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July 1 through December 31, 1973

Work performed by

Aerosol Studies Section
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**AEROSOL RESEARCH AND DEVELOPMENT RELATED TO HEALTH HAZARD ANALYSIS
JULY 1, 1973, THROUGH DECEMBER 31, 1973**

by

Harry J. Ettinger, Project Manager
Charles I. Fairchild and Lawrence W. Ortiz

ABSTRACT

A new fibrous glass aerosol produced from a hearing protection product (Swedish Wool) has been used to provide additional calibration data for the 10-mm nylon cyclone. These fibrous aerosols, characterized by the Andersen impactor, ranged from 1.3 to 5.9 μm in mass median aerodynamic diameter. Experimental data indicate best agreement with the ACGIH respirable dust curve at a sampling flow rate of 1.5 l/m, consistent with previous experimental data obtained using other fibrous test aerosols. Long-term evaluation of the permanent mounting technique for asbestos samples indicates the stability of these mounts during storage under various temperature extremes.

Additional calibration data for the 10-mm nylon cyclone using polydisperse coal dusts indicate the variation in cyclone performance at flow rates of 1.7 and 2.0 l/m, and reconfirm that the better approximation to the ACGIH respirable dust curve is at 1.7 l/m. Loading tests show that long-term operation (12 hours) of the cyclone results in a 10% decrease in penetration, which re-emphasizes the importance of daily cleaning of the cyclone after use.

Construction of the Standard Coal Aerosol Test System was completed and the unit shipped to NIOSH, Cincinnati. The unit will produce a controlled, uniform dust cloud with mass concentrations up to 10 mg/m³, relative humidities ranging from 10 to 90%, with a flow rate of 100 cfm. Variations in mass concentration and airflow over 80% of the chamber sampling area range from ± 5 to $\pm 12\%$, an improvement over the original design specifications for this system.

1. SUMMARY

A new fibrous glass aerosol produced from a hearing protection product (Swedish Wool) has been used to provide additional calibration data for the 10-mm nylon cyclone. Electron microscope (EM) sizing data indicate that this test aerosol is

composed of fibers with individual diameters ranging from ≈ 0.6 to ≈ 4.0 μm . Corresponding fiber lengths are multiple and the majority of individual fibers are too long for sizing by EM. Mass median aerodynamic diameters (mmad's) observed with the aerosol produced from this material and

characterized by the Andersen impactor, ranged from 3.3 to 5.9 μm over a four-month testing period. Because of this variation, cyclone calibration data were normalized by averaging aerodynamic size measured before and after each calibration run. These tests show agreement between experimental data and the ACGIH respirable dust curve at a cyclone sampling flow rate of approximately 1.5 liters/min. Experimental data obtained using this aerosol exhibit more scatter than that measured using the previous test aerosol, however, a correlation coefficient of 0.74 and agreement with previously suggested sampling flow rates of 1.4 to 1.7 liters/min again suggests that this approach can be used for the size selective sampling of fibrous glass aerosols.

A modification of the Millipore MF filter to EM grid transfer technique has been developed to permit electron microprobe analysis of collected aerosols. This modification allows preparation of EM extraction replicas having a single carbon substrate to support the collected aerosol. Test transfers with this technique indicate particulate losses <10%, consistent with those previously noted.

A seven-month evaluation of the permanent mounting technique for asbestos samples indicates the stability and advantages of using this procedure for fiber counting. A follow-up four-month evaluation of the permanent asbestos mounts indicates that storage of these samples at high or low temperatures does not affect the mount, while storage at high humidity destroys the mount within one month. This work is continuing. Recommendations regarding development of resolution standards using permanent mount samples were prepared.

Micronized coal dusts with mmad's of 2.8, 3.3, 3.7, 4.5 and 5.2 μm were used to calibrate 10-mm nylon cyclones at flow rates of 1.7 and 2.0 l/m. Both flow rates produced calibration curves in good agreement with previous calibrations and

reconfirmed 1.7-l/m flow rate as the best approximation to the ACGIH respirable dust curve. Loading tests using the standard coal dust at a concentration of 4.5 $\mu\text{g/l}$ showed a 10% decrease in cyclone penetration for 12-hour runs as compared to 45-minute sampling periods. These results also re-emphasize the importance of daily cleaning of the cyclone after use. Evaluation of the 5- μm membrane filter typically used for coal mine sampling showed insignificant filter penetrations against a coal dust with size characteristics similar to those found during mining operations.

Construction and performance tests of the Standard Coal Aerosol Test System (SCATS) were completed and the unit shipped to NIOSH. Pressure drop across the prefilter originally used was excessive but replacement with a cotton filter eliminated this problem. Flow velocity and mass concentration profiles in the sampling chamber satisfy initial specifications ($\pm 15\%$ variations in mass concentration and airflow over 80% of the chamber sampling area, 100-cfm flow rate) after a) insertion of a curved deflector within the opening and b) installation of a perforated disk in the lower level of the chamber. The unit will produce a controlled uniform dust cloud with mass concentrations up to 10 mg/m^3 , and relative humidities ranging from 10 to 90%.

II. FIBROUS AEROSOLS STUDIES

A. Aerosol Generation

Experiments designed to evaluate performance of the 10-mm nylon cyclone with various discrete size distributions of fibrous glass aerosols were continued. Currently under test is a fibrous aerosol produced from a commercial hearing protection product (Swedish Wool) which is composed of glass microfibers ranging from 0.6 to 4.0 μm in individual fiber diameter. Sizing data obtained by electron microscopy (EM) indicate that 84% of this material is composed of fibers smaller than 2.0 micrometers in diameter. Figure 1 illustrates

the fiber diameter number distribution for the gross test aerosol obtained as the result of 477 individual EM measurements. Corresponding fiber lengths are multiple, with the large majority of individual fibers too long for sizing by EM.

Feed material for the test aerosol is prepared by subjecting the bulk glass to high-speed blenderization as a thin-water slurry in order to reduce fiber length. The blenderized material is packed into a compact fibrous plug and the test aerosol is generated via our modified Timbrell generator previously described.

Major difficulties encountered in generating and characterizing this new test aerosol include significant variations in aerosol mass output as well as aerodynamic size. Thirty-two (32) Andersen impactor samples and more than 30 concurrent sets (3 cyclones per set) of cyclone samples taken over a four-month test period indicate that the aerosol generated varies in mass median aerodynamic diameter (mmad) from 3.3 to 5.9 μm . Table I summarizes individual mmad's and geometric standard deviations (σ_g 's) obtained on separate Andersen impactor runs during this time period. These data show an average mmad of $4.5 \pm 0.7 \mu\text{m}$ with an average σ_g of 1.5 ± 0.1 .

Attempts to reduce the problem of varying aerosol mmad from run to run have to date been unsuccessful. Several variables in the generation collection schemes were evaluated in attempts to eliminate this problem. Some of the variables examined included changing the rate at which the feed plug advances into the rotor blades; more frequent sharpening and changing rotor blades; frequent system cleanout; incorporation of new feed plugs pressed at different densities; re-calibration of all air-flow systems; additional tritide neutralizer foil placed at generator air inlet; and varying the duration of sampling runs from 5 to 60 minutes. Alteration of these variables produced only minor changes in

the resultant test aerosol and none of these alterations eliminated the problem of a variation in mmad noted in Table I. This problem of a variable and aerodynamically inconsistent test aerosol was not observed with the previous test glass (Owens/Corning, Type E glass, mmad = 3.9 μm ; σ_g 1.8).

A possible explanation for the observed variability in test aerosol size may be the pronounced accumulations of electrostatic charge on the test aerosol during generation. The phenomena of electrostatic charging is visibly more pronounced with Swedish Wool than with the previous glass (Owens/Corning Type E). During aerosol generation large quantities of loose, electrostatically bound fibers and fiber bundles progressively accumulate within the generator chamber. These loose dendritic mats of charged fibrous accumulations located within the generator outlet tube appear to function as an inefficient air cleaner that changes the relative size of the test aerosol generated. Tests are being conducted to better evaluate this troublesome variable. A high-voltage electrostatic de-ionization source has been installed at the generator inlet and should help reduce these charge-induced fibrous accumulations within the generator chamber.

Construction of a new fibrous aerosol generator designed to provide a more constant aerosol output has been completed. This unit, still a basic modification of the Timbrell device, has features to provide better control of fibrous plug packing, feeding and generation mechanisms. A rectangular feed plug and abrasion resistant rotor blades with a high velocity-low total flow air inlet system are modifications designed to provide the gentle turbulence necessary within the generator chamber to produce a more consistent aerosol. Evaluation of this unit will be conducted during the next reporting period.

TABLE I

SIZE CHARACTERIZATION OF SWEDISH WOOL FIBROUS GLASS AEROSOL*

<u>Date</u>	<u>Run</u>	<u>mmad</u> <u>(μm)</u>	<u>(σ_g)</u>
7 September '73	2	5.6	1.6
10 "	5	4.9	1.8
11 "	7	5.9	1.5
14 "	11	5.4	1.4
18 "	13	5.6	1.3
21 "	16	4.7	1.6
10 October '73	30	5.1	1.4
17 "	37	4.3	1.4
18 "	39	4.1	1.5
23 "	42	4.4	1.4
29 "	48	4.3	1.6
31 "	51	4.0	1.6
5 November '73	56	4.4	1.6
14 "	61	5.3	1.5
15 "	63	4.7	1.5
20 "	67	3.5	1.6
21 "	69	3.3	1.6
26 "	72	3.6	1.4
27 "	74	3.7	1.8
6 December '73	80	4.7	1.5
6 "	83	4.3	1.5
6 "	86	4.0	1.5
7 "	89	3.6	1.6
10 "	91	4.4	1.5
10 "	93	4.3	1.5
11 "	96	3.7	1.8
11 "	98	3.6	1.8
14 "	101	4.8	1.6
17 "	104	4.8	1.5
17 "	107	4.3	1.6
18 "	110	4.9	1.4
19 "	112	5.1	1.5
Average		4.5	1.5
Standard Deviation		± 0.7	± 0.1

* Aerodynamic characterization by Andersen impactor.

B. Cyclone Calibration

Calibration tests were conducted with the 10-mm nylon cyclone against this fibrous aerosol produced from Swedish Wool. The cyclones were tested by sampling at various incremental flow rates ranging from 0.8 to 2.4 l/m. Cyclone penetration data obtained at a given flow rate were normalized to the predicted penetration based on the average aerodynamic size measured immediately before and after each calibration run.

Figure 2 summarizes these data presented as a ratio of experimental cyclone penetration to theoretical penetration (P_{ex}/P_{th}), plotted against cyclone sampling flow rate. Theoretical penetration values were calculated as previously mentioned by taking the average mmad and corresponding σ_g of two Andersen impactor samples taken in immediate sequence prior and following each pair of cyclone sample sets. These average mmad and σ_g values were then related to the ACGIH respirable dust curve and the corresponding respirable mass fraction (theoretical penetration) obtained.¹ Experimental cyclone penetration values were obtained in the conventional manner of measuring the mass fraction penetrating a test cyclone as compared to the challenge aerosol mass. Ideally the correct sampling flow for the test cyclones with the data normalized in this fashion is at $P_{ex}/P_{th} = 1.0$. Examination of Figure 2 shows the general trend in cyclone collection efficiency with this particular test aerosol at flows between 1.2 and 2.1 l/m. Assuming a linear fit and using least-squares regression analysis a cyclone sampling flow rate of approximately 1.5 l/m best approximates the correlation between experimental data and theory. Although these data have more scatter than that measured using the previous test aerosol, the correlation coefficient of 0.74 and the agreement with the previously suggested flow rates² of 1.4 to 1.7 l/m suggests that this approach may be used for the size selective sampling of fibrous aerosols.

III. MICROSCOPY

A. Electron Microscopy Techniques (Jointly Supported By NIOSH and AEC, Division of Biomedical and Environmental Research)

A modification of the Millipore filter to electron microscope (EM) grid transfer technique previously reported has been developed to accommodate electron microprobe analysis of collected aerosols. The significant modification to the previously reported technique is the omission of chromium metal as one of the replicating films from the final EM preparation. Since this reduces the mechanical strength of the final EM replicate film, a more gentle "wash" or filter dissolution step is required to keep this single carbon replicating film intact. This is accomplished by placing a piece of filter paper (Whatman 41) on top of the porous acetone soaked polyurethane support sponge during the critical filter dissolution step. Details of the modified transfer procedure remain the same as previously reported² and include the following. A piece of the collection membrane is taped, dust side up, to a microscope slide and the porous surface fused in an atmosphere of acetone vapor. This fused filter is placed in a vacuum evaporator and the particle collecting side of the filter coated with carbon by conventional EM evaporation procedure. This evaporated carbon film adheres directly to the fused membrane surface as well as the particulates of concern. Using a petri dish as a reservoir, a piece of filter paper (Whatman 41) is placed on top of a polyurethane sponge which is 90% immersed in acetone. Several blank EM grids are placed on the acetone-soaked filter paper support and small squares of the carbon-coated and fused filter are cut and placed collection side up on these EM grids. The filter matrix is thus gently dissolved away leaving the particles of interest adhering to the insoluble carbon film. The final EM preparation consists of a single carbon film adhering to the collected

aerosol supported by an EM grid. This type of preparation is ideally suited for electron microprobe analysis as no interfering metallic elements are introduced as part of the preparation. Optionally, an additional coat of carbon may be applied to the underside of the sample grid to increase the mechanical strength of the supporting carbon film and/or produce a lightly shadowed replica. The overall transfer procedure is simple and rapid, and particle losses are < 10%. Sample electron micrographs obtained by this modified technique are included as Figures 3-6.

B. Permanent Asbestos Mounts

Two asbestos samples previously mounted by the acetone vapor clearing (permanent mount) technique² have been tested for optical stability over a 7-month period by periodic counting at monthly intervals. Table II summarizes the results of this study showing no deterioration in the "countability" of these samples.

TABLE II

PERMANENT MOUNT
ASBESTOS FIBER COUNT DATA

Month	Count / Field		Count / mm ²	
	A	B	A	B
Feb	13.4	11.7	4621	4034
Mar	12.7	13.1	4379	4517
Apr	14.5	15.6	5000	5379
May	11.0	11.9	3793	4103
Jun	12.3	12.3	4241	4241
July	12.7	12.3	4379	4241
Aug	11.4	12.5	3931	4310
Average:	12.6	12.8	4335	4404
σ :	1.2	1.3	407	457
Coef var (%) =	9.5	10.2	9.4	10.4

Two different samples (A & B) repetitively counted by a single individual.

Stability testing was terminated when the mounting cover slip started to separate from the filter wedge. Experience developed since these mounts were originally made should permit preparation of mounts which will not deteriorate over even longer time periods.

A follow-up test program initiated to evaluate the long-term stability of asbestos samples mounted this way under extreme temperature and humidity conditions is in progress. Results to date indicate that sample mounts stored at high humidities (>95% RH) were destroyed within one month, but samples stored at high (30° to 45°C) or low (0° to 4°C) temperatures have not been affected after four months of testing. Table III summarizes the average fiber count data obtained on these test wedges by four individual counters for the test period to date. Coefficients of variation are well within limits expected due to typical counting errors. This study is continuing to verify the long-term effects on samples under these environmental extremes.

Development of resolution standards for asbestos counting was also evaluated. We have recommended the use of permanently mounted asbestos samples (acetone vapor clearing technique) in a Proficiency Analytical Testing type program. The practicality of using polystyrene latex, diatoms, or a special optical grating was also evaluated, with the recommendation that of the three, the use of diatoms seems most practical, but may not be sufficiently representative of the problems associated with fiber counting.

IV. COAL DUST STUDIES

A. Cyclone Calibration

Micronized polydisperse coal dusts with mmad's determined by multiple Andersen impactor samples, of 2.8, 3.3, 3.7, 4.5 and 5.2 μ m were used to calibrate 10-mm nylon cyclone samplers operated at flow rates of 1.7 and 2.0 l/m. Four personal samplers

TABLE III

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

	<u>Sample Number* and Fibers/mm² Filter Area</u>					
<u>Month</u>	<u>92-1</u>	<u>92-2</u>	<u>92-5</u>	<u>92-6</u>	<u>92-7</u>	<u>92-8</u>
Sept	2017	914	2819	1155	2638	1000
Oct**	1621	839	2759	1092	2540	851
Nov	2173	914	2957	1138	2776	940
Dec	1724	906	2940	1035	3017	974
Mean	1884	893	2869	1105	2743	941
Std Deviation	256	36	96	54	207	65
Coef Var (%)	14	4	3	5	8	7

**Count data obtained in October are the average of 3 counters

* Sample 92-1 and 92-2 - Stored at elevated temperature (30-45° C)

92-5 and 92-6 - Stored at low temperature (0° - 4° C)

92-6 and 92-7 - Stored at room temperature (18-23° C)

were suspended within the Standard Instrument Calibration System (SIC)³ aerosol chamber together with 3 membrane filter total dust samplers and all were controlled at the desired flow rate by critical orifices. Figure 7 shows experimentally determined points (average of 4 samplers) for each test aerosol at the two flow rates and theoretical penetration based on the coal dust size characteristics and the ACGIH respirable dust curve.¹ At both flows cyclone separation characteristics agree with other investigators' results using laboratory aerosols as well as coal dust. A cyclone flow rate of 1.7 l/m produces closer agreement with the ACGIH curve than does 2.0 l/m except below 3- μ m or above 5.2- μ m mmad. Additional data are required to define cyclone operation for these smaller or larger aerosol mmad's.

Experiments to determine the effect of dust loading upon penetration through the 10-mm nylon cyclones are summarized in Table IV. These tests were conducted using the LASL SIC unit with SC-5 standard coal dust (mmad = 3.7 μ m) providing a concentration

of 4.5 μ g/l. In each experiment 4 cyclones were operated for 6 hours or 4 hours; concurrently another 2 cyclones were operated for 45-minute sampling periods two or three times during the 4- or 6-hour experiment. Three membrane filters were used to collect the total dust samples. The 6 + 6 sampling time indicates that the second stage membrane filter was changed but the cyclone body was not cleaned between two 6-hour runs. Calibrated critical orifices controlled airflow through all samplers. Table IV shows that average cyclone penetration decreases by approximately 10% for either flow rate when comparing the 2700-sec (3/4-hr) to the 43 200-sec (12-hr) sampling periods. Since this difference suggests that cyclone collection is affected by extended operation, additional data will be obtained to quantitate this variation. The coal dust aerosol had an mmad of 3.7 μ m, which the ACGIH respirable dust curve predicts will have a cyclone penetration of 46%.

TABLE IV

EFFECT OF LOADING ON 10-mm NYLON CYCLONE PENETRATION

<u>Flow</u> <u>l/m</u>	<u>Sampling Time</u>		<u>Penetration</u>		<u>(Coef. Var.)</u>
	<u>Sec.</u>	<u>(hr.)</u>	<u>%</u>	<u>Avg.</u>	
1.7	2700	(3/4)	49.9		
1.7	2700	(3/4)	36.8		
1.7	2700	(3/4)	45.7		
1.7	2700	(3/4)	39.1		
1.7	2700	(3/4)	45.9		
1.7	2700	(3/4)	42.3		
				43.4 ± 4.8	(11.2%)
1.7	14,400	(4)	46.3		
1.7	14,400	(4)	38.4		
				42.3 ± 5.6	(13.2%)
1.7	21,600	(6)	40.1		
				40.1	
1.7	43,200	(6+6)	38.6		
				38.6	
2.0	2700	(3/4)	35.9		
2.0	2700	(3/4)	34.4		
				35.2 ± 1.0	(3.0%)
2.0	21,600	(6)	33.6		
2.0	21,600	(6)	31.1		
2.0	21,600	(6)	34.2		
				33.0 ± 1.6	(5.0%)
2.0	43,200	(6+6)	28.4		
2.0	43,200	(6+6)	34.1		
2.0	43,200	(6+6)	33.4		
				32.0 ± 3.1	(9.7%)

B. Efficiency of 5- μ m Membrane Filters

Collection efficiency of 37-mm VM-1 and FWS-B filters was evaluated in the SIC unit using coal dust as the challenge aerosol. Average total coal dust concentration determined with membrane filters was 4.3 μ g/l, and two Andersen impactor samples indicated the aerosol mmad to be 3.4 μ m with $\sigma_g = 2.0$. VM-1 and FWS-B filters were used to sample both total and respirable (as defined by a 10-mm nylon cyclone pre-collector operated at 2.0 l/m, the "standard" in-mine sampling) dusts, and were backed by DM-800 (0.8- μ m pore size) filters, the GCA Respirable Dust Monitor or the TSI Particle Mass Monitor. Table V summarizes these data, showing that in the low dust

concentrations downstream of the test filters the TSI PMM functions better than filters which have moisture and charge problems, or the RDM which fails to detect any material passing the 5- μ m filter. The large standard deviations emphasize the poor sensitivity of the measurement techniques for the small mass passing the 5- μ m filter and indicate that no significant difference may be inferred between total and respirable dust penetration. The measured penetrations, 5% or less, are insignificant in actual mining work situations.

Tests were also run with the 5- μ m pore size membrane filters using 0.3- μ m monodisperse DOP test aerosol produced by the Q-127 generator. Since 76-mm-diameter VM-1 filter

TABLE V
EFFICIENCY OF 5- μ m MEMBRANE FILTERS AGAINST COAL DUST*

Dust	Sampling Time		Filter	Mass Collected	Backup	Mass Collected	% Penetration
	Sec	(min)		μ g		μ g	
Total	720	(12)	VM-1	132	DM-800	-11	0
Total	1320	(22)	VM-1	168	RDM	-	0
Total	780	(13)	VM-1	117	PMM	1.4	1.2
Total	720	(12)	VM-1	111	DM-800	-2	0
Total	720	(12)	VM-1	123	DM-800	1	0.8
					Mean		6.4 $\pm$.6
Total	720	(13)	FWS-B	112	DM-800	-5	0
Total	720	(12)	FWS-B	125	DM-800	5	3.8
					Mean		1.9 $\pm$ 2.7
Respirable**	2700	(45)	VM-1	173	DM-800	2	1.1
Respirable	2700	(45)	VM-1	182	DM-800	-1	0
Respirable	2700	(45)	VM-1	158	DM-800	8	4.9
Respirable	780	(13)	VM-1	62	PMM	1.0	1.7
					Mean		1.9 $\pm$ 2.1
Respirable	2700	(45)	FWS-B	343	DM-800	1	0.3
Respirable	2700	(45)	FWS-B	155	DM-800	-8	0
Respirable	960	(16)	FWS-B	91	PMM	1.2	1.3
Respirable	1500	(25)	FWS-B	89	RDM	-	0
					Mean		0.4 $\pm$.6

*Aerosol mmad = 3.4 μ m; σ_g = 2.0

**Respirable dust defined as material passing a 10-mm nylon cyclone operated at 2.0 l/m

media were available these were run at a higher flow rate (approximately 5 l/m) to provide the low filtration velocities consistent with field sampling practice. The FWS-B media tests were limited to 37-mm filters; therefore data could only be obtained at approximately 1 l/m, which introduced instrument instabilities and the potential for significant errors in measuring filter penetration. Thus, only VM-1 data are summarized in Table VI. Since these penetrations are significant (9 to 29%), if there is concern relative to sampling sub-micron dusts with this media, additional data should be obtained.

V. STANDARD COAL AEROSOL TEST SYSTEM (SCATS)

Construction and testing of the Standard Coal Aerosol Test System (SCATS) was completed, and the unit shipped to NIOSH, Cincinnati. An overall view is shown in Figure 8, where the primary components of the unit are identified. The aerosol chamber, recycling system, frame, and most accessories are of IASL fabrication,

TABLE VI

EFFICIENCY OF 5- μ m MEMBRANE FILTERS
AGAINST 0.3- μ m DOP

Media	Velocity m/sec (ft/min)	Penetration (%)
VM-1	0.025 (5)	18
VM-1	0.07 (15)	29
VM-1	0.965 (190)	9

while the dehumidification system is a commercial unit. The unit will produce a controlled, uniform dust cloud at relative humidities less than 10% to greater than 90%, with mass concentrations up to 10 mg/m^3 . It can be operated in a single pass or recirculating mode. Because the unit has 2 Wright dust feeders, a dust cloud of 2 different particulate materials may be generated in any desired proportions. As described in detail below, the SCATS performance satisfies the original specifications of $4.7 \times 10^{-3} \text{ m}^3/\text{sec}$ (100 cfm) aerosol flow, a flat velocity profile within $\pm 15\%$ over 80% of the diameter at the sampling level, and a uniform mass concentration of 2 mg/m^3 within

$\pm 15\%$ in this same region.

Experimentally measured performance characteristics are tabulated in Table VII for two major flow configurations, single pass or recycled, specified in Figure 9. Only valving required to achieve single pass or 100% recycling flow is illustrated, but all the valves are adjustable from open to fully throttled to permit control of airflow and humidity. Not shown is the steam injection system for producing high humidity aerosols since tests were not performed under high humidity conditions. Little effect on system performance is expected from moderately high relative humidities, (excluding effect upon the aerosol properties).

TABLE VII

SCATS PERFORMANCE CHARACTERISTICS

Test Configuration ^a	R.H. %	T °C	Differential Press, Pa	Flow* Velocity cm/sec	Mass** Concentration mg/m ³
1. ***S.P., L.L.	10	23.3	-62.2	14.8 ± 1.9 (13) [†]	$2.6 \pm .2$ (8) [†]
2. ***S.P., M.L.	7	29.4	-62.2	13.9 ± 1.5 (11)	$2.3 \pm .4$ (18)
3. ***S.P., U.L.	7	32.8	-62.2	13.8 ± 1.0 (7)	$2.5 \pm .2$ (8)
4. ***M.P., L.L.	5	33.9	64.7	20.4 ± 5.6 (27)	$2.3 \pm .2$ (10)
5. ***M.P., M.L.	6	32.2	64.7	19.7 ± 3.9 (20)	$2.5 \pm .2$ (6)
6. ***M.P., U.L.	5	35.6	64.7	19.3 ± 2.5 (13)	$2.6 \pm .2$ (8)
7. S.P., L.L., F.C.	8	21.1	-166.7	23.7 ± 2.8 (12)	$1.5 \pm .1$ (8)
8. S.P., M.L., F.C.	8	23.9	-161.7	24.3 ± 1.4 (6)	$1.6 \pm .1$ (6)
9. M.P., M.L., F.C.	5	35.6	-49.8	28.3 ± 2.1 (7)	$1.6 \pm .1$ (8)
10. M.P., M.L., F.C.	5	35.6	-47.3	27.4 ± 1.3 (5)	$1.7 \pm .1$ (7)

* Each number represents the mean of a minimum of 18 readings.

** Each number is the mean of a minimum of 5 samples.

*** Measurements made prior to installation of perforated disk and transparent fairing. These changes are included in the SCATS unit shipped to NIOSH, and the improved performance characteristics are indicated by the remaining tests.

† Numbers in parentheses are coefficients of variation.

^a Test configuration: S.P. - single-pass airflow

M.P. - multi-pass airflow with recycle flow passing through dehumidifier.

L.L. - lower level sampling port cross section.

M.L. - mid-level sampling port cross section; level with large access port.

U.L. - upper level sampling cross section.

F.C. - final chamber configuration.

During recycled dehumidified air operation, the chamber air temperature may be 10 to 12°C above ambient because the exothermic moisture adsorption and high temperature regeneration cycles in the dehumidifier transfers a large quantity of heat to the dehumidified air. Flow velocity measurements were made at nine locations (Figure 10) within the chamber at each sampling level, with a minimum of 2 velocity readings at each location. Since only one probe was available, these measurements were not simultaneous, but one complete set of measurements was made before a second set was started. Velocity profiles were measured in clean air, whereas, of course, mass concentration measurements were made in dusty air. Data listed in the last two columns (Table VII) were obtained in separate runs but are listed in the same row because the SCATS configuration was identical and the operating parameters (temperature, etc.) were similar; the parameters shown were actually measured during the air velocity tests.

Performance measurements (Table VII, runs 1-6), indicated that pressure drop through a paper prefilter, already high, increased rapidly when dust was introduced into the chamber. This prefilter was replaced with a 1-cm-thick, cylindrical, cotton prefilter which reduced the pressure drop and permitted 8-h dust loading without appreciable changes in pressure and flow velocities. Initially, velocity profile measurements also revealed a significant distortion in flow at the large access port. A transparent fairing was placed inside the access opening to smooth the chamber contour in this area, and at the same time a perforated disk was installed in the lower chamber, 23 cm above the Stairmand disk, to further improve the velocity profile.

Air velocity data shown in the first 6 rows (Table VII) were taken when the paper prefilter was in use, while data in the final 4 rows were obtained after the cotton prefilter was installed and the chamber

modifications made. These changes effected considerable improvement in flow uniformity, particularly at the mid-level sampling positions. The magnitude of air velocity in the final, single-pass flow configuration is slightly less than the design velocity, but it should increase approximately 20% because of the greater air density at Cincinnati compared to Los Alamos. Air velocity is greater when the dehumidifier is in use due to the additional blower in the dehumidifier. Figure 10 graphically indicates the variations in velocity over the chamber cross section for one of the conditions detailed in Table VII (run 8).

All mass concentration values in the final column of Table VII were obtained with the cotton prefilter installed, but only the final 4 runs were measured after installation of the access port fairing and perforated disk. Concentrations were measured simultaneously at 5 uniformly spaced sampling points (Figure 11) at each sampling level using membrane filters, a 900-to 1200-sec (15-to 20-min) sampling period, and all sampling probes facing downward into the air stream. One sample, which was taken at the center of the chamber 3600 sec (1 h) before the profile sampling started, showed the same concentration and indicates that the concentration stability is good.

Replicate (4 separate determinations) size distribution measurements made with a 6-stage Andersen impactor operated at $4.7 \times 10^{-4} \text{ m}^3/\text{sec}$ (1 cfm) during the SCATS performance tests indicated that the SC-5 dust parameters were $3.8 \pm 0.1 \text{ }\mu\text{m}$ with a σ_g of 2.3 ± 0.2 . This compares to previous measurements in the smaller SIC unit of $3.7 \pm 0.2 \text{ }\mu\text{m}$ and $\sigma_g = 2.2 \pm 0.2$. The difference between the measurements in the two units is insignificant, suggesting that SCATS produces a dust which is unbiased in distribution.

A LASL document³ describing the Standard Instrument Calibration (SIC) system design, capabilities, and accumulated performance data was released. Co-authors included LASL and NIOSH personnel.

VI. FUTURE WORK

- A. The new fibrous aerosol generator will be evaluated for generation consistency and total aerosol output during long-term, unattended operation.
- B. Additional data will be obtained regarding the aerodynamic performance characteristics of the 10-mm nylon cyclone against fibrous glass dusts.
- C. Long-term stability tests evaluating the effects of temperature on permanent asbestos mounts will continue.
- D. Development of a sampler to include representation of the interception mechanism important in defining the lung deposition of fibrous materials will be initiated.

E. Experiments will be conducted to evaluate electrical charge effect upon the operation of 10-mm nylon cyclones in a coal dust cloud.

VII. REFERENCES

- 1. O.W. Moss and H.J. Ettinger, "Respirable Dust Characteristics of Polydisperse Aerosols," *AIHA J* 31, 546 (1970).
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- 3. C.I. Fairchild, H.J. Ettinger, G.A. Carson, G.J. Gettemy, M.I. Tillery, and G. Almich, "The Standard Instrument Calibration Aerosol Test System," LA-5405-M5, 14 pp. (1973).

Fig. 1. Fiber Number Distribution by Diameter of Blenderized Swedish Wool - Gross Aerosol Sample Taken at 1.7 liter/min.

The intercept and slope of the straight line were estimated by the method of least squares.

Fig. 2 10-mm Nylon Cyclone Calibration with Swedish Wool Aerosol.

Fig. 3. Carbon Extraction Replica of Plutonium Oxide Aerosol Transferred From Millipore MF Filter to EM Grids

Fig. 4. Carbon Extraction Replica of Chrysotile Asbestos Transferred From Millipore MF Filter to EM Grid.

Fig. 5. Carbon Extraction Replica of Flyash Transferred From Millipore MF Filter to EM Grid

Fig. 6. Carbon, Carbon-Shadowed Extraction Replica of Flyash Transferred From Millipore MF Filter to EM Grid.

Fig. 7. Performance of 10-mm Nylon Cyclone Against Coal Dust, And Comparison to Prediction Based on ACGIH Curve.

Fig. 8. Standard Coal Aerosol Test System (SCATS).

Mid-Level cross section

Single-pass, clean airflow; final chamber configuration (run 8, Table VII)

Fig.10. Air velocity profile in SCATS. Number in circle is average velocity in cm/sec; numbers to right are individual measurements.

Mid-Level cross section

Single-pass airflow, final chamber configuration (run 8, Table VII)

Fig.11. Coal dust mass concentration (cm/sec) profile in SCATS. One sample taken at center 3600 sec (1 h) before other 5 simultaneous samples.