**SUMMARY OF RESULTS
EFFLUENT MONITORING
PHOEBUS IB EP-IV**

MASTER

FOR THE

**SPACE NUCLEAR PROPULSION OFFICE
NEVADA EXTENSION**

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U N C L A S S I F I E D

SUMMARY OF RESULTS
EFFLUENT MONITORING
PHOEBUS IB EP-IV

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Manager, Radiation Services

Operations Manager

P A N A M E R I C A N W O R L D A I R W A Y S , I N C.

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A B S T R A C T A N D S U M M A R Y

Emphasis for data collection during the Phoebus IB full power run was placed on the collection and analysis of ground-deposited radioactive particulates. Detailed particle collection and particle deposition measurements were performed at 2.5, 5, 15, and 25 miles. Partial coverage of the 12-mile arc was accomplished, and one positive area at a distance of 45 miles downwind was surveyed and sampled. The particles found at all distances were irregular in shape with only a few spherical ones located. Particles are generally fragile, and many were smashed during handling.

There was at least one location within the cloud at every sample distance downwind where the particle concentration was sufficiently high to equal a probability of one that a man under the cloud would be hit by a particle.

Ensemble averaging over all particles from all distances (which approximates the source term distribution) establishes a count median diameter of 67 microns with a geometric mean deviation of 2.0. The mean particle size falls off approximately as the square root of the distance. Similarly, the mean radioactivity per particle, expressed as number of fissions, falls off regularly with distance. The count median particle activity, determined by averaging all particles from all distances, is 5×10^9 fissions, with a geometric mean deviation of a factor of 10.

No reliable relationship exists between particle size and activity per particle. For a given activity the particle size range amounts to a factor of eight. Given the particle size the activity range is more than

four decades. Crude estimates of the particle density for 15 particles give an average value of 5.6 gms/cm³. The average of 22 particle weight determinations was 7.8 micrograms. The median weight is 5.2 micrograms. A total of 2.5×10^8 particles can be accounted for from ground deposition measurements made between the distances of 2.5-25 miles.

Particle activities were converted to contact beta dose rates using data presented by United States Naval Radiological Defense Laboratory (USNRDL) in their document, number TR1082. Assuming that a dose of 2000 rads to a limited area of the skin will prove to be an acceptable dose, it appears that for average particle activities this dose will not be exceeded beyond 15 miles. However, for extremely high particle activity this dose would not be exceeded beyond distances of 30 or 35 miles.

A C K N O W L E D G E M E N T

Appreciation is extended to the U. S. Naval Radiological Defense Laboratory (USNRDL) and the Aerojet General-Westinghouse Nerva Test Operation (NTO) for their contributions of data and analyses as referenced in the text.

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SUMMARY OF RESULTS
EFFLUENT RELEASE FROM PHOEBUS IB EP-IV

I. INTRODUCTION

As Support Services Contractor for SNPO-N at the NRDS, Pan American is responsible for the collection of samples of effluent data at ground level. During Phoebus IB, EP-IV, the plan was to array gamma sensing thermoluminescent dosimeters (TLDs) through 100 degrees of arc centered on the forecasted hot line. The TLDs were to be arrayed at four different distances from the test cell -- 2.5, 5, 12, and 25 miles. The plan also called for the placement of thirty medium volume air samplers interspersed with the TLDs on the 12 and 25-mile arcs.

TLDs and air samplers were positioned from 0430 to 0830 on Run Day in order to be operational for full power testing scheduled to begin by 1000.

For the Phoebus IB test, the array was established ± 50 degrees centered on 115 degrees. During delays in starting the test the winds reversed from down valley to up valley, thereby necessitating maximum effort to relocate the array. Within the limits of time and area access the final sample array for the full power test was as follows:

<u>Distance</u>	<u>Instrument(s)</u>	<u>Azimuths</u>
2.5 miles	TLDs	043° - 180°
7-11 miles	TLDs - Air Samplers	026° - 095°
15 miles	TLDs - Air Samplers	360° - 090°

The hot line, as determined from air sample and TLD data, was established to be at an azimuth of 5 degrees measured from Test Cell "C". Consequently, only the 15-mile arc of TLD and air sample data was obtained.

In addition to TLD and air sample determinations, particle deposition measurements, sizing, and radioactivity determinations were also performed. However, the emphasis for these experiments was placed on radioactive particulate collection and analysis. Final estimates are made for contact beta-dose rate, particle inventory, particle concentrations, and crosswind values for particle distance. Hopefully, the data presented herein will give some insight into the characteristics of a prediction model for downwind effluent.

II. TLD/AIR SAMPLE RESULTS

The thermoluminescent dosimeter system used was the EG&G Model TL-2B reader with enhanced sensitivity that extends the useable range on the low end to 0.25 mR. The dosimeter consists of the $\text{CaF}_2\text{:Mn}$ TL-32 detector and Model TL-52 energy compensating shield. For low dose usage, the inherent background of the dosimeter (which amounts to two and one-half times natural background) and natural background radiations (which together accumulate to about 1 mR/day), must be considered in the analysis.

The accuracy of the TLD results is ± 100 per cent for readings of 0.4 mR and less. Accuracy improves with increasing dose to ± 10 per cent for doses above 4 mR.

Real time monitoring, using a mobile unit, was performed to establish time of cloud arrival, time of cloud departure information, and to place an air sampler containing charcoal traps in the radioactive cloud. The purpose of the charcoal traps was to provide a means to determine the collection efficiency of the filter paper used in the medium volume air samplers. The medium volume air samplers do not have the capacity to draw air through the filter paper and a charcoal cartridge. The results of the real time monitoring experiment established that the collection efficiency of the filter paper for the gross activity was 83 per cent and for the iodine isotopes 64 per cent.

These correction factors have been applied to the data presented in Figure 1 and in Table I.

NTO Radiochemistry Laboratory performed radioiodine separation and analysis by wet chemistry techniques after establishing near equivalence of activity on split samples by beta counting. The activity on three of the four samples was shared relatively evenly. Only one sample split unevenly by as much as 25 per cent. However, the distribution of the several iodine isotopes on the four sample halves varied by more than 25 per cent. This variation is thought to be real and not an error in analysis.

TABLE I
TABULATION OF AIR SAMPLE RESULTS

<u>Lab No.</u>	<u>Azimuth Deg.</u>	<u>Distance Miles</u>	<u>TIC* Gross</u>	<u>I-131*</u>	<u>I-133*</u>	<u>I-135*</u>
206	1.5	15	3.3×10^3	9**	60**	90**
203	4.5	15	4×10^3	10.5	139	286
201	8.5	15	5×10^3	24.6	320	740
208	12	15	1.9×10^3	7.3**	53**	154**
205	14.5	16	7.65×10^2	0.56	9.0	38.5
202	17	16.5	2.46×10^2	0.49	10.5	308
221	19	17.6	1.73×10^2			
223	22	18	2.66×10^1			

*TIC: Time integrated concentration, normalized to time cloud passage complete in units of microcurie-seconds (μ Ci-sec) per cubic meter.

**Analyzed by Pan American World Airways, Inc. (Pan Am)

The thyroid inhalation dose at the hot line on the 15-mile arc is calculated to be 95 mrem using values for a standard man and a worker's breathing rate.

Figure 2 presents cloud gamma dose rate data for an observer at 17

degrees, 16 miles downwind and from which a mean transport speed of 16 mph can be inferred. Figure 3 presents a comparison between the theoretical decay of uranium-235 fission products and the decay of the hot line air sample. The agreement between the two curves is very good and all air samples were corrected for decay along this curve. Figure 1 shows the arcwise distribution of airborne material for the gross activity and the gamma dose during cloud passage from the TLDs.

Several air sample filter papers collected on the 15-mile arc were radioautographed to determine the existence or non-existence of large airborne particulates. The radioautographs of the air samples near the hot line show discrete particles. Because the blackened film area is not indicative solely of the particle diameter, the only conclusion that may be stated with certainty is that discrete particles are present in large numbers. This airborne material is different from "normal" air samples which, when radioautographed, produce a uniform blackening of the film. See Photograph Number 1.

III. PARTICLE DEPOSITION MEASUREMENTS

Emphasis for data acquisition for the Phoebus IB experiment was placed on the collection and analysis of ground deposited radioactive particulate material. It was planned: (1) to collect detailed data to establish the concentration of deposited particulates at several different distances downwind; (2) to determine the radioactivity per particle; (3) to obtain photographs of the radioactive particles for size determinations; and (4) to weigh a number of particles for estimation of particle density. It was considered essential to determine if even one 10 micron particle reached a downwind distance of approximately 50 miles.

The Radiation Monitors were instructed to locate an undisturbed plot of ground and to place a square meter templet at this location. By using a GM type detector, equipped with an audible popper, the Monitors were to locate and collect every indication of radioactivity within the templet. The operation was to be repeated nine more times at each designated stake location. After the particle was localized, it was scooped from the earth with a tablespoon and placed in a Kraft envelope. The stake number and arc number were written on the envelope.

Radioactive particles were collected in the field on $R + 1$, $R + 2$, $R + 3$, and $R + 6$ days. In all instances the surveyed area was controlled by the use of the square meter templet. Detailed data were obtained at downwind distances of 2.5, 5, 15, and 25 miles.

Limited but careful surveys at two downwind distances of 38 and 45 miles satisfied the long range requirement. At a distance of 38 miles, seven areas of 700 square feet each were searched, but no particles were located between 15 and 30 degrees. However, at a location near the hot line, with coordinates of 2 degrees at a distance of 45 miles, numerous particles were located. These data are presented in the appendix.

As might be expected, particle concentrations varied considerably from templet to templet at the same stake location. The variation was generally from zero to three particles within a templet at all distances with the exception of the 5-mile arc where variations ranged from 1 to 6 particles per templet on the hot line. Bar charts showing the radioactive particle deposition per 10 square meters versus angle along the arc are presented in Figures 4, 5, 6, and 7. No chart is presented for the 12-mile arc because only the eastern one-third of the cloud was accessible due to terrain. No chart is presented for the 45-mile distance because particles were only found at one location. The concentration at this point was 14 particles per 10 square meters.

If one assumes that a person sweeps out one square meter of surface area, one or more particles will be deposited on that person at one or more locations at every downwind sample distance.

IV. PARTICLE SIZE

NTO Radiochemistry sized approximately 200 particles. The majority of the particles were irregular in shape; however, a few were spherical. Most of the particles were very fragile and could be classified as debris.

In order to characterize the size of irregularly shaped particles, two dimensions must be stated. However, for analysis purposes a single dimension for each particle is desirable and was calculated by equating the product of the two dimensions to the area of a circle and solving for the diameter. The new measure, which is the equivalent spherical diameter, is then treated statistically to show the relationship between size, activity, and distance.

The apparent sources of bias in these data should be mentioned before the results of the analysis are presented:

1. Not all particles assayed for activity were sized.
2. Transporting and handling of the particles tends to produce smaller particles than would normally be found. This effect is probably responsible for the abundance of $20\ \mu$ particles on the 25-mile arc.
(See Figure 8, Panel A.)
3. An effect tending to balance the above-mentioned bias is that particles with low radioactivity content are not selected for sizing, because their low

radioactivity indication makes them difficult to locate and isolate.

Figure 8, Panels A and B, depicts the scatter diagram for particle size versus distance and the statistics of particle size versus distance. Using the 5, 15, and 25-mile arc data to establish the trend, a visually-fitted curve was drawn through the points. From these data it appears that the mean particle size falls off as the square root of the distance.

A particle size distribution plot comprised of all particles from all distances was prepared. A count median diameter (CMD) of 67 microns was determined with a geometric mean deviation (GMD) of 2.0. (Figure 9)

V. RADIOACTIVITY DETERMINATIONS

Particle activity measurements were made in a gas flow proportional counter after separation of the particle from the sand. The particles were held in place in a petri dish by transparent tape.

The radioactive decay was followed by performing at least three counts over three days. Comparisons between disintegration rate determinations made on the same particle by Pan Am and USNRDL show good agreement. Due to isotope fractionation, the observed decay curves of the several particles departed at times from the theoretical decay curve for uranium-235 fission products by as much as 40 per cent. This effect does not allow a consistent value for fissions in a particle to be calculated at different times. However, in the averaging process, the decay curve returns to the theoretical curve and values calculated earlier are re-calculated for later times.

NTO Radiochemistry performed analyses for iodine-131 on about 50 particles for estimating additional thyroid exposure that may result from the absorption of iodine from ingested particles passing through the gastrointestinal tract. The iodine activity per particle is extremely variable and bears little resemblance to any other parameters. The five highest measured activities, corrected to $H + 1$ hours, are in the range of 2 to 5 microcuries; but the particles were located within three miles of the reactor. Beyond 12 miles in only 16 per cent of the particles was NTO able to detect iodine-131. The

highest measured amount was 0.04 microcuries. If as much as 10 per cent of the iodine activity leaches from the particles and 30 per cent of the amount leached is retained by the thyroid gland, then a potential thyroid dose in the range of two millirads, in addition to the inhalation thyroid dose, is possible.

Figure 10, Panel A, depicts the scatter diagram of activity versus distance downwind. While the activity varies through five orders of magnitude, there is still a very definite trend towards lower activities with greater distance. Panel B of the same figure depicts the statistics of radioactivity per particle versus distance downwind. Four kinds of information are presented in Figure 10, Panel B. The curve labeled 5 per cent > represents the activity level where 5 per cent of the particles have activities greater than the labeled line. The line $\bar{X}$ represents the mean activity per particle at each distance. Only the data for the 12-mile arc fall off the line significantly. The letter "m" represents the count median value.

An activity distribution plot, considering all particles from all distances, was prepared and the count median activity (CMA) was 5×10^9 fissions. (Figure 11). The geometric mean deviation (GMD) is a factor of 10 (10x).

VI. CORRELATION BETWEEN SIZE AND ACTIVITY

From these data a good correlation between particle size and its associated activity could not be established. However, particle size does appear to decrease with decreasing activity. Figure 12 presents a scatter diagram in which the spherical equivalent diameter is plotted against activity. If the size is stated, the activity can vary by a factor of 160 to either side of the central trend line value. If the activity is stated, the particle size can be estimated within a factor of 2.83.

VII. CONTACT BETA DOSE RATE DATA

The contact beta dose rate from a particle to a 0.079 cm^2 disc positioned 10 microns from the particle and related to the number of fissions in the particle has been published by USNRDL. An approximate expression for the contact beta dose rate (D) to the disc is:

$$D = 1.3 \times 10^5 \text{ rads/hr} / 10^{12} \text{ fissions at } H + 1$$

(This assumes that the particles hit the skin
and reside at the same location for 3-5 hours.)

For the maximum and mean particle activity values measured at each distance, the dose rates to a disc are:

<u>Distance (Miles)</u>	<u>Maximum Dose Rate (Rads/hr)</u>	<u>Mean Dose Rate (Rads/hr)</u>
2.5	5.3×10^5	2.1×10^4
5.0	1.1×10^5	7.2×10^3
15.0	6.5×10^3	6.5×10^2
25.0	2.6×10^3	3.7×10^2
45.0	2.2×10^2	1.2×10^2

Although no maximum allowable or acceptable dose to the dermal layer of the skin has been established, a dose of 2,000 rads is probably acceptable, considering the limited size of the affected area. Therefore, it appears that the potential dose to tissue that might result from the deposition of a particle on skin would not exceed the above level at a distance of 25 miles or greater. It must also be noted that particles would arrive at downwind distances

exceeding 25 miles after $H + 1$. Thus, this calculation is somewhat conservative at greater distances.

VIII. PARTICLE DENSITY INFERENCE

Attempts were made to calculate the density using size and weight relationships for 19 particles that were both weighed and sized. The results are discouraging. Expected values for density should lie in the range of 2 to 12 gms/cm³ based on fuel design. The calculated values vary in the range of 0.2 to 56.4 gms/cm³. This range of values is clearly unrealistic and discredits the technique. The average value for density for the 19 particles calculated in this manner is 6.8 gms/cm³. If the two highest and two lowest values are thrown out and a new mean is calculated, the value becomes 5.6 gms/cm³. While these mean values are believable, they are crude and approximate at best. The average weight for 22 particles is 7.8 micrograms, and, is no doubt biased on the heavy side. Table II is a tabulation of these data.

TABLE II

Size, Weights, and Inferred Densities on Selected Particles

<u>Distance</u>	<u>Stake or Lab No.</u>	<u>Spherical Equivalent Diameter (microns)</u>	<u>Weight (μgms)</u>	<u>Calculated Density (gms/cm³)</u>	<u>Photograph Inset No.***</u>
8000'	5° P8P2	Smashed	15.3	-----	1
8000'	0° P1P2	125	1.3	1.2	2
8000'	5° P4P1	200	16.2	3.6	3
8000'	15° P1P1	170	17.0	6.2	4
2.5 miles	0° P4P1	140	14.1	9.3	5
2.5 miles	5° P1P1A	150	16.2	8.6	6
2.5 miles	5° P1P1B	Smashed	7.3	-----	7
2.5 miles	5° P5P3	103	3.2	5.0	8
2.5 miles	15° P2P1A	140	9.8	6.5	9
2.5 miles	15° P2P1B	180	21.2	6.5	10
2.5 miles	15° P3P1	65	3.5	23.4*	11
5 miles	541 P5P8	97	2.0	4.0	12
5 miles	529 P8P5	112	7.5	9.3	13
5 miles	541 P1P6	200	13.0	3.0	14
5 miles	529 P8P6	97	0.1	0.2*	----
5 miles	542 P3P1	112	3.5	4.3	----
5 miles	541 P2P7	Smashed	5.5	-----	----
15 miles	18A49 P10P1	97	0.5	1.0	----
15 miles	18A59 P9P1A	81	1.2	4.1	----
15 miles	18A51 P3P1A	63	7.5	57*	15
15 miles	18A51 P3P1B	170	1.2	0.4*	16
15 miles	18A59 P9P1B	3 @ 31	5.0	11.6	----
		Mean	7.82	5.6**	
		Median	5.25	5.0**	

* Considered to be outliers.

** After omitting two highest, two lowest values

*** From photographs 2 and 3

IX. INVENTORY OF GROUND DEPOSITED MATERIAL

The particle concentrations at the several distances were integrated across the arc and along the wind to determine the total number of particles deposited on the ground. This exercise produced the following results:

<u>Distance Interval</u>	<u>Particles (Total)</u>
2.5 to 5 miles	1.9×10^7
5 to 15 miles	1.1×10^8
15 to 25 miles	1.2×10^8
Total 2.5 to 25 miles	<hr/> 2.5×10^8 particles

An increase by a factor of two has been used to approximate the number of particles deposited from 25 miles to 100 miles. Therefore, the total number of particles deposited on the ground out to 100 miles is estimated to be 7.5×10^8 particles. There are too few weight determinations at each distance to calculate the weight loss with any precision. However, if an average particle weighs 7.8 micrograms, then 1.9×10^9 micrograms were deposited between 2.5 and 25 miles downwind from the reactor. The lack of weight data makes it impossible to estimate the mass deposited beyond 25 miles. These estimates compare somewhat favorably with an approximate 2 per cent loss of fuel determined from the core post mortem.

X. PARTICLE CONCENTRATIONS

Highest measured radioactive particle concentrations for each distance are tabulated below. Error limits on the extremes are based on $1.645 \sqrt{N}$; i. e. the 90 per cent confidence level.

<u>Distance</u> <u>(Miles)</u>	<u>Max. Concentration</u> <u>(Particles/10 m²)</u>	<u>Average Concentration</u> <u>(Particles/10 m² over 20°)</u>
2.5	23 $\pm$ 7.9	12
5	33 $\pm$ 9.4	22
12	18 $\pm$ 7	--
15	11 $\pm$ 5.45	6.1
25	14 $\pm$ 6.1	4.7
45	14 $\pm$ 6.1	--

With wide error limits such as these, a line can be faired through the points to represent the fall off of the highest measured concentrations with distance downwind. (See Figure 13.)

XI. CLOUD WIDTH DATA

Values for the crosswind diffusion parameter σ_y , the standard deviation of particle concentration, were calculated for four distances using values derived from log probability plots. The results are tabulated below versus distance downwind and versus diffusing time and presented graphically in Figure 14.

<u>Distance (Miles)</u>	<u>$\frac{x}{u}$ (Seconds)</u>	<u>σ_y (Meters)</u>
2.5	600	280
5	1200	840
15	3600	3970
25	6000	5250

An extrapolation of the trend line for σ_y versus time out to the 45-mile distance for which the diffusing time is calculated to be 10,800 seconds suggests a value for σ_y of 7000 meters.

FIGURES

Arc Wise Distribution of Airborne Material and Gamma Dose During Cloud Passage 15 Mile Arc

K&E SEMI LOGARITHMIC 46 5813
3 CYCLES X 140 DIVISIONS
MADE IN U. S. A.
KEUFFEL & ESSER CO

Microcuries-Second per Cubic Meter

10.0

TLD
Dose
mR

1.0

0.1

Degrees True From TC"C"

Figure 1

CLOUD GAMMA DOSE RATE VERSUS TIME

17 Degrees

15 Miles

† = Theory @ = Air Sample

Radioactive Particle Deposition Data 2.5 Mile Arc

KE 10 X 10 TO THE INCH 46 0780
7 X 10 INCHES
MADE IN U.S.A.
KEUFFEL & ESSER CO

Particles/10 Square Meters

Radioactive Particle Deposition Data
5 Mile Arc

Particles/10 Square Meters

10 X 10 TO THE INCH 46 0780
7 X 1 INCHES
KEUFFEL & ESSER CO.

36

32

28

24

20

16

12

8

4

355

360

5

10

15

20

25

Degrees True From TC "C"

Figure 5

Radioactive Particle Deposition Data 15 Mile Arc

Radioactive Particle Deposition Data 25 Mile Arc

Figure 7

Figure 8

Figure 9

Figure 11

Figure 12

Figure 13

Figure 14

P H O T O G R A P H S

#203

"NORMAL"

#206

PHOTO 1. Comparison of Radioautographs of Hot Line Air Samples No. 203 and No. 206, Phoebus Material and "Normal" Material.

PHOTO 2. Selected Views of Particles Weighed and Sized.

3/12.3-015/2/1A

9

3/12.5-015/2/1B

10

3/12.5-015/3/1

11

6/541, 15/3

12

6/529/10/5

13

6/541, 1/16

14

16/18ASIT/3/1A

15

16

PHOTO 3. Selected Views of Particles Weighed and Sized.

PHOTO 4. (17) One of the Larger Particles from the 5-Mile Arc. (18) One of the Particles Highest in Activity from the 2.5 Mile Arc. (19) The Largest Particle from the 25-Mile Arc. (20-25) Typical Debris from the 25-Mile Arc.

A P P E N D I X

2.5 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
1	290 x 215	284	4.5×10^{12}
1H	-----	----	3.4×10^9
1A	120	120	1.6×10^{11}
1B	-----	----	1.12×10^{11}
1C	30 x 30	34	7.1×10^9
	30 x 40	34	
	55 x 20	39	
	60 x 70	73	
1F	Smashed	----	7.5×10^{11}
1D	100 x 100	112	3×10^9
1E	50 x 70	67	1.7×10^{10}
	45 x 40	48	
1G	35 x 35	39	2.7×10^9
	12 x 20	17	
	25 x 50	40	
1-1	-----	----	1.7×10^8
1-3	-----	----	2.1×10^9
1-4	-----	----	2.3×10^8
1-5	150	150	1.5×10^{12}
1-6	118 x 138	148	1.3×10^{12}
1-7	-----	----	1.2×10^9
1-8	-----	----	3.2×10^7
1-9	-----	----	3.1×10^9
1-10	78 x 85	94	1×10^{12}
1-11	-----	----	1.1×10^{11}
1-12	-----	----	8.3×10^9
1-13	-----	----	8.3×10^9
1-14	-----	----	1.6×10^7
2-1	-----	----	1.9×10^{10}
2-2	-----	----	4.3×10^{10}
2-3	-----	----	2.9×10^{10}
2-4	-----	----	2.6×10^{10}
2-5	-----	----	2.0×10^9
2-6	-----	----	7.9×10^9
3-1	120, (scattered pieces)	120	3.2×10^{10}
3-2	-----	----	7.7×10^{10}
3-3	-----	----	9.4×10^9
3-4	-----	----	5.5×10^{10}
3-5	-----	----	1.5×10^{10}
3-6	-----	----	6.7×10^{10}
3-7	-----	----	8.4×10^{10}
3-8	-----	----	4.8×10^{10}

(Continued....)

(Continued)

2.5 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
4-1	----	----	2.2×10^{10}
4-2	----	----	3.6×10^{10}
4-3	----	----	5.8×10^{10}
4-4	----	----	2.1×10^{10}
4-5	----	----	1.0×10^{10}
4-6	----	----	6.7×10^{10}
4-7	----	----	5.86×10^{10}
4-8	----	----	3.1×10^{10}
12.8 - 025 8-1	----	----	3.7×10^{10}
12.8 - 025 8-2	----	----	1.2×10^{10}
12.3 - 015 1-1	----	----	8.9×10^{10}
12.3 - 015 1-2	----	----	2.2×10^{10}
12.3 - 015 2-1	----	----	7×10^{10}
12.3 - 015 2-2	----	----	1.3×10^{11}
12.3 - 015 3-1	----	----	1×10^{11}
12.3 - 015 3-2	----	----	5.4×10^{10}
12.3 - 015 4-1	----	----	5.7×10^{10}
12.3 - 015 4-2	----	----	2.7×10^{11}
13.2 - 005 1-1	150	150	1.1×10^{11}
13.2 - 005 1-2	----	----	1×10^{11}
13.2 - 005 1-3	----	----	8.8×10^{10}
13.2 - 005 2-1A	140	140	2.2×10^{10}
13.2 - 005 2-1B	180	180	
13.2 - 005 2-2	----	----	5.4×10^{10}
13.2 - 005 3-1	50 x 65	65	5.5×10^{10}
13.2 - 005 3-2	----	----	8.8×10^{10}
13.2 - 005 3-3	----	----	1.2×10^{11}
13.2 - 005 4-1	----	----	1.1×10^{11}
13.2 - 005 5-1	----	----	4×10^{10}
13.2 - 005 5-2	----	----	1.3×10^{11}
13.2 - 005 5-3	50 x 160	102	9×10^{10}
000 2-1	----	----	6.2×10^{10}
000 3-1	----	----	1×10^{11}
000 4-1	140	140	1.4×10^{11}
000 10-1	----	----	9×10^{10}

5 MILE ARC

Lab or ID No.	Stated Size (Microns)	Spherical Equivalent Diameter (Microns)	Activity (Fissions)
349	90 x 140	122	1.5×10^{11}
351A	----	----	1×10^{11}
350	25 x 55	42	
	40 x 50	50	1×10^{10}
	50 x 60	53	
351	30 x 90	59	5.9×10^{10}
352	140 x 160	175	6.7×10^{10}
353	60 x 70	63	2.5×10^{10}
354	120 x 150	152	1.9×10^{10}
355	----	----	1.75×10^{10}
356	300 x 400	400	1×10^{11}
357	100 x 100	112	1.7×10^{10}
358	90 x 110	110	1.8×10^{10}
359	200 x 350	310	6.8×10^{10}
360	200 x 350 (scattered)	310	3.7×10^{10}
361	60 x 130	100	2.6×10^{10}
361A	----	----	7×10^9
364	----	----	5.9×10^{11}
365	----	----	1.1×10^9
367	20 x 40	33	1.3×10^9
368	80 x 100	102	4.8×10^{10}
369	70 x 80	86	1.9×10^9
369A	----	----	1.5×10^9
370	35 x 75	58	9×10^9
	90 x 115	115	
371	200 x 250	260	1.8×10^{11}
372	80 x 130	116	6.7×10^9
373	----	----	6.1×10^{10}
374	140 x 250	215	6.8×10^{10}
	90 x 100	110	
375	Smashed	----	6.3×10^{10}
376	Smashed	----	1.6×10^{10}
377	120 x 130	144	
	60 x 70	73	5×10^{10}
378	Smashed	----	3×10^{10}
380	55 x 65	70	5.3×10^9
380A	40 x 60	56	1.1×10^{10}
380B	Smashed	----	3×10^{10}
380C	----	----	5.1×10^9
380D	----	----	1.1×10^{11}
381	120	120	4.1×10^{10}
382	----	----	3.1×10^9
383	----	----	8.7×10^{11}
383A	----	----	2.5×10^7
384	150 x 160	180	1.1×10^{11}

(Continued)

5 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
385	250 x 150	225	5.9×10^{10}
386	40 x 60	56	1.2×10^{10}
	65 x 65	74	
388A	130	130	7.6×10^{10}
389	Smashed	----	6.5×10^9
389A	30 x 60	50	7.4×10^8
	35 x 80	47	
408A	250 x 150	220	1.7×10^{11}
389B	50 x 70	67	4.1×10^9
	40 x 170	95	
389C	30 x 60	47	5.4×10^9
	60 x 110	92	
389D	----	----	7.3×10^8
389E	35 x 45	45	7.3×10^9
390A	70 x 80	85	
	50 x 80	72	6.1×10^{10}
	90 x 90	102	
390	----	----	3.02×10^{11}
391	Smashed	----	2.2×10^9
392	70 x 110	96	
	90 x 110	103	8.6×10^9
393	----	----	1.54×10^{11}
394	120	120	3.5×10^{10}
395	130	130	8.7×10^{10}
396	----	----	2.4×10^{11}
397	90 x 100	103	2.3×10^{10}
397A	60 x 60	69	
	60 x 60	69	8.4×10^{10}
	60 x 80	79	
398	130 x 170	172	2.1×10^{10}
399	60 x 80	80	
	100 x 100	116	2.3×10^{10}
400	120 x 150	152	
	120	120	4.4×10^{10}
	130 x 150	160	
401	90 x 90	102	
	90 x 100	110	1.1×10^{10}
	170 x 190	208	
402	Scattered	----	1.6×10^{11}
403	----	----	2.6×10^6
404	120 x 260	205	4.1×10^{10}
405	100 x 130	131	8.3×10^9
405A	Smashed	----	1×10^{10}

(Continued...)

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5 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
406	-----	----	3.8×10^7
406A	50 x 70	67	
	30 x 70	52	1×10^{10}
406B	-----	----	4.4×10^7
407	70 x 100	96	8.8×10^9
408	80 x 65	82	6.7×10^9

12 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
301	90 x 100	108	2.45×10^9
302	-----	----	1.99×10^9
302A	25 x 30	31	2.2×10^9
304	20 x 25	25	
	30 x 35	36	2.7×10^9
304A	-----	----	2×10^9
305	40 x 70	60	
	60 x 60	65	
	50	50	1.52×10^9
309	90 x 80	97	1.5×10^{10}
309A	20 x 30	27	5.4×10^7
309B	-----	----	4.1×10^8
310	60 x 60	68	1.25×10^9
310B	-----	----	1.25×10^9
311	80 x 40	67	
	80 x 40	67	2.13×10^9
312	-----	----	4.5×10^9
313	80 x 80	91	1.5×10^9
313A	35 x 65	53	1.3×10^9
313B	15 x 30	24	8.2×10^8
314	-----	----	1.5×10^{10}
316	110 x 95	115	6.4×10^8
316B	25 x 50	40	
	30 x 50	43	1.3×10^9
316D	-----	----	9.1×10^9
316E	60 x 50	62	
	60 x 50	62	1.2×10^9
316F	60 x 60	68	5.3×10^8
316G	-----	----	1.1×10^9
318	80 x 110	108	3.5×10^9
318B	-----	----	2×10^{10}
318C	50 x 110	85	
	40 x 90	67	2.6×10^9
320	-----	----	1.5×10^{10}
321	140 x 150	168	4.4×10^{10}
409	-----	----	1.1×10^8
410	-----	----	2.4×10^9
412	-----	----	5.3×10^9
413	-----	----	3.2×10^9
414	-----	----	4.5×10^9
416	-----	----	1×10^9
416A	-----	----	7.8×10^8

(Continued...)

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12 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
417	-----	----	1.8×10^8
419	-----	----	1.5×10^9
419A	-----	----	2×10^9
419B	-----	----	2×10^8
419C	40 x 50	50	2.2×10^9
419D	-----	----	2.34×10^9
421	-----	----	3.5×10^9
422	-----	----	8.7×10^9
423	-----	----	5.1×10^9
425	-----	----	3.6×10^9

15 MILE ARC

Sub or ID No.	Stated Size (Microns)	Spherical Equivalent Diameter (Microns)	Activity (Fissions)
306	Scattered pieces	-----	5.8×10^8
306B	Scattered	-----	4.9×10^8
306C	-----	-----	1.68×10^8
307	35 x 50	47	1.53×10^9
307B	30 x 35	36	7.7×10^8
307C	-----	-----	2×10^8
308	-----	-----	4×10^8
308B	-----	-----	7.5×10^8
314	-----	-----	3.6×10^{10}
314C	110 x 130	138	3.9×10^{10}
317	120 x 130	144	9.6×10^9
317A	-----	-----	1×10^7
317B	-----	-----	1.5×10^6
319	40 x 40	45	2.5×10^9
428	-----	-----	2×10^9
430	60 x 50	62	4.4×10^9
432	30 x 50	43	8.6×10^8
433	40 x 45	48	1.46×10^9
434	-----	-----	4×10^7
435	-----	-----	3.3×10^8
436A	30 x 35	36	
	30 x 50	43	
	40 x 50	55	1.8×10^9
	20 x 40	31	
322	-----	-----	3.4×10^8
323	-----	-----	2.4×10^9
324	-----	-----	8.2×10^8
325	70 x 100	96	8.4×10^9
326	-----	-----	1.7×10^9
329	-----	-----	7.9×10^8
330	30 x 60	48	
	40 x 70	60	4.7×10^9
330A	60 x 90	84	7×10^9
330B	85 x 105	105	3×10^9
331	15 x 40	27	
	20 x 40	32	1.1×10^9
331A	-----	-----	3.5×10^9
333	20 x 25	25	2.9×10^9
334	-----	-----	1.3×10^9
336	-----	-----	3.9×10^{10}
336A	20 x 70	43	
	25 x 65	46	3.3×10^9
338	-----	-----	2.7×10^9

(Continued)

15 MILE ARC

Lab or ID No.	Stated Size (Microns)	Spherical Equivalent Diameter (Microns)	Activity (Fissions)
338A	-----	-----	7.9×10^8
339	-----	-----	4.8×10^9
340	-----	-----	2.6×10^8
341	-----	-----	9.6×10^8
342	-----	-----	6.5×10^9
343	-----	-----	1.3×10^9
344	-----	-----	2.5×10^9
345	-----	-----	1.6×10^9
346	-----	-----	9.8×10^8
347	-----	-----	1.4×10^9
348	-----	-----	3.6×10^8
437	Scattered	-----	5.4×10^9
18A49 1-1	-----	-----	1.8×10^9
18A49 2-1	-----	-----	3.7×10^8
18A49 6-1	-----	-----	1.8×10^9
18A49 7-1	-----	-----	1.8×10^{10}
18A49 8-1	-----	-----	7.2×10^9
18A49 8-2	-----	-----	1.8×10^9
18A49 9-1	-----	-----	1.8×10^9
18A49 10-1	120 x 60	100	5.5×10^{10}
18A51 1-1	-----	-----	1.8×10^9
18A51 3-1	-----	-----	1.8×10^{10}
18A51 3-1A	60 x 70	73	
18A51 3-1B	140 x 150	168	1.8×10^{10}
18A51 3-2	-----	-----	7.2×10^9
18A51 3-3	-----	-----	1.1×10^{10}
18A51 4-1	-----	-----	5.5×10^9
18A51 8-1	-----	-----	3.7×10^9
18A53 1-1	-----	-----	3.7×10^9
18A53 2-1	-----	-----	1.8×10^9
18A53 3-1	-----	-----	3.7×10^9
18A53 4-1	-----	-----	7.2×10^9
18A53 4-2	-----	-----	-----
18A57 2-1	-----	-----	1.8×10^9
18A57 3-1	-----	-----	5.5×10^9
18A57 6-1	-----	-----	3.7×10^9
18A57 6-2	-----	-----	1.8×10^9
18A59 2-1	-----	-----	3.7×10^9
18A59 3-1	-----	-----	1.4×10^9
18A59 4-1	-----	-----	1.8×10^9
18A59 5-1	-----	-----	1.8×10^9
18A59 7-1	-----	-----	5.5×10^9
18A59 9-1A	50 x 100	80	
18A59 9-1B	25 x 30 (3 pieces)	3 @ 31	2.2×10^{10}
18A60 1-1	-----	-----	7.2×10^9
18A60 1-2	-----	-----	5.5×10^9

(Continued...)

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15 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
18A60 2-1	----	----	2.5×10^9
18A60 4-1	----	----	3.7×10^9
18A60 8-1	----	----	2.6×10^{10}
18A60 9-1	----	----	5.9×10^9
18A65 2-1	----	----	1.8×10^{10}
18A65 10-1	----	----	7.2×10^9

25 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
439	140 x 30	72	2.2×10^9
440	70 x 80	85	
	40 x 60	55	1.8×10^9
	35 x 45	45	
	3 @ 20	3 @ 20	
441	-----	----	7.5×10^9
442	30 x 40	39	2.6×10^9
444	20 x 20	22	7.5×10^8
445	35 x 100	58	4.9×10^9
447	6 of 15-30	6 @ 23	2.2×10^9
448	-----	----	9.2×10^7
449	35 x 50	47	3.7×10^8
456	-----	----	1×10^8
457	95 x 140	133	6.1×10^8
458	3 @ 20	3 @ 20	3.1×10^7
458A	-----	----	2.4×10^9
461	70 x 110	100	1.8×10^9
462	25 x 160	62	
	60 x 80	80	6.7×10^8
468	45 x 80	67	3.5×10^8
469	-----	----	5.6×10^7
471	20 x 40	32	2.2×10^9
472	-----	----	1.8×10^9
474	40 x 40	45	
	20 x 20	22	3.3×10^9
475	-----	----	1.9×10^9
477	-----	----	2.2×10^9
479	50 x 40	50	2.3×10^9
480	Scattered 10-20	----	5.8×10^9
481	10 x 20	15	
	20 x 20	22	2.4×10^9
	15 x 25	21	
486	-----	----	1×10^9
489	40 x 85	66	7.8×10^9
490	40 x 55	53	2.4×10^9
493	Scattered	----	1.3×10^{10}
494	35 x 20	29	6.7×10^9
504	-----	----	3.8×10^8
505	70 x 110	100	1.85×10^9
507	50 x 70	68	
	50 x 80	70	3×10^9
	50 x 90	75	
508	45 x 50	53	4.2×10^8

(Continued...)

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25 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
510	----	----	2.6×10^9
513	----	----	1.2×10^9
514	----	----	8.9×10^9
516	80 x 160	130	8.3×10^9
517	50 x 80	72	5.8×10^9
520	----	----	9.8×10^8
525	50 x 80	72	
	55 x 55	62	1.2×10^{10}
	15 x 20	19	
518	30 x 16	24	-----
12T17 6-1	----	----	5.5×10^9
12T17 9-2	----	----	1.1×10^9
12T17 1-1	----	----	4.4×10^9
12T17 9-1	----	----	2.5×10^9
12T19 10-1	----	----	2.9×10^9
12T19 8-1	----	----	2.2×10^{10}
12T19 4-1	----	----	1.8×10^9
12T19 5-1	----	----	1.1×10^{10}
12T21 4-1	----	----	2.9×10^9
12T21 6-1	----	----	2.2×10^9

45 MILE ARC

<u>Lab or ID No.</u>	<u>Stated Size (Microns)</u>	<u>Spherical Equivalent Diameter (Microns)</u>	<u>Activity (Fissions)</u>
529	10 x 20	19	6.4×10^8
531	-----	----	1.5×10^8
532	-----	----	7.4×10^8
534	-----	----	1.1×10^9
537	-----	----	2.8×10^8
538	25 x 35	33	4.6×10^8
539	-----	----	1.33×10^9
541	-----	----	1.7×10^9
542	55 x 20	38	1.8×10^9
	30 x 20	27	