.2	

APPENDIX F-1. OPTICAL MEASUREMENTS: ENVIRONMENTAL AIR SAMPLES. (concluded)

IDENTIFICATION	COLOR	MCC	TRACKS	SIZE	COMMENTS
EPA 61 205	OPAQUE	32	35.	0.	
EPA 61 206C207		100	87.	5.0	
EPA 61 207E206	OPAQUE	32	0.	1.2	LOST
EPA 61 208A209	ORANGE BROWN	16	0.	8.5	ORGANIC
EPA 61 209B208	OPAQUE	32	1001.	0.	UOX
EPA 61 210A211	ORANGE BROWN	16	150.	9.9	ORGANIC
EPA 61 211B210	OPAQUE	32	150.	0.	
EPA 61 212	BROWN ORANGE	24	150.	0.	
EPA 61 213	OPAQUE	32	150.	0.	
EPA 61 214		100	300.	0.	
EPA 61 215		100	300.	0.	
EPA 61 216		100	850.	0.	
EPA 61 217		100	350.	0.	
EPA 61 218		100	50.	0.	
EPA 61 219		100	200.	0.	
EPA 61 220		100	700.	0.	SOLUBLE URANIUM
EPA 61 221E206	GREEN GREY	28	87.	3.8	
EPA 59 224B223	OPAQUE	32	500.	2.0	
EPA 59 225		100	90.	0.	
EPA 59 226		100	150.	0.	
EPA 59 227E202		100	1001.	2.0	UOX + ZR
EPA 59 228B222		100	125.	0.	UOX
EPA 60 201	OPAQUE	32	150.	0.	
EPA 60 202		100	200.	0.	
EPA 60 203		100	150.	0.	
EPA 60 204	NO COLOR	100	500.	0.	
EPA 60 205		100	250.	0.	
EPA 60 206		100	500.	0.	
EPA 60 207		100	40.	0.	
EPA 60 208		100	110.	0.	
EPA 60 209	OPAQUE	32	200.	1.2	
EPA 60 210	BROWN YELLOW	100	1001.	0.	
EPA 60 211		100	100.	0.	
EPA 60 212	NO COLOR	100	1001.	0.	
EPA 60 213A216	GREY GREEN	24	0.	26.5	
EPA 60 214A215	GREY GREEN	16	0.	9.5	ORGANIC
EPA 60 215B214	OPAQUE	32	300.	4.1	
EPA 60 216B213		100	1001.	5.0	UOX + ZR
EPA 61 201	OPAQUE	32	23.	0.	
EPA 61 202	OPAQUE	32	33.	0.	
EPA 61 203	OPAQUE	32	44.	0.	
EPA 61 204	OPAQUE	32	58.	1.0	

APPENDIX F-2. PARTICLE CONSTITUTION BY EMP: ENVIRONMENTAL AIR SAMPLES.

IDENTIFICATION	ELEMENTAL CONCENTRATION WT.%	ELEMENTS < 1.0%
EPA 41 201	O48,CA27,S24	SI
EPA 41 202	CA70,O29	SI,FE
EPA 41 203	O46,CA31,S23	
EPA 41 501	U82,O17	SI
EPA 41 504	O47,SI24,AL11,FE10,K3.1,S2.0, NA1.3,CL1.0	TI,MG
EPA 41 505	O50,SI25,AL22,FE2.5	CA,TI,MG,K
EPA 41 509	ZR41,O38,SI18,FE1.4,Y1.1	P,AL,HF,CA,S, F
EPA 41 510	FE67,O32,S1.2	ZR,CL,SI,NA
EPA 41 511	FE54,O33,K5,S3.1,NA2.1,SI1.8	
EPA 42 201	O46,SI30,K15,AL4.5,FE2.7	BA,NA
EPA 42 501	C88,O4.5,FE2.1,SI2.1,AL1.6, S1.0	NA,K,CL
EPA 42 503	C89,O8,SI2.4	FE,AL
EPA 42 509	C89,O4.7,P2.1,S1.8,FE1.5	ZN,CL,SI,AL,MG, K
EPA 42 510	C69,O12,SI9,S4.2,FE3.2,K1.9, AL1.5	PB,ZN,NA,P,MG, CA,CL
EPA 42 701	C91,O4.3,SI1.5,FE1.3,TI1.3	CL,AL,S,P,NA, MG,CA
EPA 42 702	O43,FE18,SI16,AL14,K5,MG2.8, TI1.2	
EPA 42 703	C81,O13,SI3.6,AL2.4	S,FE,NA,MG,CA, K
EPA 50 701	O47,SI20,AL15,FE9,K4.1,S1.7, NA1.1,CR1.0	P
EPA 50 702	FE55,O32,S1.1,SI1.0	AL,ZN
EPA 50 703	NB65,O30,FE1.6,U1.5,K1.0	
EPA 50 706	O45,SI18,FE11,U8,AL7,S4.4, K2.3,TI2.1,NA2.0	
EPA 50 710	O42,PB24,S15,SI9,NA4.9,FE1.5, P1.4	
EPA 50 712	O49,SI27,AL9,PB4.9,S2.9,K2.7, NA2.5,FE1.4	
EPA 50 713	O51,SI33,AL12,K3.5	MG,TI,NA
EPA 50 714	O49,SI31,FE12,AL6,S1.3	NA,P
EPA 50 715	U83,O17	
EPA 54 201	O51,SI31,AL15,FE1.5	CA,MG
EPA 54 203	C76,O12,SI9,AL1.8,FE1.3	K,S

APPENDIX F-2. PARTICLE CONSTITUTION BY EMP: ENVIRONMENTAL AIR SAMPLES. (continued)

IDENTIFICATION	ELEMENTAL CONCENTRATION WT.%	ELEMENTS < 1.0%
EPA 54 204	049,SI33,FE10,K3.8,AL3.0	P,S
EPA 54 205	U83,017	
EPA 55 101	047,SI17,AL16,FE15,CA4.2	MG
EPA 55 102	U83,017	
EPA 55 103	NB37,U34,025,FE1.0,S1.0	PB,SI,ZR
EPA 55 104	050,SI26,AL21,NA1.3	TI
EPA 55 204	C97,01.1,PB1.0	SI,FE,S,NA
EPA 55 208	048,SI26,AL17,FE6,CA1.5	K,TI,MG
EPA 55 701	U57,ZR18,06,FE3.9	
EPA 55 702	U73,ZR15,03.3,FE4.8,P2.4, S1.2	NA
EPA 55 703	S60,FE40	NA
EPA 56 208	U81,018,SI1.2	
EPA 56 209	FE55,031,PB8,S4.2,CL1.5	
EPA 57 201	C74,SI12,07,AL4.1,K2.5	S,CA,FE
EPA 57 203	C86,06,SI3.0,S2.5,FE1.8	K,AL,PB,CA,MG, NA
EPA 57 204	FE59,030	S,SI
EPA 57 205	045,CA33,S22	
EPA 57 207	C90,07,SI2.7	PB,FE,S,AL,TI, P,K
EPA 57 208	C91,05,SI3.4	AL,FE,S,PB,P
EPA 57 210	U83,017	
EPA 57 211	U83,017	
EPA 58 210	U83,017	SI
EPA 58 211	FE59,032,SI2.2,U2.0,CL1.6, S1.4,NA1.2	CR
EPA 58 212	ZR73,029	U,SN
EPA 58 213	U83,017	FE
EPA 58 215	U83,017	FE,NI
EPA 58 216	U83,017	NI
EPA 58 225	U73,NB10,016	FE
EPA 59 202	040,CA39,SI11,S5,K2.0,FE1.5, AL1.1	NA,P
EPA 59 205	U63,NB20,017	CR,MN,FE
EPA 59 206	AL23,SI24,053	
EPA 59 208	U83,017	
EPA 59 209	U83,017	
EPA 59 213	U83,017	

APPENDIX F-2. PARTICLE CONSTITUTION BY EMP; ENVIRONMENTAL AIR SAMPLES. (continued)

IDENTIFICATION	ELEMENTAL CONCENTRATION WT.%	ELEMENTS < 1.0%
EPA 59 218	C99	O,S,CL,NA,CA,SI
EPA 59 220	O53,SI45	K,NA,FE
EPA 59 222	C86,O8,SI4.4,AL1.0	NA,S
EPA 59 223	O51,SI43,CA6	
EPA 59 227	U74,O14,ZR12	
EPA 59 228	U83,O17	
EPA 60 213	O51,SI26,AL22,ZN1.0,TI1.0	FE,NA
EPA 60 214	C93,O3.9,SI2.8	AL,ZN,TI
EPA 60 216	U74,O14,ZR12	
EPA 61 208	C95,O3.5,P1.0	FE,AL,NA,S,SI,K,CL
EPA 61 209	U83,O17	
EPA 61 210	C89,O6,SI2.3,PB1.5,AL1.0	NA,K,S
EPA 61 221	O49,SI36,FE3.2,K3.2,AL2.7,PB1.6,S1.6	

APPENDIX F-2. PARTICLE CONSTITUTION BY EMP: ENVIRONMENTAL AIR SAMPLES (concluded)

IDENTIFICATION	ELEMENTAL CONCENTRATION WT.%	ELEMENTS < 1.0%
BCL62 1 201	C88,O10,SI1.7	CA,FE,AL,NA,S
BCL62 1 202	O46,AL20,SI19,K12,FE1.8,NA1.5	
BCL62 1 203	O39,FE27,TI16,SI9,AL5,K1.1	NA,MG,CA
BCL62 1 204	O50,SI38,FE4.1,AL2.2,NA2.1	CL,K,MG,S
BCL62 1 205	O37,K24,SI17,CL5,NA4.2,FE4.1, CA2.4,AL2.4,TI2.2	
BCL62 1 206	C90,O7,SI1.5,S1.1	AL,CA,TI,FE,BA, NA
BCL62 1 207	O46,SI25,AL12,NA6,CA4.6,FE3.5, MN1.1,K1.0	CR
BCL62 1 208	O43,FE27,SI17,NA6,AL5	S,CA,TI
BCL62 1 212	U83,O17	ZR
BCL62 1 213	U83,O17	
BCL62 2 202	C77,O12,FE6,AL3.2,SI1.9,CA1.0	NA,K,S
BCL62 2 203	FE38,O32,CL13,SI3.8,S3.1, CA2.4,AL2.0,TI1.8,P1.2,NA1.0	MN,K,MG,PB
BCL62 2 205	O40,FE27,SI9,AL5,P4.8,S2.5, PB2.1,CA1.7,NA1.7,MG1.6,CL1.4	TI
BCL62 2 206	O44,SI15,FE11,AL9,S6,CA6, K2.3,PB2.2,F1.4,NA1.2	TI,MG,P
BCL62 2 207	C67,O19,SI6,AL3.6,FE3.5	S,NA,K,TI,CA, MG,PB,P,MN
BCL62 2 208	O50,SI33,AL5,K3.1,FE2.9,S2.5	CA,TI,PB,NA
BCL62 2 209	FE44,O34,NI8,SI6,S2.2,AL2.1, CL1.5	NA,MN,CU,PB,K, P,TI
BCL62 2 210	U83,O17	
BCL62 3 206	C90,O5,FE3.3,AL1.4	S,NA,P,CA,SI, U

APPENDIX F-3. URANIUM ISOTOPES FROM MASS SPECTROMETRY RESULTS, ENVIRONMENTAL AIR SAMPLES

			ISOTOPIC DISTRIBUTION OF URANIUM							
IDENTIFICATION			%234	+SD	%235	+SD	%236	+SD	%238	+SD
EPA	41	101	0.521	0.004	49.762	0.106	0.075	0.001	49.642	0.106
EPA	41	102	0.523	0.004	49.850	0.105	0.075	0.001	49.552	0.104
EPA	41	103	0.510	0.005	49.462	0.106	0.075	0.001	49.953	0.107
EPA	41	104	0.517	0.004	49.413	0.104	0.075	0.001	49.995	0.105
EPA	41	105	0.489	0.005	46.683	0.105	0.069	0.001	52.759	0.105
EPA	41	106	0.511	0.004	49.069	0.105	0.074	0.001	50.346	0.105
EPA	41	107	0.514	0.004	49.513	0.105	0.073	0.001	49.900	0.105
EPA	41	108	0.520	0.005	49.778	0.111	0.073	0.001	49.629	0.111
EPA	41	110	0.519	0.004	49.813	0.105	0.077	0.001	49.592	0.104
EPA	41	111	0.523	0.005	49.505	0.108	0.076	0.001	49.896	0.108
EPA	41	112	0.520	0.004	49.702	0.106	0.075	0.001	49.704	0.106
EPA	41	501	0.001	0.000	0.236	0.003	0.004	0.000	99.759	0.003
EPA	41	503	0.025	0.001	2.656	0.020	0.002	0.000	97.317	0.020
EPA	41	504	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	41	505	0.001	0.000	0.231	0.003	0.005	0.000	99.763	0.003
EPA	41	508	0.022	0.001	2.510	0.017	0.011	0.001	97.458	0.017
EPA	41	509	0.006	0.000	0.726	0.008	0.	0.	99.268	0.008
EPA	41	512	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	42	501	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	42	504	0.394	0.037	45.191	0.503	0.153	0.030	54.262	0.506
EPA	42	508	0.016	0.001	1.976	0.018	0.	0.	98.009	0.018
EPA	42	509	0.025	0.001	3.022	0.025	0.013	0.001	96.940	0.025
EPA	42	510	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	42	701	0.016	0.001	1.989	0.015	0.	0.	97.994	0.016
EPA	42	702	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	50	701	0.015	0.001	1.957	0.015	0.009	0.000	98.018	0.015
EPA	50	704	0.	0.	2.133	0.039	0.	0.	97.867	0.040
EPA	50	705	0.017	0.001	2.111	0.025	0.010	0.001	97.861	0.025
EPA	50	707	0.013	0.001	2.238	0.022	0.	0.	97.748	0.022
EPA	50	713	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	50	716	0.015	0.001	2.090	0.023	0.009	0.001	97.886	0.023
EPA	54	201	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	54	204	0.061	0.001	6.393	0.030	0.021	0.001	93.525	0.031
EPA	55	102	0.018	0.000	2.046	0.014	0.011	0.000	97.925	0.014
EPA	55	104	0.016	0.000	2.004	0.013	0.001	0.000	97.980	0.013
EPA	55	106	0.	0.	7.281	0.054	0.	0.	92.719	0.054
EPA	55	107	0.327	0.005	32.938	0.092	0.091	0.002	66.644	0.093
EPA	55	108	0.280	0.005	27.944	0.109	0.069	0.003	71.706	0.109
EPA	55	202	0.096	0.004	8.064	0.056	0.	0.	91.840	0.057
EPA	55	204	0.260	0.021	23.796	0.340	0.	0.	75.943	0.341
EPA	55	205	0.338	0.025	37.775	0.372	0.097	0.018	61.791	0.374

APPENDIX F-3. URANIUM ISOTOPES FROM MASS SPECTROMETRY RESULTS, ENVIRONMENTAL AIR SAMPLES. (continued)

			ISOTOPIC DISTRIBUTION OF URANIUM							
IDENTIFICATION			%234	+SD	%235	+SD	%236	+SD	%238	+SD
EPA	55	207	0.001	0.000	0.228	0.003	0.003	0.000	99.768	0.003
EPA	55	209	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	56	201	0.024	0.001	2.718	0.017	0.008	0.000	97.251	0.017
EPA	56	202	0.026	0.001	2.985	0.016	0.018	0.000	96.971	0.016
EPA	56	203	0.019	0.000	2.280	0.014	0.007	0.000	97.694	0.014
EPA	56	204	0.035	0.001	3.329	0.023	0.044	0.001	96.592	0.023
EPA	56	207	0.	0.	0.720	0.021	0.	0.	99.280	0.022
EPA	56	208	0.033	0.001	3.351	0.016	0.045	0.001	96.570	0.017
EPA	56	209	0.191	0.018	21.681	0.384	0.031	0.010	78.098	0.384
EPA	56	211	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	56	213	0.021	0.001	2.547	0.017	0.004	0.000	97.429	0.017
EPA	57	207	0.030	0.001	3.365	0.016	0.008	0.000	96.597	0.016
EPA	57	209	0.027	0.001	3.342	0.020	0.008	0.000	96.623	0.020
EPA	57	210	0.029	0.001	3.361	0.017	0.008	0.000	96.602	0.017
EPA	58	204	0.001	0.000	0.231	0.002	0.005	0.000	99.764	0.002
EPA	58	205	0.001	0.000	0.218	0.003	0.003	0.000	99.778	0.003
EPA	58	206	0.	0.	0.208	0.005	0.003	0.000	99.789	0.005
EPA	58	208	0.	0.	0.256	0.005	0.004	0.000	99.741	0.005
EPA	58	209	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	58	210	0.001	0.000	0.229	0.003	0.005	0.000	99.766	0.003
EPA	58	213	0.005	0.000	0.724	0.006	0.	0.	99.271	0.006
EPA	58	215	0.001	0.000	0.230	0.002	0.004	0.000	99.765	0.003
EPA	58	216	0.001	0.000	0.231	0.002	0.005	0.000	99.763	0.002
EPA	58	220	0.001	0.000	0.236	0.003	0.006	0.000	99.757	0.003
EPA	58	221	0.001	0.000	0.242	0.004	0.006	0.000	99.751	0.004
EPA	58	222	0.001	0.000	0.236	0.003	0.005	0.000	99.758	0.003
EPA	58	223	0.001	0.000	0.228	0.003	0.005	0.000	99.766	0.003
EPA	58	225	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	59	205	0.427	0.043	44.522	0.309	0.	0.	55.051	0.310
EPA	59	208	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	59	209	0.021	0.001	2.556	0.017	0.003	0.000	97.419	0.017
EPA	59	216	0.023	0.001	2.722	0.014	0.004	0.000	97.251	0.014
EPA	59	219	0.	0.	0.	0.	0.	0.	00.000	0.
EPA	59	221	0.	0.	0.	0.	0.	0.	00.000	0.
EAP	60	211	0.025	0.001	2.879	0.015	0.017	0.001	97.079	0.015
EAP	61	201	0.	0.	0.701	0.010	0.	0.	99.299	0.011
EAP	61	203	0.018	0.001	2.959	0.017	0.016	0.001	97.008	0.017
EAP	61	205	0.016	0.001	2.402	0.016	0.010	0.001	97.573	0.016
EAP	61	212	0.022	0.000	2.557	0.014	0.013	0.000	97.409	0.014
EAP	61	213	0.510	0.005	48.855	0.112	0.111	0.002	50.524	0.113
EAP	61	214	0.091	0.001	9.249	0.032	0.026	0.001	90.634	0.032

APPENDIX F-3. URANIUM ISOTOPES FROM MASS SPECTROMETRY RESULTS, ENVIRONMENTAL AIR SAMPLES. (concluded)

	ISOTOPIC DISTRIBUTION OF URANIUM							
IDENTIFICATION	%234	+SD	%235	+SD	%236	+SD	%238	+SD
EAP 61 218	0.296	0.003	28.616	0.078	0.077	0.001	71.011	0.079
EAP 61 220	0.335	0.004	34.162	0.098	0.088	0.002	65.416	0.098
EAP 61 221	0.021	0.000	2.572	0.013	0.005	0.000	97.402	0.014

*

	ISOTOPIC DISTRIBUTION OF URANIUM							
IDENTIFICATION	%234	+SD	%235	+SD	%236	+SD	%238	+SD
BCL62 1 207	0.125	0.011	11.743	0.657	0.035	0.007	88.098	0.653
BCL62 1 209	0.032	0.002	4.040	0.018	0.	0.002	95.928	0.018
BCL62 1 213	0.038	0.000	4.030	0.011	0.004	0.000	95.929	0.011
BCL62 2 201	0.039	0.005	3.976	0.070	0.005	0.004	95.981	0.075
BCL62 2 208	0.079	0.001	7.822	0.099	0.021	0.000	92.078	0.100
BCL62 2 214	0.009	0.007	2.716	0.087	0.	0.005	97.275	0.096
BCL62 3 203	0.037	0.001	4.003	0.012	0.004	0.000	95.955	0.012
BCL62 3 204	0.012	0.000	1.650	0.040	0.009	0.000	98.329	0.041

*

APPENDIX G. PARTICLE PHOTOGRAPHS

CONTENTS

EXPLANATION OF ELECTRON MICROPROBE (EMP) IMAGING

Electron images and X-ray images of the particle were recorded photographically to determine the spatial distribution of several elements in the specimen. The black and white photographs (3 in each case) were then photographed on a Polaroid® color print using the additive color separation process with the three primary color filters. The color composition is interpreted in the following manner:

Where red and green overlap:	Yellow will be recorded
Where red and blue overlap:	Magenta will be recorded
Where green and blue overlap:	Cyan will be recorded
Where red, green and blue overlap:	White will be recorded

Figure G1-A. Particle V000864-702(B); photomicrograph.

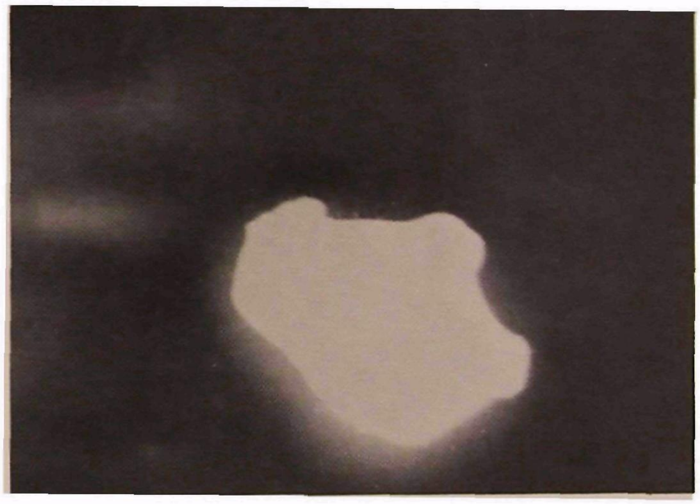

Figure G1-B. particle V000864-702(B); TEM* photograph

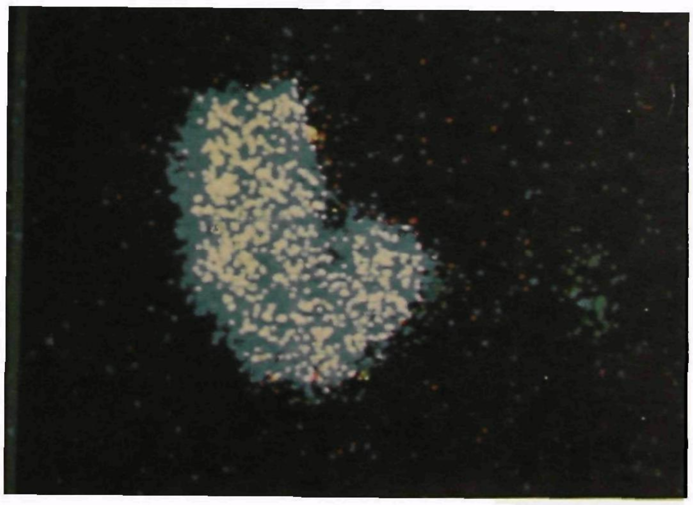

Figure G1-C. Particle V000864-702(B); EMP Scan. Red: Zr; Blue: U; Green: Fe

*Transmission Electron Microscope

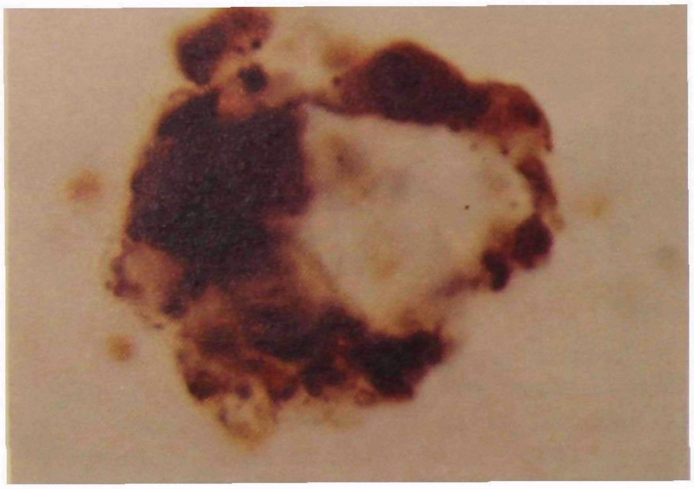

Figure G2-A. Particle V000867-514, 515. Photomicrograph

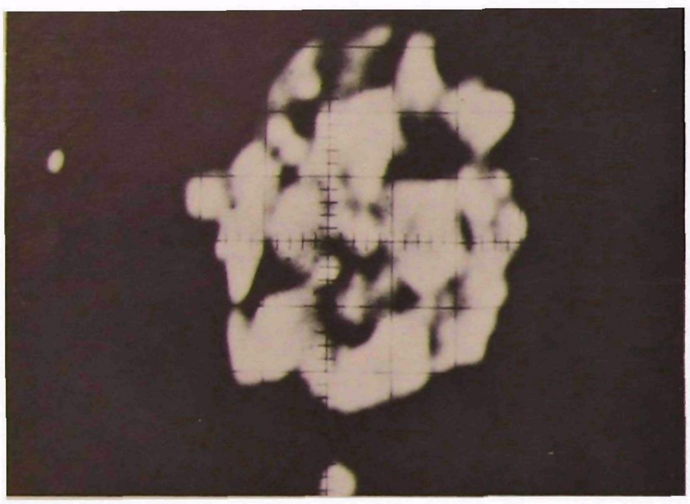

Figure G2-B. Particle V000867-514, 515. TEM photograph

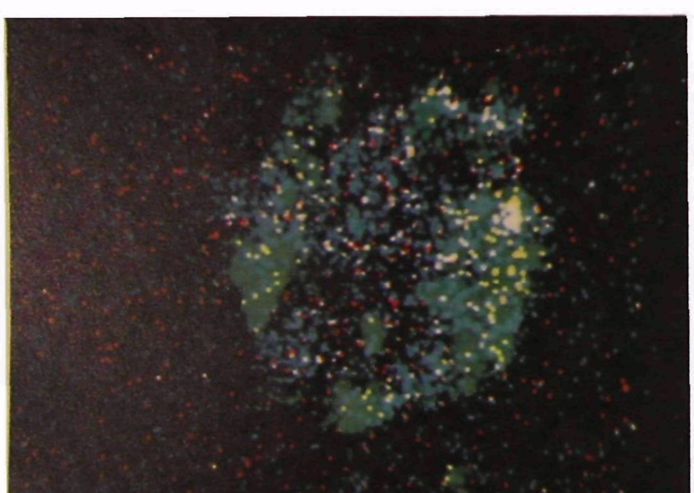

Figure G2-C. Particle V000867-514, 515. EMP Scan. Red: Pu; Green: Fe; Blue: U

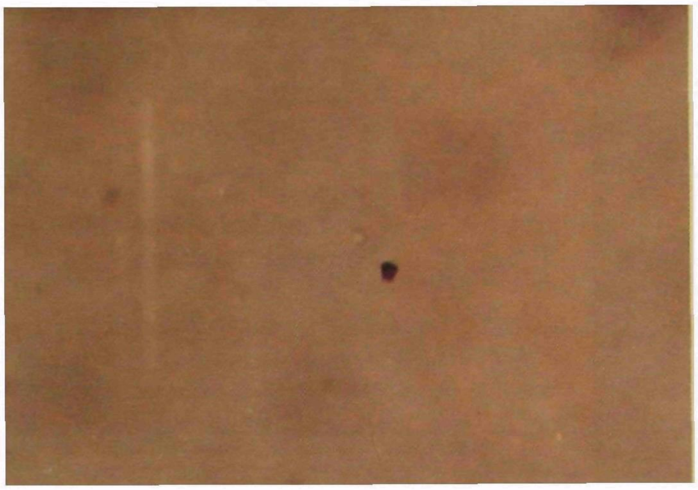

Figure G3-A. Particle V000867-712, 724. Photomicrograph

Figure G3-B. Particle V000867-712, 724. TEM photograph

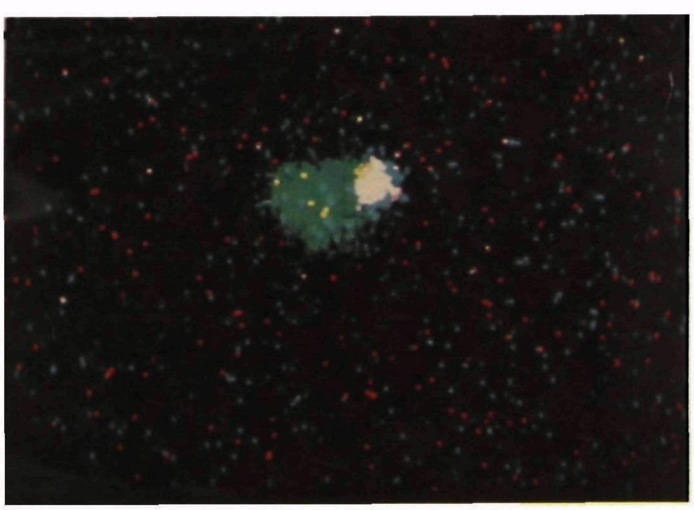

Figure G3-C. Particle V000867-712, 724. EMP Scan. Red: Pu; Green: Si; Blue: U

Figure G4-A. Particle V000867-720, 723. Photomicrograph

Figure G4-B. Particle V000867-720, 723. Scan. SEM*

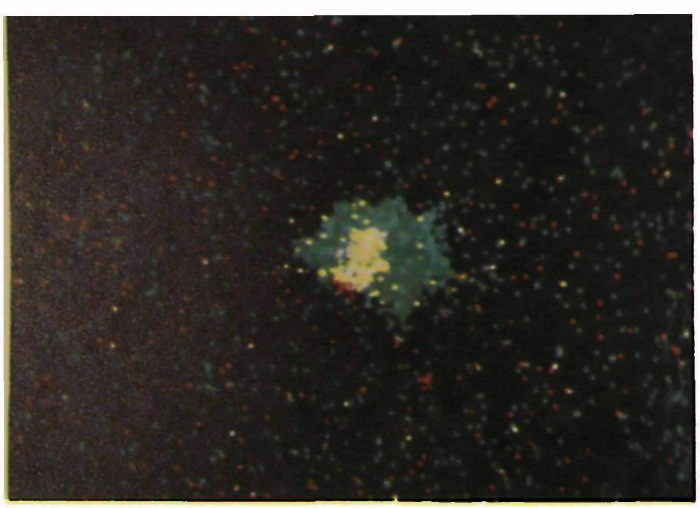

Figure G4-C. Particle V000867-720, 723. EMP Scan. Red: Pu; Green: Si; Blue: U

*Scanning Electron Microscope

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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16. ABSTRACT

To develop accurate monitoring techniques for the radioactive emissions from new types of nuclear facilities, it is necessary to characterize those emissions as completely as possible. The first facility selected was a mixed-oxide fuel fabrication plant. In-stack, standard hi-vol, and special ultra-high volume air samplers were used to collect particulate samples at the Babcock and Wilcox plant in Parks Township, Pennsylvania.

The number of radioactive particles emitted, the particle sizes, plutonium and uranium isotopic content, and the concentration of other materials were determined. These characteristics are used to propose an appropriate air-monitoring technique for facilities of this type.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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