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January 1 through June 30, 1974

Work performed by

Aerosol Studies Section
Industrial Hygiene Group

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AEROSOL RESEARCH AND DEVELOPMENT RELATED TO HEALTH HAZARD ANALYSIS
JANUARY 1, 1974 THROUGH JUNE 30, 1974

by

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ABSTRACT

Evaluations of 10-mm nylon cyclones for estimating respirable mass of airborne fibrous glass were continued during this quarter. Current results indicate reasonable estimates of respirable mass fraction when the cyclone is operated at a flow rate of 1.7 l/min. Mass median aerodynamic diameters (mmad) of the aerosols used in this evaluation have ranged from 3.1 to 4.0 μ m with geometric standard deviations of $\sim$ 1.8.

Measurements of coal dust loading effects on performance of nylon cyclone personal samplers were completed during this quarter. Cyclone loading was found to cause negligible errors in estimates of respirable mass under normal sampling conditions. Loading of the second stage filter was found to have a greater effect. These errors are small relative to inherent field sampling errors. Electrical charge was also observed to have a minimal effect on performance of the cyclone when sampling coal dust.

I. INTRODUCTION

Evaluation of the 10-mm nylon cyclone personal sampler for measuring respirable fraction of airborne fibrous glass was continued during this period. Performance of the cyclone was evaluated against two additional aerosols having "respirable" mass fractions of more than 50%. Performance of the cyclone has now been evaluated against aerosols generated from five different sizes of fibrous glass. In all cases the aerosols were generated by a modified Timbrell-type generator, operating by mechanically abrading the surface of a compacted plug of fibrous glass. This plug is prepared by suspending the bulk fibrous glass in water then chopping the glass in a conventional high-speed blender. The slurry is then compacted in a mold to form the plug. For these aerosols a cyclone sampling rate of 1.7 l/min provides a best estimate of the "respirable" fraction as

defined by the American Conference of Governmental Industrial Hygienists Respirable Dust Curve. Except for one type of fibrous glass, the error in estimating the "respirable" fraction has been less than $\pm$ 5% when operating the cyclone at 1.7 l/min. For the one glass it was impossible to generate a reproducible aerosol so an accurate assessment of "respirable" mass could not be made.

Evaluation of a permanent mounting technique for asbestos counting samples was continued. Samples exposed to temperature extremes ranging from 0°C to 40°C have been counted at regular intervals to evaluate long-term stability. The samples have shown no deterioration after eight months of exposure. Samples exposed to high humidities (>95% R.H.) deteriorated rapidly and could not be counted after one month.

The Standard Coal Aerosol Test System (SCATS)

was transferred to NIOSH, Cincinnati. The unit was reassembled and tested at the NIOSH Laboratory. The unit will provide high system flow rates $\sim 2.831 \times 10^3$ L/min (100 cfm) with maximum aerosol concentration variations of $\pm 8\%$ across the chamber.

Evaluation of the performance of 10-mm nylon cyclones as a function of operating time indicated that at normal dust concentration, loading will have an insignificant effect on performance of the cyclone. The greatest effects noted were on the pressure drop across the second-stage filters used to collect the mass penetrating the cyclone. Flow rate through the filter as a function of loading varied depending on the type of filter. In general, the second-stage loading effects would not significantly affect the estimate of "respirable" mass under normal field sampling conditions, (i.e., one shift sample at ~ 4.0 mg/m³ and $\sim 50\%$ respirable). However, for long-term samples, or for sampling high concentrations of "respirable" mass, loading of the second-stage filter can cause significant underestimation of "respirable" mass concentration. For samples of seven hours at concentrations of 12.0 mg/m³ the maximum underestimate of "respirable" mass was 20%. In general, the errors will be insignificant relative to errors inherent to field sampling.

During this reporting period the inventory of standard coal dust has been increased to 1.350 kg. Coal dust was shipped to NIOSH, Cincinnati (250 g) and to Eastern Associated Coal (75 g) for experimental purposes.

The effect of electrical charge on the performance of the 10-mm nylon cyclone for estimating the "respirable" mass of coal aerosols is currently being studied. Most efforts during this reporting period have been devoted to quantitating the charge on the coal aerosol generated in the Standard Instrument Calibration (SIC) unit. These studies have indicated that electrical charge has no significant effect on the size distribution of the aerosol. The average charge on the unneutralized aerosol generated in the SIC was found to be $\sim 180e^-$ per particle. These studies also indicated that under the conditions of test the 200-mCi Tritium source would effectively eliminate the aerosol charge. Anomalous effects noted at high relative humidities are currently being investigated to permit operation under all conditions of interest.

II. RESPIRABLE SAMPLING OF FIBROUS GLASS AEROSOLS

Calibration tests have been completed for two additional fibrous glass aerosols in the program to evaluate performance of the 10-mm nylon cyclone sampler for fibrous glass aerosols. Both aerosols were produced from bulk materials by high-speed blenderization of an aqueous slurry to reduce individual fiber lengths; then packing this material into a compact plug for generation by the modified Timbrell generator previously described.¹ The first of these test aerosols was produced from a bulk material obtained from Owens/Corning (O/C) Fiberglass Corporation and is labeled O/C AAA-10. The nominal fiber diameter assigned to this material by Owens/Corning is ~ 0.7 μ m. An Andersen cascade impactor² used to characterize the aerosol produced from this test glass indicates a mass median aerodynamic diameter (m_{mad}) = 3.1 ± 0.1 μ m and a geometric standard deviation (σ_g) = 1.8 ± 0.1 . These values are the average obtained from eleven (11) separate impactor samples taken in incremental sequence between sets of cyclone runs during the test sequence. Individual impactor characterization results are summarized in Table I. Correlation of these impactor-defined parameters ($m_{mad} = 3.1$ μ m, $\sigma_g = 1.8$) to the ACGIH

TABLE I
ANDERSEN IMPACTOR CHARACTERIZATION OF BLENDER
GROUND O/C AAA-10 FIBROUS GLASS AEROSOL

Run Code	Mass Median Aerodynamic Diameter (m_{mad} - μ m)	Geometric Standard Deviation (σ_g)
JIM - 18485 - 140	3.2	1.7
JIM - 18485 - 141	3.2	1.8
JIM - 18485 - 143	3.0	1.8
JIM - 18716 - 4	3.1	1.6
JIM - 18716 - 7	2.9	1.9
JIM - 18716 - 10	3.1	2.0
JIM - 18716 - 13	2.9	1.8
JIM - 18716 - 17	3.2	1.7
JIM - 18716 - 21	3.2	1.8
JIM - 18716 - 24	3.2	1.8
JIM - 18716 - 27	3.0	1.7
Average:	3.1	1.8
Standard Deviation:	0.1	0.1
Sample Size:	11	11

Respirable Dust Curve³ indicates a "respirable" mass fraction of ~54%.

Figure 1 illustrates the test results obtained for the entire cyclone sampling series with the Owens/Corning AAA-10 fibrous glass.

This plot of cyclone penetration versus sampling flow rate indicates that a cyclone sampling flow rate of ~1.9 l/min best approximates the ACGIH "respirable" dust fraction for this test aerosol.

Additional cyclone calibration tests completed against a second fibrous aerosol generated from Gelman Type A glass fibers produced similar results. The bulk material for this test aerosol is commercially available filter media marketed as Gelman Type A glass fiber filters.⁴ This filter media consists of glass microfibers without organic binder and was chosen as a cyclone calibration test material because of the physical similarity to the previously tested O/C AAA-10 material (i.e., the Gelman Type A material has an estimated nominal fiber diameter ~1.0 μ m). Specific interest in testing an aerosol produced from this material (Gelman Type A Fibrous Glass) is related to the fact that this is a widely used, commercially available product. This material would also provide an additional cyclone calibration checkpoint with a fibrous glass aerosol having a large "respirable" fraction (i.e., potentially >50% "respirable" mass).

Impactor characterization of the test aerosol produced from this fibrous glass resulted in an average $m_{ad} = 3.1 \pm 0.3$ with a $\sigma_g = 1.7 \pm 0.1$. These values are the average of twenty-two (22) separate impactor samples taken during an extensive cyclone calibration series. Individual impactor characterization results are summarized in Table II. The "respirable" mass fraction corresponding to this particular test aerosol size, as defined by the ACGIH Respirable Dust Curve, is ~56%.

A plot of Cyclone Penetration versus Sampling Flow rate indicates that a cyclone sampling flow rate of 1.8 l/min best approximates the ACGIH "respirable" dust fraction for this test aerosol. Figure 2 illustrates the test results obtained for this cyclone sampling series.

Impactor characterization of these test aerosols was obtained with an Andersen eight-stage cascade impactor. The impaction plates were covered with membrane filters to provide a stable collection

TABLE II
ANDERSEN IMPACTOR CHARACTERIZATION OF BLENDER
FOUNDED GELMAN TYPE A FIBROUS GLASS AEROSOL

Run Code	Mass Median Aerodynamic Diameter (m_{ad} - μ m)	Geometric Standard Deviation (σ_g)
JIM - 18716 - 82	3.1	1.7
JIM - 18716 - 83	3.2	1.7
JIM - 18716 - 84	3.2	1.7
JIM - 18716 - 85	2.8	1.9
JIM - 18716 - 86	2.7	1.5
JIM - 18716 - 87	2.9	1.8
JIM - 18716 - 89	3.0	1.8
JIM - 18716 - 92	3.3	1.8
JIM - 18716 - 95	3.2	1.6
JIM - 18716 - 98	3.2	1.8
JIM - 18716 - 101	3.4	1.6
JIM - 18716 - 104	3.3	1.6
JIM - 18716 - 107	3.3	1.6
JIM - 18716 - 109	2.8	1.8
JIM - 18716 - 111	2.7	1.8
JIM - 18716 - 114	2.7	1.7
JIM - 18716 - 117	2.9	1.7
JIM - 18716 - 121	2.8	1.7
JIM - 18716 - 124	3.3	1.6
JIM - 18716 - 127	3.4	1.6
JIM - 18716 - 130	2.9	1.7
JIM - 18716 - 133	3.5	1.5
Average:	3.1	1.7
Standard Deviation:	0.3	0.1
Sample Size:	22	22

surface and to limit rebound. The mass of material, collected at each stage, was determined by weighing the filter before and after sampling. The particle size distribution assumed to be log-normal was determined by plotting the cumulative mass associated with particles smaller than the effective cutoff diameter for successive stages on log probability paper. The mass median aerodynamic diameter (m_{ad}) was then determined from the 50% mass intercept and the geometric standard deviation from the slope. The "respirable" mass fraction of each test aerosol was determined by relating the m_{ad} and corresponding σ_g to the Respirable Dust Curve of the American Conference of Governmental Industrial Hygienists.

Experimental cyclone penetration data obtained for both test aerosols represents the average fibrous mass penetrating three (3) cyclone samplers operated simultaneously at various sampling points in the aerosol chamber during a one-hour sampling period. The mass penetrating these cyclones was obtained by measuring the fibrous mass collected downstream of each cyclone and comparing this to the average challenge mass determined by open face filter samples operating simultaneously. Sampler calibration for each aerosol was conducted by sampling with the 10-mm nylon cyclone at incremental flow rates ranging from 0.8 to 2.4 l/min.

Recommended cyclone sampling flow rates for both the Gelman Type A aerosol and the O/C AAA-10 material was obtained by calculating the best fit - using linear regression - least squares analysis, for all cyclone data points between sampling flows of 1.2 and 2.4 l/min. Cyclone test points for flows of less than 1.2 l/min were omitted from the linear regression calculations because cyclone collection efficiency is poorly defined and difficult to reproduce at low flow rates.

Table III summarizes individual results obtained for the five (5) fibrous glass aerosols tested to date. Aerodynamic characterization, in each case, was by Andersen impactor and recommended sampling flows for the 10-mm nylon cyclone are the experimentally determined best approximations to the

ACGIH Respirable Dust Curve for each aerosol. The range of sampling flows recommended for the 10-mm nylon cyclone extends from 1.6 to 1.9 l/min for these aerosols. These variations in sampling flows to approximate the ACGIH "respirable" mass fraction may be the result of physical differences between individual fibrous glass aerosols. Variations in fiber surface texture, fiber flexibility, and fiber dielectric properties may account for the observed differences in aerodynamic characteristics, impactor characterization, and/or cyclone collection mechanisms. Variations of this type could cause slight shifts in cyclone sampling flows necessary to fractionate the test aerosols according to the ACGIH respirable dust definition.

These data indicate that cyclone collection efficiency as a function of sampling flow rate is not as precisely defined for fibers as for particulates. However, consideration of potential error in estimating the "respirable" fraction due to this range, must be considered in terms of variations inherent in field sampling, and acceptable errors. For example, if the O/C AAA-10 aerosol were sampled at 1.6 l/min rather than the "recommended" 1.9 l/min flow rate, the "respirable" fraction would be overestimated by 11%. This would be the maximum error posed by sampling at the "recommended" flow extremes. A more practical assessment of the recommended flow rates is the feasibility of sampling each test

TABLE III

SUMMARY OF IMPACTOR/ACGIH/CYCLONE CORRELATIONS AGAINST FIVE (5) SEPARATE FIBROUS GLASS TEST AEROSOLS

Test Aerosol Designation	No. of Tests	Impactor Characterization			Recommended Sampling Flow to Approximate ACGIH Cut-off - 10 mm Nylon Cyclone l/min
		mmad (μ m)	Geometric Standard Deviation (σ_g)	% "Respirable" ACGIH Curve	
O/C Type E, AA-12	12	3.9	1.8	$\approx$ 43	1.6
O/C AA-10	11	4.0	1.7	$\approx$ 41	1.7
"Swedish Wool" ^a	32	Variable 3.3-5.6	1.5	Variable 54-24	1.5
O/C AAA-10	10	3.1	1.8	$\approx$ 54	1.9
Gelman Type A	21	3.1	1.7	$\approx$ 56	1.8

^a Extreme fluctuations in aerodynamic size and cyclone collection characteristics were observed with "Swedish Wool." See LA-5555-PR for details.

TABLE IV
COMPARISON OF "RESPIRABLE" MASS FRACTION AT RECOMMENDED CYCLONE SAMPLING FLOW
VERSUS CYCLONE SAMPLING AT 1.7 l/min

Test Fibrous Aerosol Designation	ACGIH Respirable Mass Fraction (%)	Recommended Cyclone Sampling Flow Rate l/min	Predicted Respirable Mass Fraction at 1.7 l/min (%)	Relative Difference Respirable Fraction (%)
O/C Type E, AA-12	≈ 43	1.6	≈ 41	-2
O/C AA-10	≈ 41	1.7	≈ 41	0
"Swedish Wool" ^a	Variable 24-54	1.5	--	--
O/C AAA-10	≈ 54	1.9	58	+4
Gelman Type A	≈ 56	1.8	58	+2

^aExtreme fluctuations in aerodynamic size and cyclone collection characteristics were observed with this particular test aerosol. See LA-5555-PR for details.

aerosol at a fixed flow rate of 1.7 l/min. The maximum error associated with sampling four of the five test aerosols (Table IV) at a flow of 1.7 l/min is a 4% overestimate of the ACGIH defined "respirable" mass fraction. This type of general comparison is not possible for the test aerosol produced from "Swedish Wool" because of large variations in apparent aerodynamic size.

The experimental evidence accumulated, to date, suggests that a fixed sampling flow rate of 1.7 l/min for the 10-mm nylon cyclone provides an adequate measure of the "respirable" mass fraction, as defined by impactor characterization, of various fibrous glass aerosols.

An important assumption inherent to these calibrations is that aerodynamic diameter measured by the cascade impactor is the same as aerodynamic diameter defining percent deposited in the lung. This assumption has been shown to be valid for compact particles but not for particles of extreme shape, such as fibers. Another assumption is necessary if these data are to be used for predicting probable inhalation potential. This assumption is that deposition of fibers is predominately a function of aerodynamic diameter as it is for compact particles. Several future studies are planned to investigate the validity of these assumptions.

III. PERMANENT ASBESTOS MOUNTS

Long-term stability testing of acetone vapor

mounted asbestos samples was continued. These tests are designed to evaluate the optical stability of permanent mount samples under extreme temperature and humidity conditions. Results to date indicate that the optical quality of these samples stored at high (30° to 40°C) or low (0° to 4°C) temperatures has not been affected after eight (8) months. As reported previously, two sample mounts stored at high humidities (>95% R.H.) were destroyed within one month. Table V summarizes the average fiber count data obtained on these samples by four (4) individual counters each counting the same sample for the eight-month test period. Coefficients of variation are well within expected limits. These samples will continue to be stored at the designated environmental extremes for two additional months at which time they will be recounted and stability testing terminated, since this will complete the 12-month test period.

IV. STANDARD COAL AEROSOL TEST SYSTEM (SCATS)

The Standard Coal Aerosol Test System (SCATS) described in a previous progress report⁵ was transferred to NIOSH, Cincinnati, in January. Prior to shipping, the system was modified to reduce variations in aerosol concentration and velocity over the cross-section of the chamber. Installation of a perforated plate in the lower chamber reduced concentration variation to less than ± 8% and velocity variation to less than ± 12%. A LASL technician traveled

TABLE V
ASBESTOS COUNT DATA - PERMANENT MOUNT STABILITY TEST
AVERAGE COUNTS OBTAINED BY FOUR COUNTERS EACH COUNTING THE SAME SAMPLE WEDGE

Month ^c	Sample ^a and Fibers/mm ² Filter Area					
	92-1	92-2	92-5	92-6	92-7	92-8
September	2017	914	2819	1155	2638	1000
October ^b	1621	839	2759	1092	2540	851
November	2173	914	2957	1138	2776	940
December	1724	906	2940	1035	3017	974
January	2052	879	3319	1052	3052	948
February ^b	2172	862	3035	966	2920	989
March ^b	2207	736	3034	1069	2908	862
April ^b	2482	782	2632	1081	3149	1023
Mean:	2056	854	2937	1074	2875	948
Standard Deviation:	276	65	208	59	210	63
Coefficient of Variation (%):	13	8	7	6	7	7

^a Sample 92-1 and 92-2 - Stored at elevated temperature (30°C to 45°C); 92-5 and 92-6 - Stored at low temperature (0°C to 4°C); 92-7 and 92-8 - Stored at room temperature (18°C to 23°C).

^b Count data obtained in October, February, March, and April are the average of 3 counters.

^c Test period from September, 1973, to April, 1974.

to NIOSH, Cincinnati, to reassemble and check the operation of the reassembled unit. Transfer of this unit to NIOSH completes the present LASL commitment for development and construction of aerosol test systems for personal samplers.

V. CYCLONE SAMPLING OF COAL DUST

The effect of operation time on the estimate of respirable mass using the 10-mm nylon cyclone is currently being studied. Initial results of this study indicated that cyclones operated continuously for 12 hours measured about 9% less "respirable" mass than the average measured by a series of short (45-min) cyclone samples taken throughout the 12-hour period. Similar results were obtained for samplers operating at flow rates of either 1.7 and 2.0 l/min. To determine the cause of this penetration decrease, additional experiments have been conducted at a sampling rate of 2 l/min. The "respirable" mass or mass penetrating the cyclone was collected on Gelman VM-1 and MSA FWS-B, 37-mm membrane filters. Tests were conducted with the LASL Standard Instrument Calibration Unit (SIC).⁶ Aerosols utilized for

this study were generated from three different standard dusts (SC-5, SC-6, and SC-7). This dust is prepared by a controlled process of grinding and blending to obtain an aerosol having a mass median aerodynamic diameter (mmad) ~3.7 µm and a geometric standard deviation (σ_g) ~2.0. For this size distribution, the "respirable" mass will be ~46%. To provide realistic sampling conditions, SIC chamber concentration was maintained at 4.0 to 4.5 mg/m³ providing a "respirable" mass concentration of ~2.0 mg/m³. In each experiment, four cyclones were operated for 6, 7, 12, or 14 hours; concurrently, two cyclones were operated for 45-min sampling periods three to six times during the course of the experiment. In addition, three membrane filters collected total dust samples. These included two small filters operated simultaneously with the 45-min cyclone samples and one large filter (81-mm-diameter) that sampled continuously throughout the experiment. The final two columns of Table VI show the difference between short-term (3/4-hour) penetration and long-term (seven or more hours) penetration on a percentage basis referred to the short-term penetration, i.e., (%P s.t.-%P l.t.)/%P s.t.

TABLE VI

LOADING EFFECT ON CYCLONE PERFORMANCE

No.	Sampling Time		Coal Dust	Filter	Penetration %		% Decrease in Penetration	
	Second	(Hour)			Range	Average	Each Filter	Average
1	2,700	(3/4)	SC-5	VM-1	33.4-46.1	38.5	--	--
2	21,600	(7)	SC-5	VM-1	32.4-38.0	36.1	6.2	6.2
3	2,700	(3/4)	SC-7	VM-1	41.8-45.3	43.5	--	--
4	25,200	(7)	SC-7	VM-1	38.5-44.2	42.0	3.4	--
5	50,400	(7+7)	SC-7	VM-1	37.2-43.7	39.3	8.3	5.8
6	2,700	(3/4)	SC-6	VM-1	34.6-41.6	37.7	--	--
7	25,200	(7)	SC-6	VM-1	33.6-36.5	35.4	6.1	6.1
8	2,700	(3/4)	SC-6	FWS-B	30.5-42.0	--	--	--
9	25,200	(7)	SC-6	FWS-B	34.8-41.0	36.8	-0.8	-0.8
10	2,700	(3/4)	SC-7	FWS-B	36.6-46.1	41.4	--	--
11	25,200	(7)	SC-7	FWS-B	36.8-46.7	40.5	2.2	--
12	50,400	(7+7)	SC-7	FWS-B	37.5-41.3	39.4	4.8	3.5
13	2,700	(3/4)	SC-7	VM-1	46.5-54.6	50.4	--	--
14	43,200	(12)	SC-7	VM-1	40.3-40.5	40.4	19.8	19.8
15	2,700	(3/4)	SC-7	FWS-B	40.5-45.3	44.5	--	--
16	2,700	(12)	SC-7	FWS-B	39.8-42.5	41.2	7.4	7.4

The results of these tests shown in Table VI indicate that: 1) for routine sampling conditions the quantity of material collected in the cyclone body has an insignificant effect on cyclone performance, and 2) these sampling conditions may have greater effects on the collection characteristics or flow rate of the second-stage membrane filter. The sampling times of seven + seven hours indicate experiments in which the second-stage filter was replaced halfway through the run, but the cyclone body was not cleaned. These split runs for both filters indicate slightly more deviation during the last half of the sampling period. For the FWS-B second-stage filter, this decrease in "respirable" mass is ~3.5% (Table VI, Nos. 11 & 12) and for the VM-1 filter ~6% (Table VI, Nos. 4 & 5). Assuming that these decreases are the result of changes in the performance of the cyclone, then loading effects cause a less than 5% decrease in "respirable" mass estimate for 14-hour runs at air concentrations of ~4 mg/m³. This effect is insignificant for normal sampling conditions and also insignificant relative to the errors inherent to field sampling with personal samplers. The errors encountered for long

sampling periods with the same second-stage filter can be much larger and these errors are quite variable depending on the type of filter used. These results indicate a higher loading effect on one type of second-stage filter. The same results would be noted if the loading effect caused either a decrease in flow or a decrease in collection efficiency. Examination of the filters by optical microscope indicated a variation in the structure of the filters. The VM-1 filter has a uniform pore structure throughout; whereas the FWS-B has large pore sizes (~50 μ m) on the upstream face decreasing to small pore size (~5 μ m) on the downstream face. The filters also showed markedly different collection characteristics. The VM-1 filter collected most of the coal on the upstream face and this face was black after sampling. The FWS-B filter collected a large fraction of the dust near the rear face, which resulted in a gray upstream face and a darker downstream face.

These data indicate that use of the personal samplers for periods of up to seven hours should not produce a significant error in the estimate of respirable dust concentration with either of the second-stage filters tested. However, for long

periods of sampling or for sampling high concentrations, loading of the second-stage filter can result in underestimates of the "respirable" mass. From a practical standpoint, the magnitude of this error for usual sampling conditions is less than the magnitude of errors inherent to field sampling.

VI. STANDARD COAL DUST

The inventory of standard coal dust has been increased to 1.350 kg. The size distribution parameters of the new dust are $m_{\text{mad}} = 3.6 \pm 0.26 \mu\text{m}$ and $\sigma_g = 2.0 \pm .13$. This is within the limits previously defined for the standard dust. Standard coal dust has been shipped to NIOSH, Cincinnati, (250 g) and to Eastern Associated Coal (75 g) for general experimental purposes. The present inventory is expected to satisfy NIOSH requirements until a supply is available from a commercial source.

VII. ELECTRIC CHARGE OF COAL DUST AEROSOL AND EFFECTS ON SAMPLER PERFORMANCE

The effect of electric charge on the estimate of "respirable" mass by the nylon cyclone personal sampler is currently being studied. In the initial phase of this study, the effect of charge on the size characteristics of the test aerosol were measured. These measurements were made at low humidity using the Standard Instrument Calibration (SIC) chamber. A total of six experiments were conducted with a dummy charge neutralizer alternated with a tritium-filled holder to produce charged or neutralized coal dust clouds. The size distribution of the coal dust clouds was measured with an Andersen cascade impactor to determine if selective losses from the charged cloud would cause significant changes in the size distribution. The results of the study shown in Table VII indicate that the charged aerosol is not significantly smaller than the neutralized aerosol. Thus, charge effects can be measured without the complication of comparing aerosols of different size distributions.

Several systems have been utilized to quantify the aerosol particle charge generated in the SIC chamber by the Wright dust feed. In addition to the SIC, the systems have included a humidifier to precondition the supply air, and several particle charge collection devices. The experimental arrangement used for aerosol charge measurements is shown in Figure 3.

TABLE VII
EFFECT OF CHARGE UPON COAL
AEROSOL SIZE DISTRIBUTION

Run	Dust	Condition	Size Parameters ^a	
			m_{mad} (μm)	σ_g
140	SC-7	Charged	3.5	2.0
140-1	SC-7	Charged	3.5	2.0
140-2	SC-7	Charged	3.4	1.9
145	SC-7	Charged	3.9	2.0
145-1	SC-7	Charged	3.5	1.9
147-1	SC-7	Charged	3.2	2.2
147-2	SC-7	Charged	3.6	2.1
147-3	SC-7	Charged	3.3	1.8
147-4	SC-7	Charged	3.9	2.0
147-5	SC-7	Charged	3.5	2.0
147-6	SC-7	Charged	3.3	1.8
Average	SC-7	Charged	$3.5 \pm .23$ (6.6%) ^b	$2.0 \pm .12$ (6%)
F-136-1	SC-7	Neutralized	3.7	2.1
F-137-1	SC-7	Neutralized	4.0	2.1
F-137-2	SC-7	Neutralized	3.7	1.9
F-137-3	SC-7	Neutralized	3.4	1.9
F-141-1	SC-7	Neutralized	4.0	2.3
F-141-2	SC-7	Neutralized	4.0	2.2
F-141-3	SC-7	Neutralized	3.7	1.9
F-144-1	SC-7	Neutralized	3.6	2.0
F-144-2	SC-7	Neutralized	3.3	2.0
F-144-3	SC-7	Neutralized	3.7	2.0
F-144-4	SC-7	Neutralized	3.4	2.0
Average	SC-7	Neutralized	$3.7 \pm .25$ (6.8%)	$2.0 \pm .13$ (6.5%)

^a Size parameters defined by Andersen Impactor

^b Numbers in parentheses are coefficients of variation.

Initial charge measurements were made with a Wesix ion collector which consists of seven parallel plates with alternate plates collected to opposite electrical potentials. Current flow between the plates is measured to determine total charge on the aerosol. This arrangement was used to gather preliminary data on air flow, necessary collection potential and collection efficiency. During these tests, leaks were discovered in the ion collector. To eliminate these leaks, the entire ion collector

was enclosed in a leak-tight container. The large outer surface of the container made the measurement system sensitive to induced capacitance and image charge, resulting in poor electrical signal to noise ratios. A concentric charge collector having a smaller surface was then constructed. This collector consisted of a 2.54-cm by 25-cm-long copper tube outer grounded collector, with a 1-cm-diameter center rod serving as the charged electrode. This collector, operated in a vertical orientation with an upward, 2-l/min aerosol flow, significantly decreased electrical noise. However, a lower flow rate (~2 l/min) and a higher potential (~750 volts/cm) was required to provide satisfactory collection of the coal dust.

Current through the ion collector was measured with a Keithly vibrating capacitor electrometer. This instrument measures currents as low as 10^{-15} ampere. The measurement of currents in this range requires careful exclusion of spurious voltages and capacitance effects. The input resistance of the pickup head for the electrometer could be as high as 10^{16} ohms for very low measurements. However, for most cases, 10^{10} to 10^{12} ohms are sufficient. All possible leakage paths must have significantly higher resistances to insure an accurate measurement of particle charge. This required short, well-insulated conductors and clean Teflon insulators between the collector electrodes. Careful attention to these points, and use of the concentric collector, provided signal-to-noise ratios of >100 for most measurements.

The humidity in the chamber was initially regulated by bubbling a portion of the dilution air through water heated to ~90°C. This air was then mixed with dry dilution air to obtain the desired relative humidity. For high humidities (>40%), the current measured with neutralized aerosol was higher than for dry, unneutralized aerosol. These results suggested the generation of charged water droplets by the bubbling air. To eliminate these possible droplets, air was passed through loosely packed, water-saturated wood chips for humidification and then passed through a membrane filter before dilution of the aerosol. In spite of these modifications, higher currents were noted with air of high relative humidities (Table VIII, Runs 26-30). Higher background currents were also noted with clean,

moist air and no potential across the ion collector. Possible causes of higher background currents include increased conductivity of the humid air and/or higher conductivity of resistance paths between electrodes. An attempt will be made to eliminate these effects or to quantitate the effects so inherent backgrounds can be subtracted from the aerosol charge measurements.

The SIC system was operated at normal conditions (30 l/min through WDF, 90 l/min dilution air, concentration ~4 mg/m³). A 200-millicurie tritium charge neutralizer was alternated with a dummy neutralizer to study charge effects. Charge was measured by passing 10 l/min of coal dust through the parallel plate ion collector (shown in Figure 3) or 2 l/min through the concentric ion collector. A preweighed 47-mm membrane filter located downstream of the ion collector served to determine the amount of coal dust penetrating the ion collector. The penetrating mass was subtracted from the chamber concentration to determine the collected mass or mass contributing the measured charge. For the coal aerosol generated from standard coal dust SC-7, the average charge was found to be 7.9×10^{-6} C/g. This data was utilized with the size distribution of the aerosol and the collected mass data to calculate an average charge per particle. This charge was $180e^-$ per particle. In agreement with other studies made on coal aerosols generated from metal generators, this charge was negative. The results of charge measurements made on aerosols of various histories are given in Table VIII. The history of the aerosol is defined in the comments column. The total dust designates aerosols taken directly from the chamber, cyclone designates measurements made on the aerosol penetrating a 10-mm nylon cyclone operated at 2 l/min, neutralized designates an aerosol that passed through the tritium charge neutralizer, and unneutralized designates an aerosol that passed through the dummy neutralizer. The charge measured on the neutralized aerosols taken directly from the chamber and after passing through the cyclone indicate that the 200-millicurie neutralizer is effectively removing the charge under these conditions. The slight difference in charge of the unneutralized aerosol after passing through the cyclone suggests that selective collection of the charged particles by the cyclone is minimal. Any error arising from neglecting this effect will

TABLE VIII
COAL DUST AEROSOL ELECTRIC CHARGE MEASUREMENTS

Run No.	Concentration (ug/l)	Total Charge (Coulombs)	Total Mass (mg)	Average Charge Per Particle	Relative Humidity	Comments
19	4.2	1.5×10^{-8}	1.9	180	--	Total dust, unneutralized
20	3.7	1.6×10^{-10}	1.6	2.2	--	Total dust, neutralized
21	2.1	a	--	0	12	Cyclone, neutralized
22	2.0	2.0×10^{-8}	1.5	100	20	Cyclone, unneutralized
23	1.6	1.6×10^{-10}	0.9	1.3	15	Cyclone, neutralized
24	1.7	2.5×10^{-8}	1.3	150	15	Cyclone, unneutralized
26	4.3	2.4×10^{-8}	2.6	210	63	Total dust, unneutralized
27	4.9	--	--	220	53	Total dust, unneutralized
28	5.0	--	--	250	78	Total dust, unneutralized
30	2.1	a	--	2100	89	Total dust, unneutralized

^a Signal to noise ratio ≈ 1 , charge measurement not reliable.

be smaller than errors inherent to personal sampling in the field. Additional studies are being conducted to quantitate the effect of charge on cyclone performance.

VIII. FUTURE WORK

Calibration of the 10-mm nylon cyclone for sampling fibrous glass dusts will be completed by the end of October. A topical report on the fibrous glass results will be written including a description of the fibrous glass aerosol generator.

Fiber size of the aerosol upstream and downstream of the 10-mm nylon cyclone will be obtained for one aerosol. The cyclone will be operated at the average flow rate determined by the calibration of the cyclone using a cascade impactor to characterize the fibrous aerosol. This study will conclude evaluation of the 10-mm nylon cyclone for fibrous glass aerosols.

The stability of the permanent asbestos mounts will be completed during the next reporting period.

The effect of aerosol charge on the estimate of

respirable coal dust determined by the 10-mm nylon cyclone will be completed during the next reporting period.

An evaluation of particulate collection efficiency of charcoal vapor sampling tubes will be initiated during the next reporting period. This evaluation will be carried out with respect to particle size and flow rate through the tube.

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Fig. 1. Cyclone penetration vs sampling flow rate.

Fig. 2. Cyclone penetration vs sampling flow rate.