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DENSITY AND SHAPE FACTOR
OF SODIUM AEROSOL

MASTER

Progress Report
for Period April 1, 1976 - June 30, 1976

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ABSTRACT

This report covers the period April 1, 1976 to June 30, 1976. The following techniques have been implemented to improve the accuracy of aerosol centrifuge sampling and analysis systems; increased number of SEM photos, improved interpolation for sodium mass measurements, calculation of diameter of average volume, use of new standard sphere calibration photographs, and use of back-up filter on aerosol centrifuge. Results of the first full scale trial sampling run for 1 lb. sodium fire in a 90 m³ chamber gave density modification factors of 0.22 to 0.41.

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During the quarterly reporting period, April through June, 1976, several new techniques were implemented to improve the accuracy of measurements and calculations of airborne density, shape factor, and density modification factor of sodium fire aerosol particles.

The scanning electron microscopy (SEM) photographic procedure was revised to meet two conditions. First, sufficient photos were taken at 2000-5000 magnification to yield at least 100 particles per SEM foil segment for sizing. This quantity is adequate to determine the mean particle size because the particles have been fractionated according to aerodynamic diameter by the aerosol centrifuge, and consequently present only a narrow range of sizes on each SEM foil segment as shown in Figures 1-5. The second condition requires an additional set of photos taken at low magnification, 500X-1000X, to provide a count of greater than 1000 particles for the determination of number concentration. This improves the statistical reliability of our count data to the degree that the maximum percent standard deviation is about 3%. In previous experiments it was as great as 17 percent.

Additionally, two steps have been taken to improve the accuracy of the measurement of aerosol mass on the SEM foil strips. Aerosol mass on centrifuge deposition foil segments used for SEM is estimated by interpolation from adjacent foil segments. These adjacent strips have been increased in size to 5 mm and are combined

for the sodium analysis. Future experiments will utilize interpolation of over a still wider range. Simultaneously with each centrifuge run, filter samples are taken to provide a ratio of total mass to sodium mass. This ratio is needed to convert the atomic absorption measurements of elemental sodium on the foil segments to total particulate mass. The chemical composition of the sodium particles (oxide, hydroxide, carbonate, bicarbonate) and the amount of liquid water and water of hydration present on these filter samples will be determined in future experiments.

In earlier experiments the arithmetic average of equivalent diameters ($\overline{De}$) was calculated for each SEM foil strip. Currently we are calculating average $\overline{De}$ by:

$$\overline{(De)}_v = \left(\frac{\sum n_i (De)_i^3}{\sum n_i} \right)^{1/3} \quad (1)$$

where n_i is the number of particles with equivalent diameter $(De)_i$ and $\overline{(De)}_v$ is the diameter of the particle with average volume. The quantity, $\overline{(De)}_v^3$, is proportional to particle volume and when multiplied by the total number of particles on the strip gives the total particle volume. The latter is needed to obtain the correct particle density. The effect of this change is small because of the narrow size distribution present on the SEM foil strips--typically $\overline{(De)}_v$ is about 4% greater than the arithmetic average.

A new series of calibration sphere photographs has been prepared from SEM photos of polystyrene latex microspheres. Spheres were photographed under conditions identical to that for the sodium aerosol samples. The size of each sphere photo in the series was adjusted to have twice the volume of the preceding sphere. Sizing of sodium particles is done by grouping particles according to calibration sphere sizes.

It is suspected that the filter at the end of the aerosol centrifuge channel that collects particles smaller than the smallest centrifugal deposition size, may have leaked during certain runs. Because of space limitations in the deposition channel it is difficult to obtain a good edge seal on this filter. Consequently, future runs will include a back-up filter in the centrifuge outlet line.

The first full scale trial run was conducted in which four aerosol centrifuge samples were taken over a six hour period following a one pound sodium fire in a 90 m³ chamber. Sodium fire and sample taking procedures have been described in quarterly report COO-2803-2.

Centrifuge samples were started at 41, 89, 175 and 376 minutes after cessation of burning. Duration of these samples ranged from 3 minutes for the first one to 60 minutes for the last. For each

centrifuge sample, five 3 mm wide foil segments corresponding to aerodynamic diameters of 0.80, 1.18, 1.80, 2.65 and 3.99 μm were cut out and examined by SEM. Sample SEM photographs for these aerodynamic diameters are shown in Figures 1-5.

The relative humidity for this run was unexpectedly high, 53%, which led to the formation of droplet particles as described by Clough and Garland.¹ Close inspection of SEM photographs appeared to confirm this fact. Some particles showed a flattened dried appearance in the high vacuum of the SEM. Samples from two of the centrifuge runs were excessively flattened and unsatisfactory for SEM analysis. Despite these difficulties, the remaining samples were analyzed fully, primarily to perfect the measurement and analytical system. The results are given in Table I, where unit shape factor was assumed for all particles. The decrease in density as particle size gets smaller may be a result of greater adsorption of water due to the higher surface to volume ratio for the smaller particles. The very largest particles may have a lower density due to interstitial voids or incomplete reaction to carbonate. The slight decrease in particle density, ρ_p , between 89 and 376 minutes is probably not significant.

Additional sampling runs will be made during the next reporting period which will include the provision of dry air containment of the samples during all stages of handling.

Table I

Summary of Results for Run R-23
(assuming unit shape factor)

Aerodynamic Diameter	89 min.		376 min.	
	ρ_p	α^*	ρ_p	α^*
3.99 μm	-	-	0.77	0.28
2.65	1.1	0.41	0.96	0.35
1.80	1.1	0.41	1.04	0.38
1.18	0.69	0.25	0.69	0.25
0.80	-	-	0.60	0.22

ρ_p - particle density gm/cm^3

α^* - density modification factor for a material density of 2.74 gm/cm^3

References

1. Clough, W.S. and Garland, J.A., "The Behavior in the Atmosphere of the Aerosol from a Sodium Fire," J. Nucl. Energy, 25:425-435 (1971).

5. $D = 0.80 \mu\text{m}$
 $t_a = 376 \text{ min}$
 $rh = 53\%$

—
5 μm