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UNDERGROUND EVALUATION OF A FAN/FILTER SYSTEM FOR DUST REDUCTION CAPABILITIES

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ABSTRACT

The HCI family of fans manufactured by Cogema (France) and distributed in Canada by Teledyne are compact units that were primarily designed to reduce fan noise emissions. In order to protect the silencer a dust filter system that is part of the fan has been developed by Cogema. This filter system may also help reduce exposure to airborne dust when used to support secondary ventilation.

A model HCI80/F80 (16 m^3/s, 34,000 cfm) fan was tested for dust filtering efficiency in an underground mine in areas where the bulk of airborne dust consisted of diesel dust particles. Results showed that the fan was 10 to 30% efficient for dust particles ranging between 0.2 and 2.0 μm in size. Respirable dust concentration was reduced by up to 32% in dust clouds having mass-median aerodynamic diameters of 0.31 μm.

Key words: Dust control; Underground mine environments; Dust filtration.

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ÉVALULATION SOUTERRAINE D'UN SYSTÈME DE VENTILATION ET DE FILTRATION POUR RÉDUIRE LES POUSSIÈRES

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RÉSUMÉ

La série HCI, fabriquée par Cogema en France et distribuée au Canada par Teledyne, sont des ventilateurs compacts conçus principalement pour réduire les bruits émis par les ventilateurs. Afin de protéger le silencieux, un système de filtration des poussières, faisant partie intégrante du ventilateur, a été mis au point par Cogema. Ce système peut aussi aider à réduire les poussières en suspension dans l'air lorsqu'il est utilisé comme dispositif d'appoint à la ventilation secondaire.

On a fait l'essai d'un ventilateur de modèle HCI80/F80 (16 m^3/s, 34 000 cfm) afin d'évaluer l'efficacité de filtration dans une mine souterraine, aux endroits où la majeure partie des poussières en l'air sont des particules de poussières du diesel. Selon les résultats, l'efficacité du ventilateur était de 10 à 30 % pour les particules de poussières dont la dimension variait entre 0,2 et 2,0 µm. La concentration de poussières inhalables était réduite d'environ 32 % dans les nuages de poussières ayant un diamètre aérodynamique médian en masse de 0,31 µm.

Mots-clés : contrôle de la poussière, environnements miniers souterrains; filtration de la poussière.

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INTRODUCTION

Several sources of respirable airborne dust are present in underground hard rock mines. Health and safety conscious practice, as well as engineering control, help suppress dust at the source. Other tactics are aimed at reducing exposure to dust that is already airborne. Secondary ventilation and personal protective devices such as respirator masks fall in this category.

Recently, a fan system manufactured by Cogema (France) has been developed. This fan is a compact system incorporating a silencer to reduce noise exposure. In order to protect the sound damping materials of the silencer, a dust filter section has been added to the fan intake section. As well as protecting the fan mechanism and the silencer, it is claimed that the filter also helps reduce airborne dust and radioactive contaminants when the fan is used as a secondary ventilation unit.

This evaluation was conducted in an underground uranium mine. Tests were designed to assess the filter's ability to reduce airborne respirable dust as well as airborne radioactive contaminants. Results of the radiation part of the survey are given elsewhere (1).

THEORY OF FILTRATION

Inertia, interception and diffusion are the main physical processes for removal of dust particles in fibrous filters. These filters generally consist of a thick bed of small fibers supported by a skeleton of larger strands. Fiber diameter is usually small relative to interfiber distance to minimize the pressure drop across the filter.

Fiber filters made of densely packed fine fibers are used at low gas velocities through the filter. In this fashion, submicron particles are removed by diffusional effects. Loose mats of coarser fibers, on the other

hand, are used at high gas velocities to remove large particles. In this instance, inertial effects are dominant. The fan filtering system evaluated here operates along these lines. Under conditions of high gas velocity through coarse fiber beds, the effects of diffusion and interception are negligible compared to inertial effects.

Other factors affecting filtering efficiency are dust particle diameter, filter mat packing density and thickness as well as fiber diameter. As a rule, filtering efficiency is directly proportional to particle diameter, fiber packing density and mat thickness and inversely proportional to fiber diameter.

Once particles come in contact with filter fibers, it is generally assumed that van der Waals forces, surface tension and electrostatic forces are sufficient to hold dust particles trapped within the filter bed. This is generally accepted except for cases where very high gas velocities (>0.35 m/s) through the filter mat are likely to prevent particles with high kinetic energy (particles with diameters larger than 5 μm) from adhering to fibers. Furthermore, these particles may dislodge already trapped dust (2).

COGEMA INSULATED COMPACT HELICOID FAN DESCRIPTION

The fan evaluated in this study is manufactured by Cogema (Limoges, France). This model was originally designed to suppress noise with the use of silencers. It was later found that the efficiency of the sound proofing mechanism decreased markedly as dust accumulated on the sound damping material. In order to remedy this problem, the manufacturer designed a filter cage at the fan intake. This also helped prevent damage or imbalance to revolving mechanical parts of the fan.

These fans may also improve the working environment of mine workers when used as secondary ventilation units. It is reasonable to assume that

respirable dust concentrations will be reduced and the manufacturer also claims that, in some cases, radioactive dust concentrations have been reduced.

The unit tested (Cogema HCI-80 with F80 filter element) is a compact design made up of a fan with an integrated diffuser-silencer unit. The intake to the fan is fitted with a squirrel cage type frame designed to receive the fan-folded filtering element. The HCI-80 Insulated Compact Helicoid fan is shown in Figure 1. This fan operated at an air volume of 16 m^3/s (approximately 34000 cfm).

The manufacturer claims a total filtering surface of 9 m^2 for the HCI-80 model. The filtering material is made of a coarse synthetic fiber material held between a folded metal mesh. This filter comes in four sections that are easily installed or removed. In order to extend the life of the filter, a pre-filter material (Agent AR100) is used in front of the filter and held in place by fan suction.

SITE AND INSTRUMENT DESCRIPTION

Evaluation of the fan was conducted in an underground uranium mine. The unit was used to supply secondary ventilation air as shown in Figure 2. The working site was a sill drift where the air volume was 19.6 m^3/s (41,600 cfm) on average. The fan itself operated at an air volume of 16 m^3/s (33,900 cfm). The air was directed into an inclined production heading (dead end). Mineral dust concentrations in the area were very low and the average respirable silica dust content accounted for less than 5% of the airborne respirable dust mass. The dust cloud consisted mainly of submicron diesel particulate.

Three types of instruments were used to evaluate the Cogema fan. These were 10-mm nylon cyclones for the determination of respirable dust concentration. The cyclones were operated with self-regulated sampling pumps

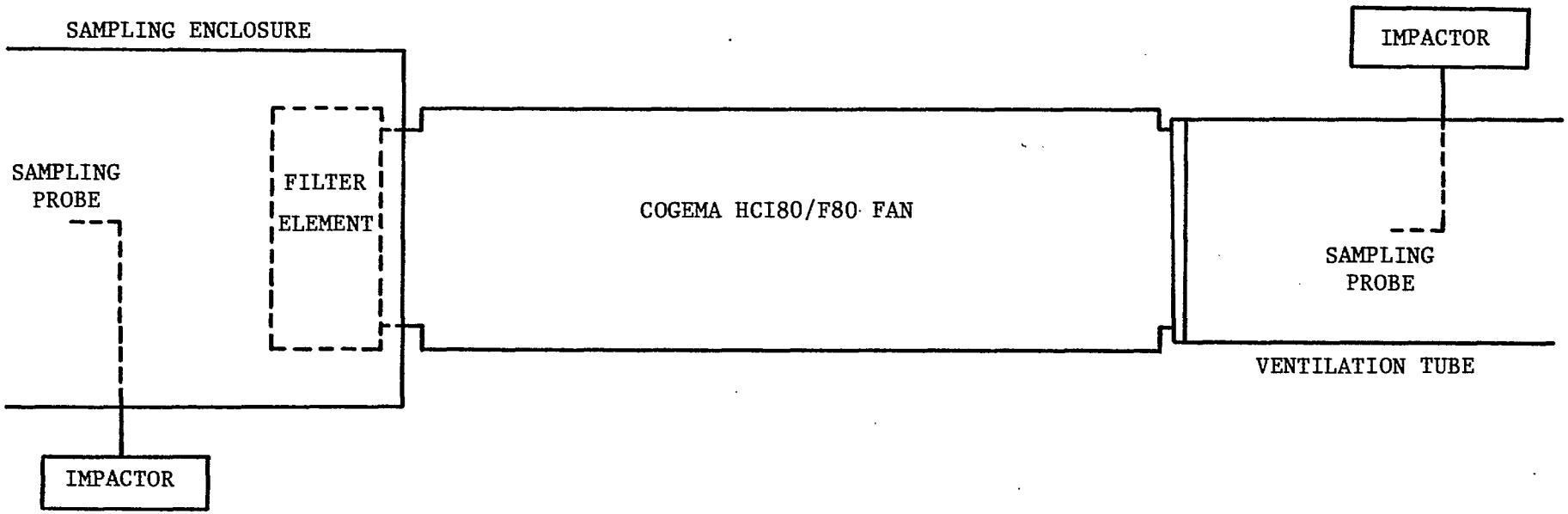

Fig. 1 - Schematic diagram showing the COGEMA fan/filter system and the sampling apparatus used to determine the filter's efficiency as a function of dust particle size.

which were calibrated on-site on a daily basis. Eight-stage cascade impactors (Sierra Instruments Ltd.) operating at a flow rate of 13.4 L/min, helped determine the dust size distribution in various areas as well as the filtration efficiency of the fan as a function of dust particle size. A continuous dust monitor was also used to measure airborne dust concentrations on a continuous basis close to the fan intake.

Four nylon cyclones were located in an area approximately 15 m from the intake to the fan (25 m from the incline). Four more cyclones were placed in the incline to monitor the fan exhaust. Two cyclones were used in the sill drift, down from the incline, as shown in Figure 2.

Two cascade impactors were used to monitor the intake and exhaust areas. During most of the evaluation these were used to determine the airborne dust size distribution at the fan intake (sill drift) and the exhaust area (incline). On two occasions, the impactors were sampling the fan intake and exhaust directly. In this configuration the intake impactor was sampling inside a specially designed enclosure (1.8 m in diameter and 3 m in length). The exhaust impactor was sampling on the ventilation duct (see Figure 1). Sampling in high velocity air streams requires that special sampling probes be designed in order that duct air velocities be matched to air entry velocities in the probes (isokinetic sampling conditions). Two such probes were built taking intake and exhaust air velocity into account.

A total of five tests were conducted. On one of these tests, the fan was operated without the F80 filter element. Four tests were conducted while the fan operated with the filter element. During two of these tests, the special enclosure mentioned above was not used and area sampling was conducted. For the remaining two tests, the enclosure was installed and impactors were used directly on the fan system as previously described.

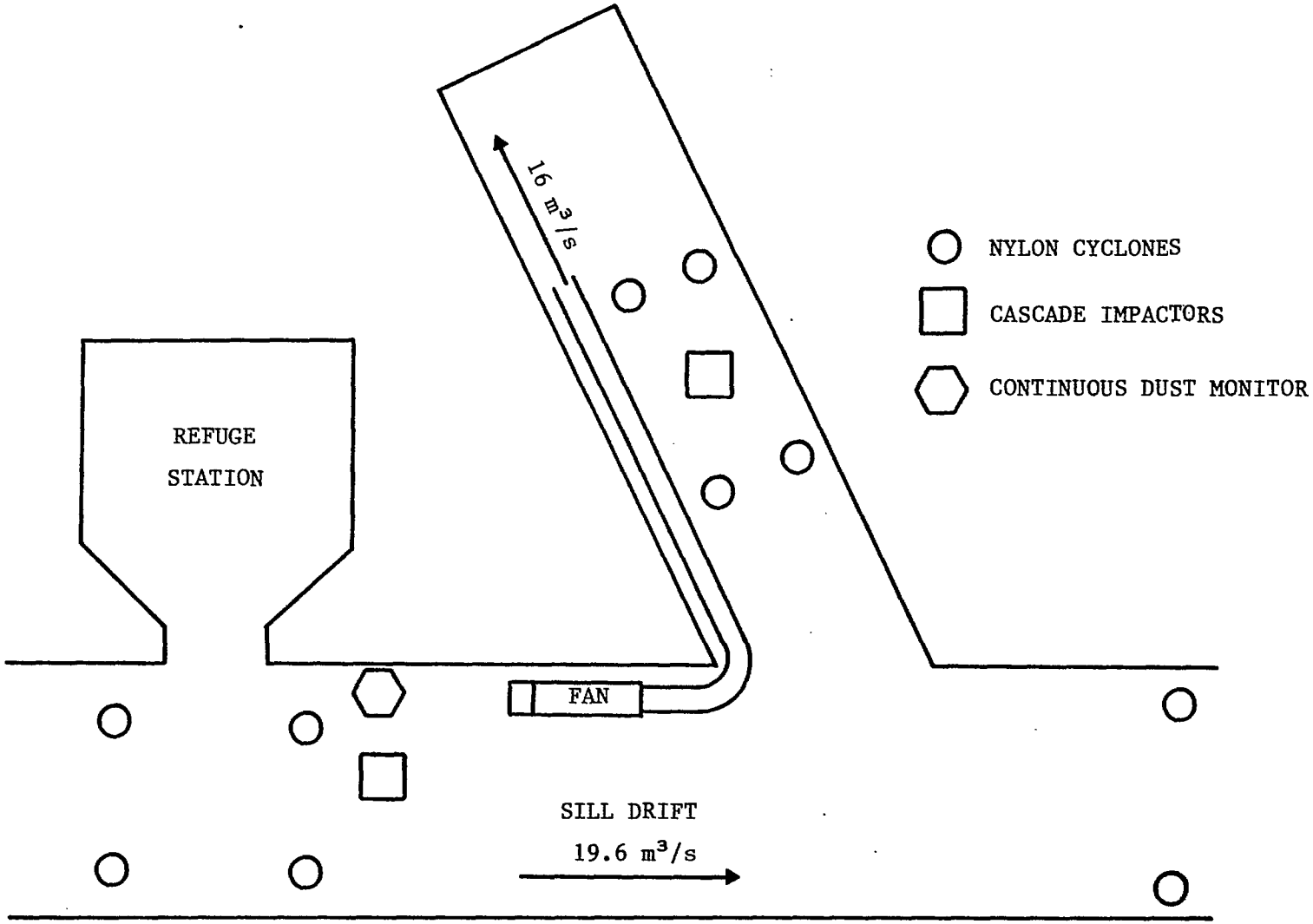

Fig. 2 - Mine area where evaluation of the filter/fan system was conducted. Also shown are the positions of samplers and average ventilation air volumes measured.

RESULTS AND DISCUSSION

Table 1 shows data gathered by cascade impactors sampling the general areas at the fan intake and exhaust. Two parameters are used to determine the dust cloud size distribution. The mass-median aerodynamic diameter (MMAD) defines the median dust particle size. Fifty percent of the dust mass is associated with particles smaller (and also larger) than the MMAD value. The geometric standard deviation (GSD) gives the degree of spread of the distribution. A monodispersed dust cloud in which all particles were, for example 5 μm in size, would have an MMAD of 5 μm and a GSD of 1. Typically in most industrial settings the GSD is larger than 1, with values between 2 and 5 when coarse mineral dust particles are present and higher values in finer size dust clouds. Also shown in Table 1 is the percentage difference in MMAD between the intake and exhaust areas.

Data in Table 1 show very low MMAD values confirming that diesel soot forms a large portion of the airborne dust mass. Typically MMAD values are in the 2 to 3 μm range in production areas and are as high as 5 μm close to rock breaking operations in these mines. On the day when the filter element was not installed a 35% reduction in MMAD was measured. When the filter was installed this reduction was measured in two occasions at 31 and 42%. On the basis of these data there is no statistical evidence to show that the filter system significantly altered the airborne dust size distribution.

The graph in Figure 3 shows the dust removal efficiency of the filter element as a function of dust particle size when the impactors were installed on the ventilation system. The efficiency is given in the size range between 0 and 2 μm. Not enough mass was gathered on upper stages of the impactor to allow the filtering efficiency to be established for larger dust sizes. The fact that most of the airborne dust was small in diameter, however, allowed

Table 1 - Airborne dust size distribution in intake and exhaust areas.

Test	Filter	Intake Area MMAD (μm)	Intake Area GSD	Exhaust Area MMAD (μm)	Exhaust Area GSD	Decrease in MMAD %
1	Off	0.20	6.84	0.13	4.22	35
2	On	0.16	8.71	0.11	7.34	31
3	On	0.31	8.32	0.18	12.31	42

the efficiency of removal of small dust particles to be determined more accurately. According to Figure 3, the filter efficiency increases as a function of size with a value of 12% at 0.3 μm, and 30% at 1.5 μm. The solid curves are the results obtained from two different tests with the average being shown by the broken line.

Although it had been expected that the filter might be more efficient for larger particle sizes, the efficiency seems to be peaking between 1 and 1.5 μm. This seems to indicate that under the testing conditions encountered, the maximum filtering efficiency may be in the range between 30 and 40% for any size of airborne dust particles. This is also supported by the fact that in fibrous filter media large diameter particles (>5 μm) may not be trapped by the filter when gas velocities exceed 0.35 m/s. Table 2 gives some specifications for the Cogema family of fan fan/filter assemblies. Shown are the filtering surfaces of the filter and pre-filter elements as well as air volumes and air velocities through the filter system. In every case, the air velocity is in excess of 0.35 m/s, ranging between 0.66 and 1.70 m/s for the main filter element which offers a greater filtering surface due to the folded design and between 1.45 and 5.65 m/s for the pre-filter which is simply laid over the filter. For the model tested the air velocity through the filter and pre-filter are estimated to be 1.51 and 4.74 m/s, respectively.

Table 3 lists respirable dust data gathered using nylon cyclones. Shown are the average respirable dust concentrations (mg/m^3) measured at the intake and the exhaust. The percentage difference between the intake and exhaust concentrations is also shown along with the MMAD measured by the impactor located at the intake on each day. During test 1, the filter element was not installed and a decrease of 11.6% was measured in respirable airborne dust concentration. This decrease is probably caused by inertial impaction of dust on fan blades, silencer walls and ventilation duct inner walls and

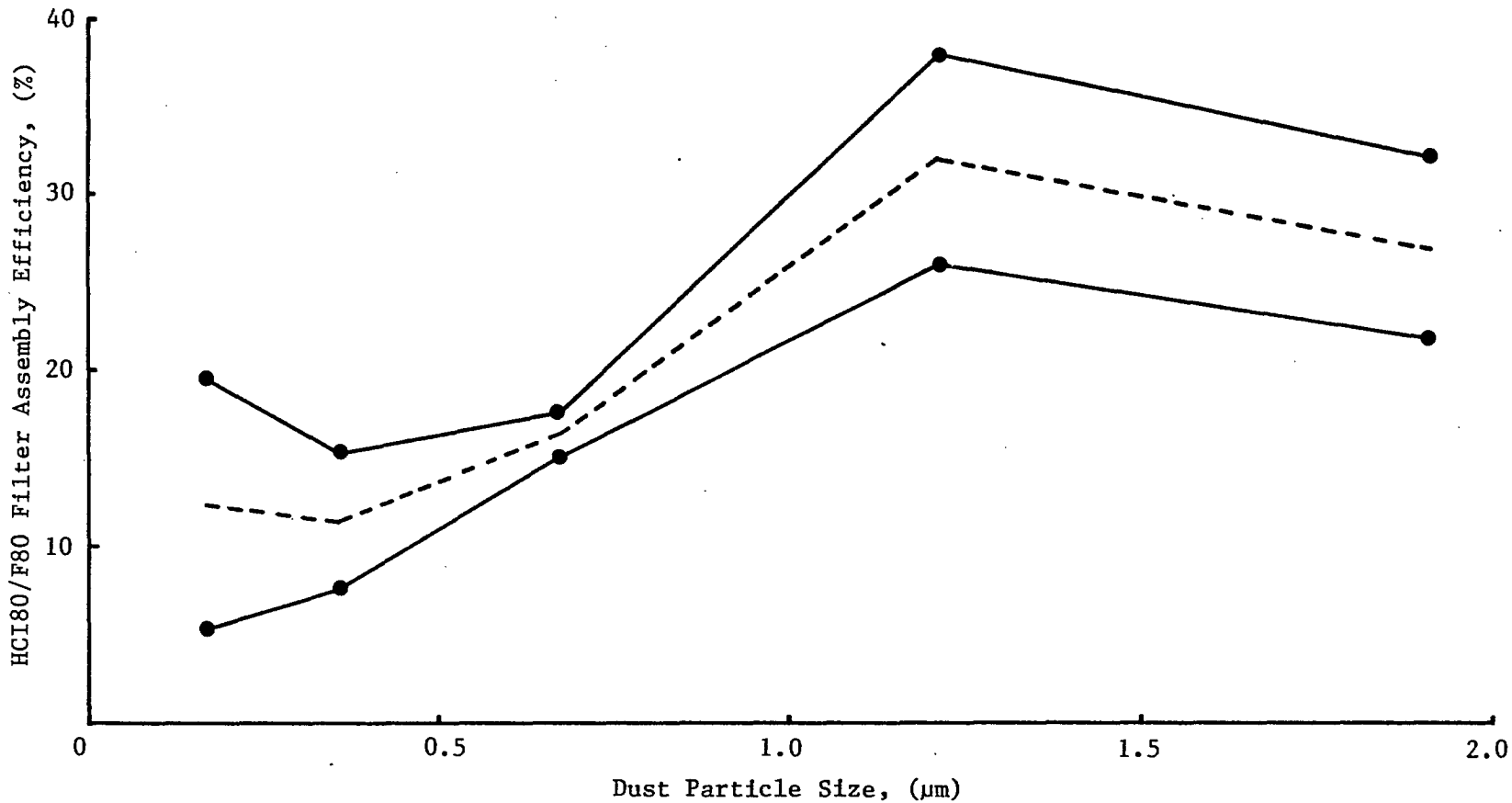

Fig. 3 - HCI80/F80 filter/fan efficiency as a function of particle size. Two separate tests are shown as well as the average of both tests.

Table 2 - Cogema model HCI fan specifications and air velocity through filter and pre-filter elements (3).

Model	Air Volume (m^3/s)	Filtering Surface (m^2) Pre-Filter	Filter	Air Velocity Through Element (m/s) Pre-Filter	Filter
HCI40/F40	1.6	1.11	1.52	1.45	1.05
HCI45/F45	2.0	1.18	3.01	1.69	0.66
HCI50/F50	3.2	1.26	3.01	2.57	1.08
HCI56/F56	3.8	1.36	3.01	2.79	1.26
HCI63/F63	6.3	1.45	4.51	4.34	1.40
HCI71/F71	9.3	2.59	6.72	3.59	1.38
HCI80/F80	13.5	2.85	8.96	4.74	1.51
HCI90/F90	19.0	3.36	11.19	5.65	1.70

Table 3 - Respirable dust concentration and reduction data.

Test	Filter	Respirable dust Conc. (mg/m^3) Intake	Exhaust	% Difference Intake-Exhaust	MMAD at Intake (μm)
1	Off	0.95	0.84	11.6	-
2	On	0.75	0.61	18.7	0.16
3	On	0.34	0.23	32.4	0.31
4	On	1.02	0.81	20.6	0.18

elbows. When examining the MMAD values given for days when the filter element was installed, it is noticed that the respirable dust reduction varies between 18.7 and 32.4% and increases with the MMAD value. This is expected and is in agreement with the data given earlier for the efficiency of dust removal of the filter as a function of size. The percentage decrease in respirable dust as a function of measured MMAD at the intake is graphically shown in Figure 4. The reduction is seen to increase linearly in the MMAD range between 0.1 and 0.3 μm.

CONCLUSIONS

The evaluation conducted shows no evidence that the filter significantly altered the aerosol size distribution in the area tested. Decreases in MMAD ranging between 31 and 42% were measured whether the filter unit was installed or removed. The filtering efficiency of the unit ranged between 10 and 30% for particles in the 0.2 to 2.0 μm range. It is possible that the filter might operate more efficiently at larger dust particle sizes. Tests performed here, however, seem to indicate that the maximum filtering efficiency for airborne particles of any size may be in the area of 40%. This may be partly attributed to the high kinetic energy imparted to larger particles by high air velocities through the filter unit.

Reductions in respirable dust concentration ranged between 18 and 32% when the filter was in place. It is conceivable, although it could not be proven here, that reductions higher than 32% may be achieved for dust clouds where the MMAD is larger than those measured here.

In conclusion, the HCI system evaluated has been shown to reduce the respirable dust concentration. It should be clear, however, that the filtering units were primarily designed for the purpose of extending the life of the sound damping materials in the silencer. The positive effect of the

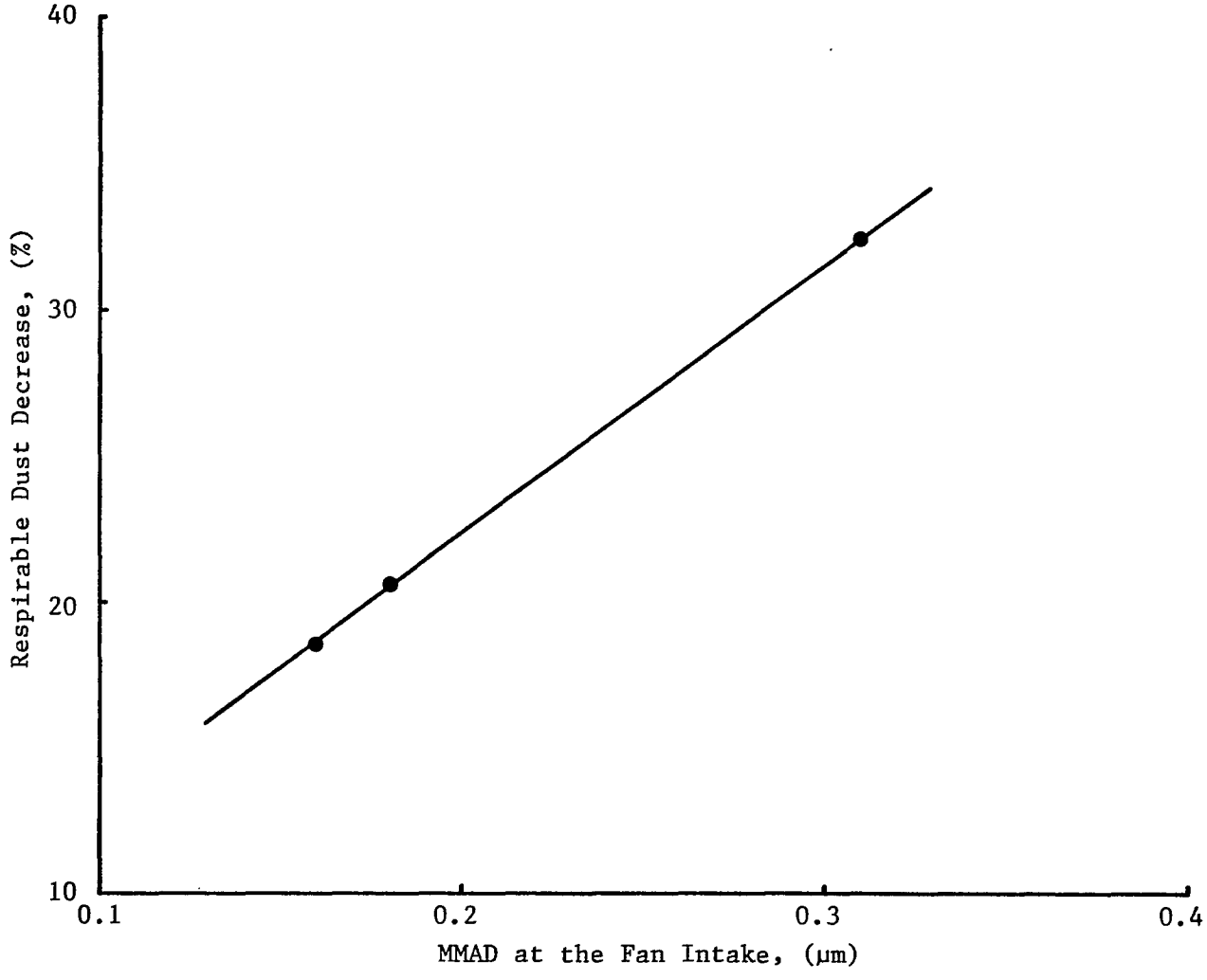

Fig. 4 - Percent respirable dust decrease measured between areas at the fan intake and exhaust as a function of MMAD measured at the intake.

filter in reducing respirable dust concentration should be regarded as a bonus and should not attract attention away from the fact that airborne dust must be suppressed at the source whenever possible.

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