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EVALUATION OF A WATER TYPE DUST COLLECTOR AT AN UNDERGROUND CRUSHING OPERATION

M.G. GRENIER, S. HARDCASTLE AND J. BIGU

ELLIOT LAKE LABORATORY

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by

M.G. Grenier*, S. Hardcastle* and J. Bigu**

ABSTRACT

A self-induced wet dust collector operating at 8.7 m^3/s was evaluated at a crushing station of an underground hard rock mine. The new dust collector replaced a bag-house dust collector. The unit was evaluated for dust removal efficiency as a function of particle size. Performance was also assessed by comparing airborne respirable dust (total and silica) in the general area prior to, and after installation of the new collector system. The use of cascade impactors and optical particle counters at the intake and exhaust of the dust collector revealed a high efficiency (>90%) for particles greater than 2 μm in size. The efficiency dropped to approximately 70% and 25% for 1.0 μm and 0.5 μm particles, respectively. The overall respirable dust reduction in the immediate crusher vicinity was measured with 10 mm nylon cyclones and another type of personal dust sampler designed by the Mining Research Laboratory in Elliot Lake, Ontario. The results showed an average total respirable dust reduction of 51%, with a maximum of 64% in some areas. For respirable silica dust, the average reduction was higher at 70% with maxima of up to 79%.

Key words: Dust control; Dust collector; Mine atmosphere.

*Research Scientist, **Research Scientist and Radiation/Respirable Dust/Ventilation Project Leader, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.

ÉVALUATION D'UN DÉPOUSSIÉREUR HUMIDE AU COURS DES OPÉRATIONS DE BROYAGE DANS UNE MINE SOUTERRAINE

par

M.G. Grenier *, S. Hardcastle ** et J. Bigu ***

RÉSUMÉ

On a évalué un dépoussiéreur humide auto-induit fonctionnant à 8,7 m^3/s dans une station de broyage d'une mine souterraine en roche dure. Ce nouveau dépoussiéreur a remplacé un dépoussiéreur domestique à sac. Le rendement de l'unité au niveau de la suppression des poussières a été évalué par rapport à la dimension granulométrique. On a étudié, en outre, la performance en comparant la quantité totale de poussière aéroportée ainsi que la quantité de silice contenue dans le milieu environnant en général, avant et après l'installation du nouveau système de dépoussiérage. L'emploi d'impacteurs en cascade et de compteurs à particules optiques à l'entrée et à la sortie du dépoussiéreur a révélé un rendement élevé (> 90 %) pour les particules de dimension granulométrique plus grande que 2 µm. L'efficacité a baissé à environ 70 % et 25 % respectivement pour les particules de 1,0 µm et 0,5 µm. La suppression totale de poussières respirables dans le voisinage immédiat du broyeur a été mesurée à l'aide de cyclones en nylon de 10 mm et d'un autre échantillonneur personnel de poussière mis au point au Laboratoire de recherche minière à Elliot Lake en Ontario. Les résultats de l'étude ont montré une diminution totale de 51 % de la poussière respirable, allant jusqu'à un maximum de 64 % à certains endroits. Pour la poussière de silice respirable, la diminution moyenne était au-dessus de 70 % jusqu'à un maximum de 79 %.

MOTS-CLÉS: Contrôle de la poussière; Dépoussiéreur; Atmosphère de la mine.

*Chercheur scientifique, **Chercheur scientifique et Chef de projet Rayonnement/Poussières respirables/Ventilation; Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources, Canada, Elliot Lake, Ontario.

INTRODUCTION

Wet collectors have long been used as a means of dust control by industry. This type of dust collector, although less common in underground hard rock mines, may be an attractive alternative in underground dust control applications where dry filtration may pose problems. Wet scrubbing is advantageous as disposal of trapped dust is a clean process with little or no dust re-entrainment. Wet or sticky materials may be collected and will not affect the performance of scrubbing units. In theory, the performance of wet dust collectors is not affected as the load of collected dust increases. The ease of maintenance should lead to lower operating expenses.

On the other hand, this type of dust collector is usually less efficient than some dry filtration units in trapping finer dust particles. Higher efficiency for small particle sizes can only be obtained at the cost of higher energy consumption. Finally, wet scrubbing units are subject to corrosion problems; also, fair amounts of water must be disposed of on a regular basis.

In wet dust collectors, dust is captured by inertial impaction, interception and by exchange of momentum. The theory of dust collection by spheres (water droplets) shows that collection efficiency is inversely proportional to the size of collecting spheres and directly proportional to particle size and the relative velocity between the sphere and the particle (1). Since the velocity of smaller water droplets decays relatively faster, contact between droplets and particles must take place as soon as possible after droplet formation. In an effort to enhance the efficiency of wet dust collectors, scrubbing agents may be added to the water. This practice, however, has not been shown to significantly affect the performance of such collectors (1,2).

Several types of wet dust collectors have been designed; among these are spray towers, centrifugal spray dust collectors, venturi and self-induced dust collectors. The unit evaluated here is of the self-induced type and water droplets are formed as dusty air is drawn into a wedge-shaped duct whose lower horizontal plane is submerged. Air is then forced under a lip which causes fragmentation of the water to occur. The design and principles of operation of this type of dust collector require that water be maintained at a critical level and also that the unit be mounted on a perfectly horizontal surface. Except for the fan which is an external and separate unit, the wet dust collector contains no moving mechanical parts. In this type of dust collector, large particles are removed by impingement on the liquid surface while the induced spray removes smaller dust particles. Wetted dust settles to the bottom of the tank, which is desludged on a regular basis. The cleaned gas is released after going through dewatering plates and a felt-like filter material approximately 2 cm in thickness. This particular unit is available in a variety of models covering air volumes between 1.9 m^3/s (4,000 cfm) and 23.6 m^3/s (50,000 cfm).

Wet dust collectors are sometimes quoted as operating at efficiencies in excess of 95%. Although such efficiencies are achievable on a total mass basis, they may vary considerably depending on the size distribution of airborne dust to be removed. An earlier model of the dust collector described here is quoted elsewhere as having an efficiency of 82 to 86% by mass (2). Although these numbers seem to indicate acceptable efficiency levels, much controversy remains concerning the health hazard that the remaining 14 to 20% of the dust poses.

The purpose of this work was to perform an in-field evaluation of a self-induced wet dust collector at an underground crushing plant. The dust collector was tested for particle removal efficiency as a function of dust particle size. The overall impact of the dust collector on air quality in the vicinity was also assessed for total and quartz respirable dust.

AREA DESCRIPTION

The area under investigation was a crushing plant at an underground hard rock mine. The rock matrix in this area contained as much as 65% quartz. A plan view of the mine area studied is shown in Figure 1. The crusher was fed by two ore passes and one waste pass. There was an open flow of muck where these three passes joined to feed the screen and the crusher. These filled a surge bin, which was drawn by an attendant at the tail pulley of a belt conveyor in a drift approximately 15 m below. This area was accessible from the crushing plant using a short raise. On average, the plant crushed 1360 tonnes of ore or waste daily throughout the evaluation. Although work habits varied from one crusher attendant to another, a typical working cycle consisted of 15 to 20 min of crushing to fill the surge bin, and a 30 to 45 min period to allow the bin to empty.

The plant was ventilated with approximately 9.4 m^3/s (20,000 cfm) of air coming from the workings of an upper level. This air was always quite low in mineral dust content, but substantial diesel soot concentrations were detected. Ventilation air entering the crusher plant exhausted into the raise leading down to the tail pulley (see Figure 1). The dust collector and the geometry of the area caused an appreciable portion of the air to be recirculated, the exact extent of which could only have been assessed accurately by tracer gas techniques.

The wet dust collector was an 8.7 m^3/s (18,400 cfm) unit, 4.5 m in length, 1.5 m in width, and 2.0 m in height. Clean air, which was drawn out of the dust collector by an external fan, was fed back into the room. Dusty air was fed to the dust collector via an intake plenum and ducts. More

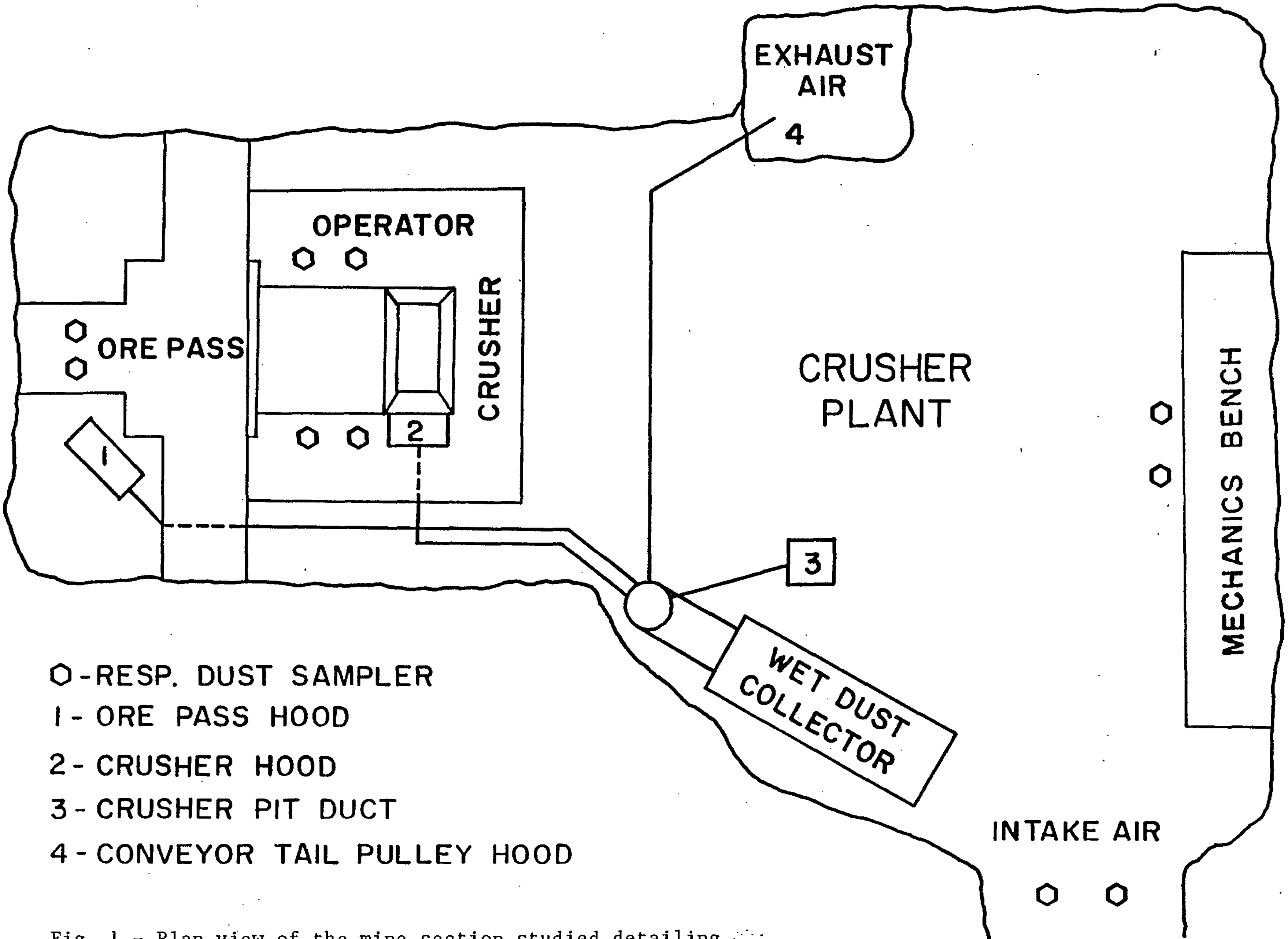

Fig. 1 – Plan view of the mine section studied detailing sampler locations and dust collection points.

specifically, dust was collected from:

1. below the crusher screen and jaws;
2. the crusher pit;
3. an open hood extracting dusty air from the open ore pass junction area above the crusher platform;
4. from a hood at the tail pulley transfer point.

The dust collector operated on a continuous basis and was flushed daily at the beginning of the shift. The filter fabric at the exhaust was cleaned (hosed down) on a weekly basis as part of the regular crusher maintenance schedule. The appropriate water level for optimum operation was maintained by an automatic overflow valve system. A pitot tube traverse at the intake of the dust collector indicated that the unit was operating very close to the manufacturer's suggested volume of 8.7 m^3/s (18,400 cfm). Installation of the wet dust collector has affected the meteorological variables in the area as the temperature increased slightly, on average from 16 to 18^{o}C. The relative humidity remained high, but constant, at 95%. This temperature rise translated into a 13% increase in water content of the air, from 13.2 g/m^3 to 15.0 g/m^3.

The wet dust collector replaced a 7.1 m^3/s (15,000 cfm) bag collector which drew air from underneath the crusher jaws and from the tail pulley transfer point dust collection hood; it exhausted into an adjacent ore pass. This system had deteriorated since installation and was plagued with mechanical and engineering problems.

EXPERIMENT

Evaluation of the wet dust collector system was conducted over a time span of eleven weeks. At first a five day period was used to establish the level and characteristics of airborne dust contaminants in and around the crusher area while the dry collection system was still in use. To this end, twelve gravimetric sampling trains were used as area monitors. These consisted of 10 mm nylon cyclones and CAMPEDS (3) respirable dust samplers used in conjunction with their assigned sampling pumps. These sampling trains were tested separately underground prior to the beginning of the study to establish their integrity (4). Flow calibration for the samplers was performed underground to avoid flow rate changes brought about by air density increases with depth (5). Respirable dust sampling was conducted over a five hour period on each of the five days. Total respirable and quartz respirable dust concentrations were measured in five areas of interest (see Figure 1). These were the air intake to the crusher plant, the crusher plant floor area (which will be referred to as the mechanics workbench), the crusher platform (crusher attendant work station), the ore passes feeding the crusher and the return air going to the tail pulley area.

Cascade impactors (Anderson, 13 L/min) were used to determine the size distribution of dust at the mechanics' workbench and on the crushing platform. A GCA Miniram PDM-3 continuous dust monitor was installed on the crushing platform to measure the extent of dust concentration fluctuations close to the crusher operator. The Miniram was also previously calibrated along with the gravimetric samplers. Relative humidity, temperature and ventilation parameters were also measured.

The old dust collector was dismantled and the wet dust collector with associated duct work was installed approximately a month later during the mine's summer shutdown. After shutdown the wet dust collector was allowed to run on a steady basis for a month before the second part of the evaluation took place. This was done in order to allow the mine staff to become acquainted with routine maintenance and operation of the new unit. It also allowed a 'breaking in' period for the dust collector.

During the second phase of evaluation (after wet collector installation) respirable dust, size distribution, continuous dust concentration on the crushing platform, relative humidity and temperature were measured as before. In this period, the dust removal efficiency of the wet dust collector was determined with the help of cascade impactors and optical particle counters. Sampling ports were provided for this purpose at the intake and exhaust of the unit. A set of sampling probes was designed to allow sampling to be performed under conditions that were near isokinetic. Data from optical counters and cascade impactors allowed the efficiency of the wet dust collector to be determined as a function of particle size.

WET DUST COLLECTOR - EFFICIENCY

The efficiency of collection as a function of particle size is shown in Figure 2. The cascade impactors and the optical counters were in agreement for particle diameters larger than 2 μm. For smaller dust particles the instrument reading disagreed by as much as 40% (at 1 μm). There are two possible explanations for this discrepancy. First, whereas efficiency values from the cascade impactor are calculated from an entire sampling shift, data from the optical counters could only be obtained during periods of relatively low dust concentration. Close examination of counter data showed evidence of particle coincidence and/or electronic saturation at periods of high dust production. Second, the sampling probe designed for the cascade impactor was truly isokinetic. Unfortunately, time constraints did not allow us to build a probe to match the flow rate of optical counters isokinetically. For these reasons the data from cascade impactors should be regarded as more representative of the removal efficiency of the wet collector. These results are in agreement with efficiencies expected for self-induced wet dust collectors (1).

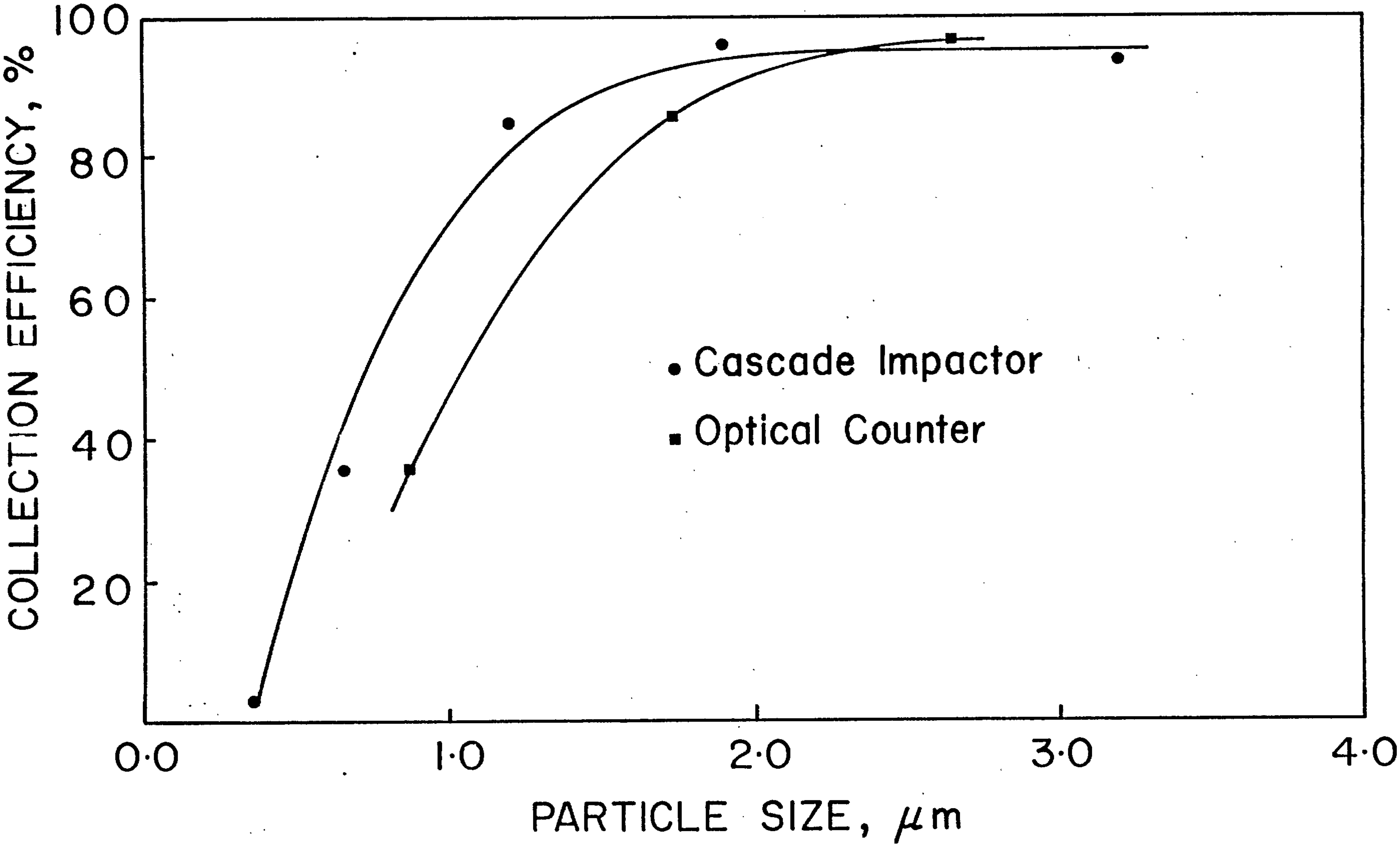

Fig. 2 - Wet collector dust removal efficiency as a function of particle size.

On a total mass basis, data from cascade impactors showed a removal efficiency of approximately 85% and a respirable dust removal efficiency of approximately 73%. The respirable dust removal efficiency was calculated by estimating the portion of respirable dust on each impactor stage (6). An earlier version of this wet dust collector was evaluated in the U.K. and the respirable dust removal efficiency for coal dust was reported to be between 82% and 86% (2). A recent evaluation of a 16.5 m^3/s (35,000 cfm) unit similar to the one tested here shows a respirable dust removal efficiency of 84% (7). The value of 73% obtained in the present study is mostly due to a substantial fraction of the respirable dust being diesel exhaust particles. These particles are for the most part smaller than 0.5 μm, and it is expected that the dust collector is very inefficient in that size range and for this type of dust (8).

WET DUST COLLECTOR - IMPACT ON AIR QUALITY

Time-weighted average (TWA) concentrations of respirable total and quartz dust are shown in Tables I and II, respectively, for both parts of the study. These numbers do not represent personal dust samples. These area samples were collected from a five hour sampling interval during comparatively high activity periods. The concentrations are not meant to indicate the degree of exposure of workers to total and quartz respirable dust, but rather are a measure of the improvement in the area. These data may, however, be used to give an idea of the degree of improvement to be expected from routine personal sampling in the future.

The ore pass and the crushing platform showed the most improvement. On average total and quartz airborne respirable dust concentrations were reduced by 60% and 76%, respectively. This large reduction is attributable to the dust collector's ability to effectively wet mineral dust and to the proper

TABLE I

Total Respirable Dust (mg/m^3) Comparison
Dry vs Wet System

Area	Dry	Wet	Reduction (%)
Crusher Platform	1.21 ± 0.28	0.53 ± 0.19	56
Mechanic Bench	0.34 ± 0.11	0.35 ± 0.11	0
Ore Pass	1.36 ± 0.49	0.49 ± 0.18	64
Return Air	0.81 ± 0.19	0.55 ± 0.24	32
Intake Air	0.25 ± 0.03	0.24 ± 0.08	4

TABLE II

Quartz Respirable Dust (mg/m^3) Comparison
Dry vs Wet System

Area	Dry	Wet	Reduction (%)
Crusher Platform	0.70 ± 0.19	0.15 ± 0.08	79
Mechanic Bench	0.10 ± 0.06	0.07 ± 0.03	30
Ore Pass	0.70 ± 0.24	0.18 ± 0.10	74
Return Air	0.37 ± 0.08	0.16 ± 0.07	57
Intake Air	0.05 ± 0.01	0.04 ± 0.01	20

ducting and dust extraction system installed as part of the project. The return air down from the tail pulley extraction hood improved as well, but to a lesser extent. The duct linking the dust collector to the tail pulley dust extraction hood is mostly responsible for the relative lack of improvement in that area. This is the smallest diameter duct in the system and also by far the longest.

The mechanics' workbench area showed no improvement in total respirable dust and only a very marginal improvement in quartz respirable dust concentration. This is due to the area being in the path of incoming 'fresh air'. This effectively isolates the area from dust produced by the crushing operation (see Figure 1). As expected, the intake air was not affected in any way by the new dust collector. Concentration remained very constant over the evaluation period.

Some konimeter samples were taken by mine personnel at the discharge of the dust collector and in some other areas of interest. The results showed an average of 50 ppcc in incoming fresh air, 140 ppcc at the tail pulley (return air) and at the mechanics' workbench, approximately 360 ppcc on the crushing platform, and 420 ppcc at the dust collector's discharge. The Mines Accident Prevention Association of Ontario (MAPAO) suggests that for ores containing 30% quartz or more, 200 ppcc should be the upper limit value (9). Work done on a similar unit elsewhere suggests that unless a sufficient volume of clean air is available to dilute contaminants to a level below 200 ppcc, the exhaust from the dust collector should not be recirculated (10).

Although the konimeter has been, and still is, a valuable engineering tool, data analysis in the case of interest here must be performed carefully and the statistical significance of the results properly assessed. It has been suggested that konimeter performance might be affected by water condensation on dust particles as air passes through the konimeter jet (11).

If this phenomenon does indeed occur, it would only be compounded by high relative humidity environments and by water pick up through the dust collector in this particular case. It is reported that water pick up through a 16.5 m^3/s unit is approximately 0.7 g/m^3 (10). It is apparent that more work is required before the health hazard posed by the discharge of wet dust collectors can be properly assessed.

Size distributions of airborne dust are shown in Figures 3 and 4 for measurements taken at the crushing station and at the mechanics' workbench, respectively. Measurements were taken before and after installation of the wet collector. These data show a reduction of the mass median aerodynamic diameter (MMAD) from 4.4 μm to 1.6 μm at the crushing platform. This decrease is caused by the removal of the coarse dust fraction by the collector. The reduction in MMAD is not as important at the mechanics' workbench since, as indicated above, this area is somewhat isolated from the crushing operation by fresh air. In both cases, the geometric standard deviation has increased indicating a more polydisperse cloud. The respirable portion of the dust collected in both impactors was again estimated (6) in order to establish the improvement to both areas. These were compared to improvement data calculated from gravimetric samples collected in corresponding areas. The cascade impactor data show a total respirable dust reduction of 6% and 64% for the mechanics' workbench and the crusher platform, respectively. This compares well with corresponding gravimetric sampler data (0% and 56% for the respective areas).

Figure 5 shows typical daily airborne respirable dust concentration as a function of time before and after the wet dust collector was installed. Prior to the installation of the wet collector, crushing intervals are clearly visible as respirable dust concentration increases to between 5 mg/m^3 and 10 mg/m^3. A similar profile after the unit was put into operation has dust

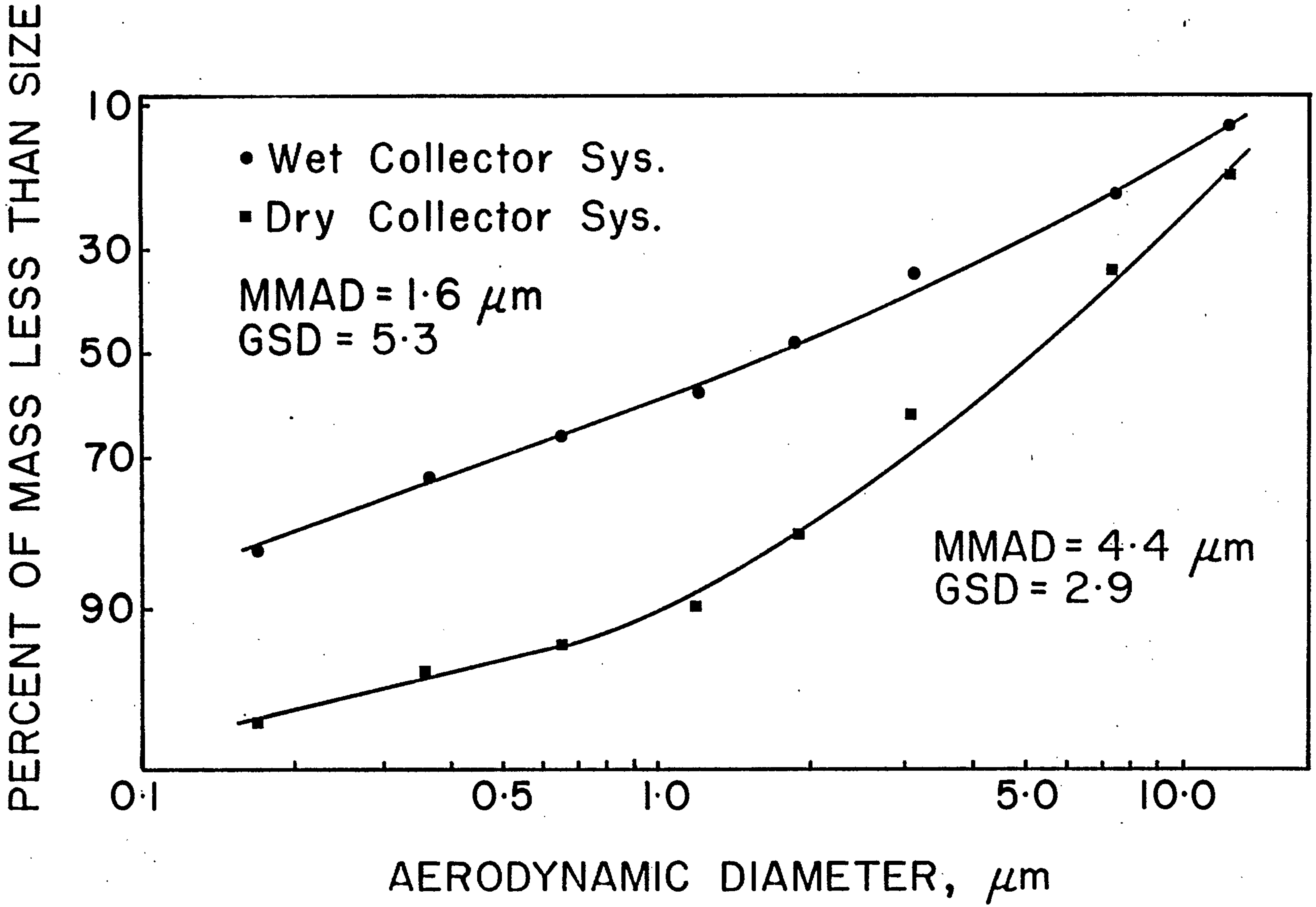

Fig. 3 – Airborne dust size distribution measured at the crushing platform, before and after installation of the wet dust collector.

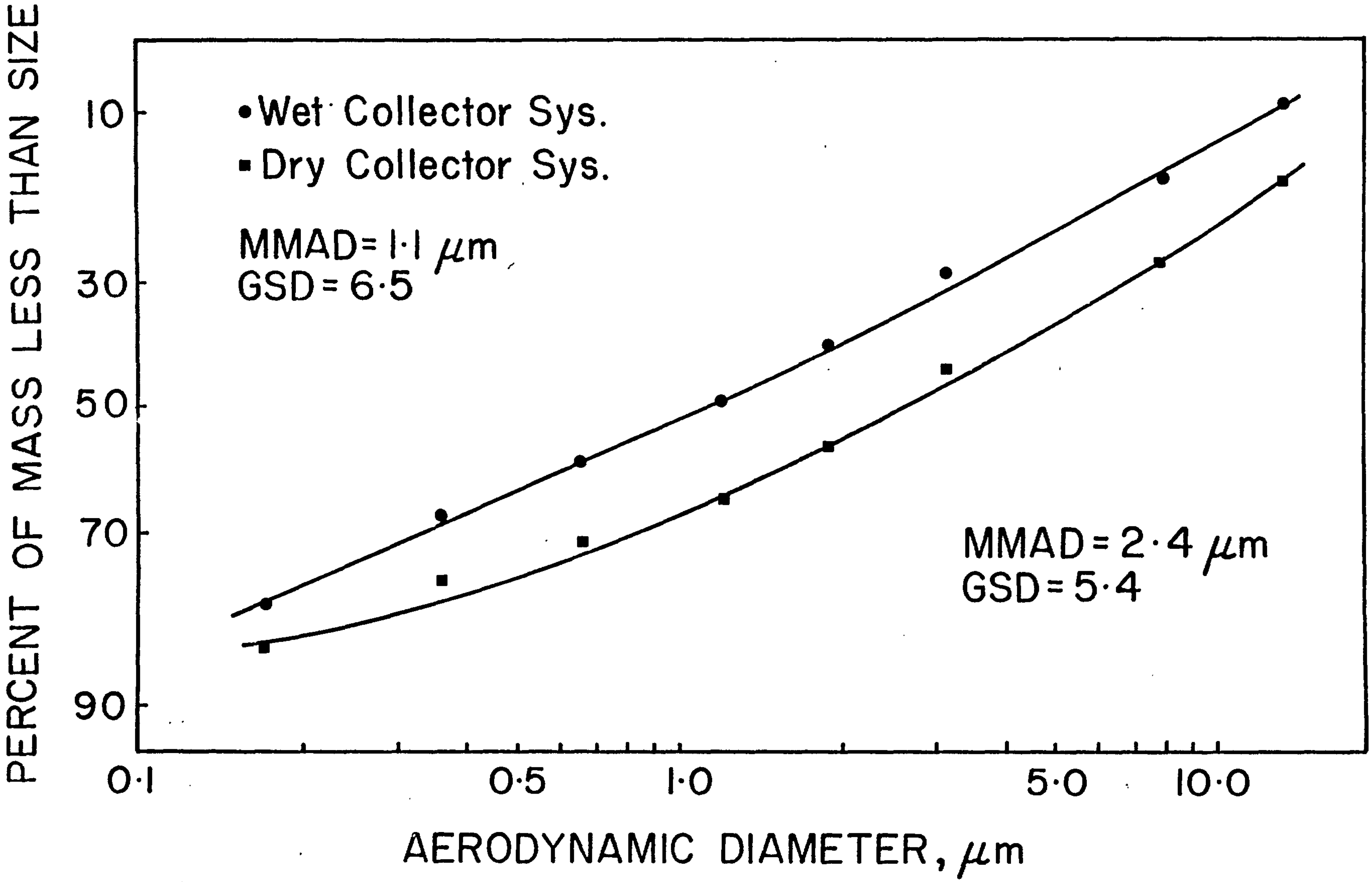

Fig. 4 – Airborne dust size distribution measured at the mechanics' workbench, before and after installation of the wet dust collector.

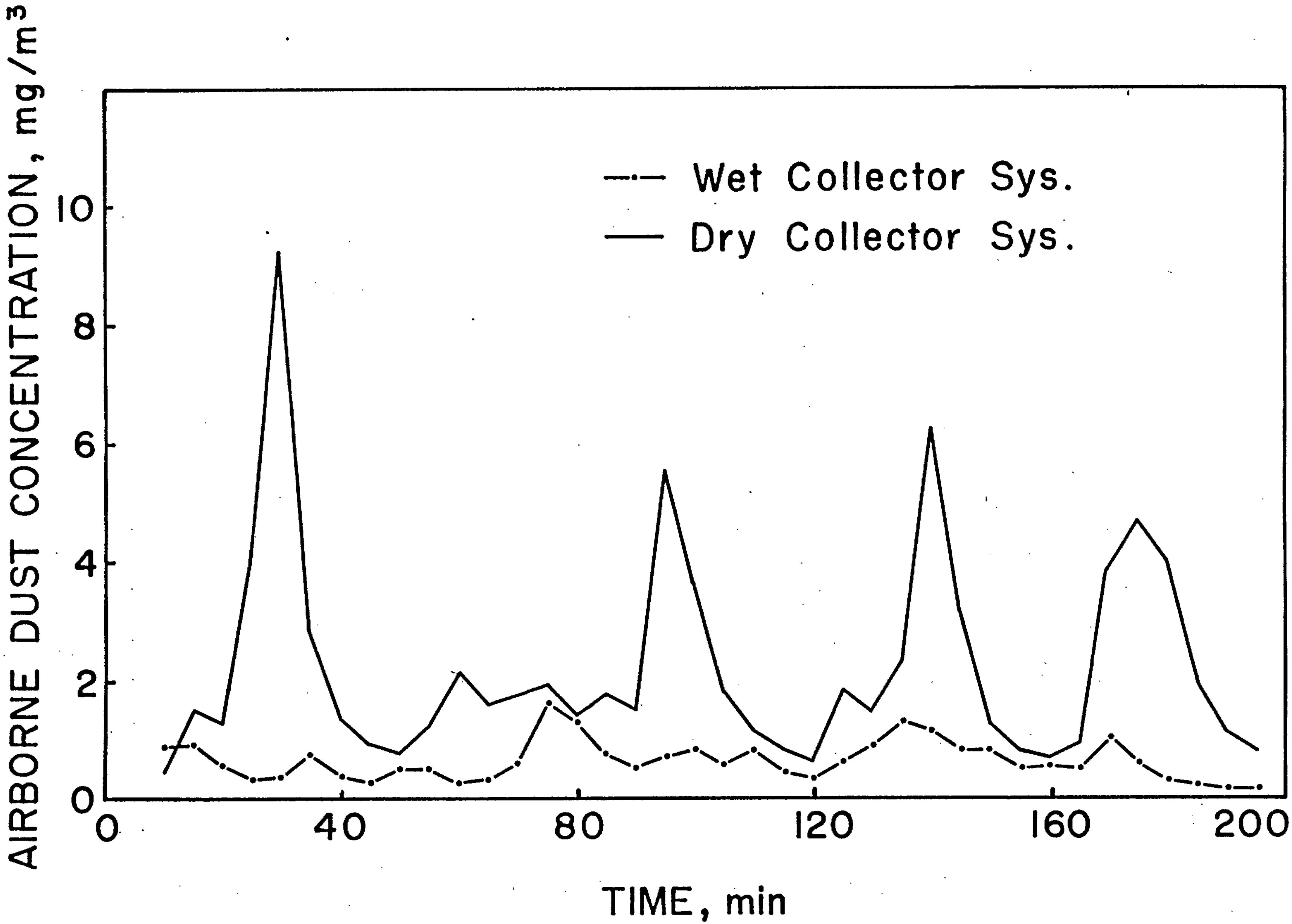

Fig. 5 - Airborne dust concentration as a function of time measured at the crushing platform, before and after installation of the wet dust collector.

concentrations confined to levels below 2 mg/m^3.

CONCLUSION

The self-induced water dust collector evaluated in this study was close to 100% efficient for dust particles larger than 2 μm. The efficiency decreases rapidly for smaller particles. Cascade impactor data show 70% and 25% efficiency for 1.0 μm and 0.5 μm dust, respectively. The total dust collection efficiency was 85%, which was lower than expected. This was mainly due to the presence of diesel soot in the intake air.

Total respirable dust collection efficiency was estimated to be approximately 73% by mass. But other studies have shown efficiencies as high as 85% in areas where the bulk of airborne contaminants are mineral in nature. These studies also show an efficiency of collection for respirable quartz in excess of 90%.

The average reduction of airborne respirable contaminants in areas with initially high dust concentrations (the return air, the ore pass and the crusher platform) was 51% and 70% for total and quartz dust, respectively.

Ducts and collection hoods are an important part of the dust collecting system. The dust collecting system described here was well designed (within the constraints of practicality) with the possible exception of the tail pulley transfer point hood/duct assembly. The ratio of the diameter to length of the duct was out of proportion compared to the rest of the system.

Konimetry measurements conducted by mine personnel are in disagreement with gravimetric results collected here. Konimetry guidelines set by MAPAO suggest that the exhaust from the wet dust collector not be recirculated. In view of this, it seems that there is a need for the development of standard methods to properly assess the efficiency and environmental impact of wet dust collectors under field conditions.

One of the major advantages of wet dust collectors is that units require very little maintenance over extended periods. As a follow-up to this study plans are being made to test the efficiency of the wet collector after a year or so of continuous operation. This will reveal any possible deterioration in the efficiency of collection. Also, some tests will be conducted to assess the effect of adding wetting agents to the wet dust collector water tank.

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