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A PORTABLE COMPUTER CONTROLLED MULTI-SIZE RANGE, AEROSOL COUNTING  
SYSTEM FOR USE IN UNDERGROUND MINING ENVIRONMENTS

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A PORTABLE COMPUTER CONTROLLED MULTI-SIZE RANGE, AEROSOL COUNTING SYSTEM  
FOR USE IN UNDERGROUND MINING ENVIRONMENTS

by

S.G. Hardcastle\* and J. Cavan\*\*

ABSTRACT

Respirable particulate control is a major concern in the underground mining environment. The Elliot Lake Mining Research Laboratory has recognized a need for, and have had developed, a real-time particle counter to further their dust control studies. Extensive modifications to a commercially available 'clean-room' aerosol counter have customized a unit for use in underground environments.

The particle counter uses near forward light scattering to count particles into six threshold size ranges, five of which start in the respirable range. Applications of the counter include: i) characterizing dust from different mining operations; ii) evaluating the efficiency of dust removal/suppression methods; iii) determining dust transportation/sedimentation characteristics of mine ventilation systems; and iv) quantifying size dependent characteristics of other dust/particulate measurement methods.

The aerosol counter has the following specifications: threshold size ranges of 0.5, 1.5, 2.0, 3.5, 5.0 and 10.0  $\mu\text{m}$  (optical) diameter; maximum count of  $4 \times 10^5$  particles/L without dilution; and normal sample flow rate of 2.8 L/min with on-line optional 100:1 dilution. A rechargeable hand-held computer provides remote control and logging facilities, and off-line communicates with a standard PC computer which analyzes data with an electronic spread sheet.

To date, two particle counters have been used in the evaluation of a dust filtration unit and a dust transportation study. Evaluation of two similar filter units highlighted the size dependency of the filter units and how aerosol size distribution has a significant effect on the units bulk efficiency. Such is the potential of the units in mining environmental dust control studies.

Key words: Dust; Environmental monitoring; Mine environment.



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SYSTÈME PORTABLE ASSISTÉ PAR ORDINATEUR POUR LE COMPTAGE DES AÉROSOLS  
DE TOUTES DIMENSIONS DANS LES ENVIRONNEMENTS MINIER SOUTERRAINS

par

S.G. Hardcastle\* et J. Cavan\*\*

RÉSUMÉ

Le contrôle des particules inhalables dans l'environnement minier souterrain constitue un problème sérieux. Le Laboratoire de recherche d'Elliot Lake s'est rendu compte de la nécessité de développer un compteur de particules en temps réel afin de poursuivre les recherches dans ce domaine. Les chercheurs ont donc adapté un compteur d'aérosols commercial, destiné à la purification de l'air, en vue de l'utiliser pour le contrôle des aérosols dans les environnements souterrains.

L'appareil procède par la diffusion quasi-directionnelle de la lumière et compte les particules selon une échelle comprenant six dimensions-seuils dont cinq débutent par la gamme des particules inhalables. Le compteur peut être appliqué à : i) la caractérisation de la poussière produite pendant divers travaux d'exploitation minière; l'évaluation de l'efficacité des méthodes d'enlèvement et d'élimination de la poussière; iii) la détermination des caractéristiques du processus de sédimentation/ transport de la poussière dans le système de ventilation des mines; et iv) la quantification des éléments liés à la taille des particules qui caractérisent les autres méthodes de mesure de la poussière et des particules.

Le compteur d'aérosols possède les caractéristiques suivantes: capacité de compter les particules dont le diamètre (optique) a une dimension maximale de 0,5, 1,5, 2,0, 3,5, 5,0 et 10,0  $\mu\text{m}$ ; comptage maximal de  $14 \times 10^5$  L/particules, sans dilution; débit normal des échantillons de 2,8 L/min avec dilution directe facultative de 100:1. Le contrôle à distance est effectué à l'aide d'un ordinateur rechargeable, portable manuellement. Cet ordinateur, qui comprend une unité d'enregistrement, est relié à un ordinateur ordinaire PC qui analyse les données au moyen d'un programme de calcul.

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Mots-clé : Poussière, Contrôle de l'environnement; Environnement minier.

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À ce jour, deux compteurs de particules ont été utilisés pour évaluer une unité de filtrage de la poussière et aux fins d'une étude portant sur le transport de la poussière. Une évaluation de deux unités de filtrage semblables a souligné l'importance de la dimension des unités de filtrage et l'effet considérable de la distribution granulométrique des aérosols sur l'efficacité globale des unités. Tel est le potentiel de ces unités pour les études portant sur le contrôle de la poussière dans les environnements miniers.

## INTRODUCTION

The Mining Research Laboratory at Elliot Lake has been investigating airborne particulates since the early 1960s. The main interest has been measuring and quantifying mineral dusts generated by mining operations that may be injurious to health with long term inhalation exposure. The areas of interest form five major categories (1):

1. Instrument calibration and design, such as the CAMPEDS two-stage personnel impactor (2);
2. Establishing measurement techniques and analysis methods, including the following;
3. The development of direct on filter analysis by X-ray diffraction for quartz (2);
4. Promoting, designing and evaluating particulate control in the mining environment; and
5. General investigations of dust underground.

In all the above, the primary concern has been with dust of the respirable size range, between 0.5 and 10.0  $\mu\text{m}$ .

Presently, a major thrust is being carried out into the control of dust produced from underground operations. Historically, particulate control assessments have been performed mostly with gravimetric samplers that normally collect the whole respirable range. Some use has been made of light scattering monitors, cascade samplers and konimeters. The light based monitors typically provide a real-time history of dust concentrations for the respirable range. The cascade samplers provide size distribution information but only as a time-weighted average (TWA). A konimeter is a useful engineering tool in that it effectively takes an instantaneous sample of which the particle number concentration can be counted.

To further particulate control investigations an aerosol counting

system has been redesigned and modified for use in underground environments. Specific modifications include: a) size reduction to improve and allow portability; b) optional battery operation to provide power independency; c) protection against the mining environment; d) increased maximum loading of the sensing chamber to handle high concentrations; and e) provision of data logging facilities. This instrument combines the real-time capability of the light based monitors, the size differentiation of cascade samplers and pure particle counts of the konimeter. With data reduction the instrument could also provide both real-time and TWA gravimetric and particle number concentrations, and size distribution information.

The possible applications (3) of real-time aerosol counting systems in mining are where there is a need to investigate size dependent characteristics of dust clouds; these include:

- i) categorizing dust producing operations by their dust characteristics;
- ii) assessing dust removal/suppression methods such as water sprays and filters;
- iii) investigating dust transportation, pick-up and deposition by a mine airstream; and
- iv) evaluating the measurement instruments used to evaluate a miner's dust exposure.

The redesigning and modifying of two aerosol counters was performed under contract by Mono Research Laboratories Ltd., Brampton, Ontario (4). The units modified were originally HIAC/ROYCO Model 4102 light scattering particle counting systems.

#### BASIC DESCRIPTION OF THE HIAC/ROYCO 4102 PARTICLE COUNTING SYSTEM

##### SYSTEM CONFIGURATION

The 4102 system in its original state is a clean-room laboratory based

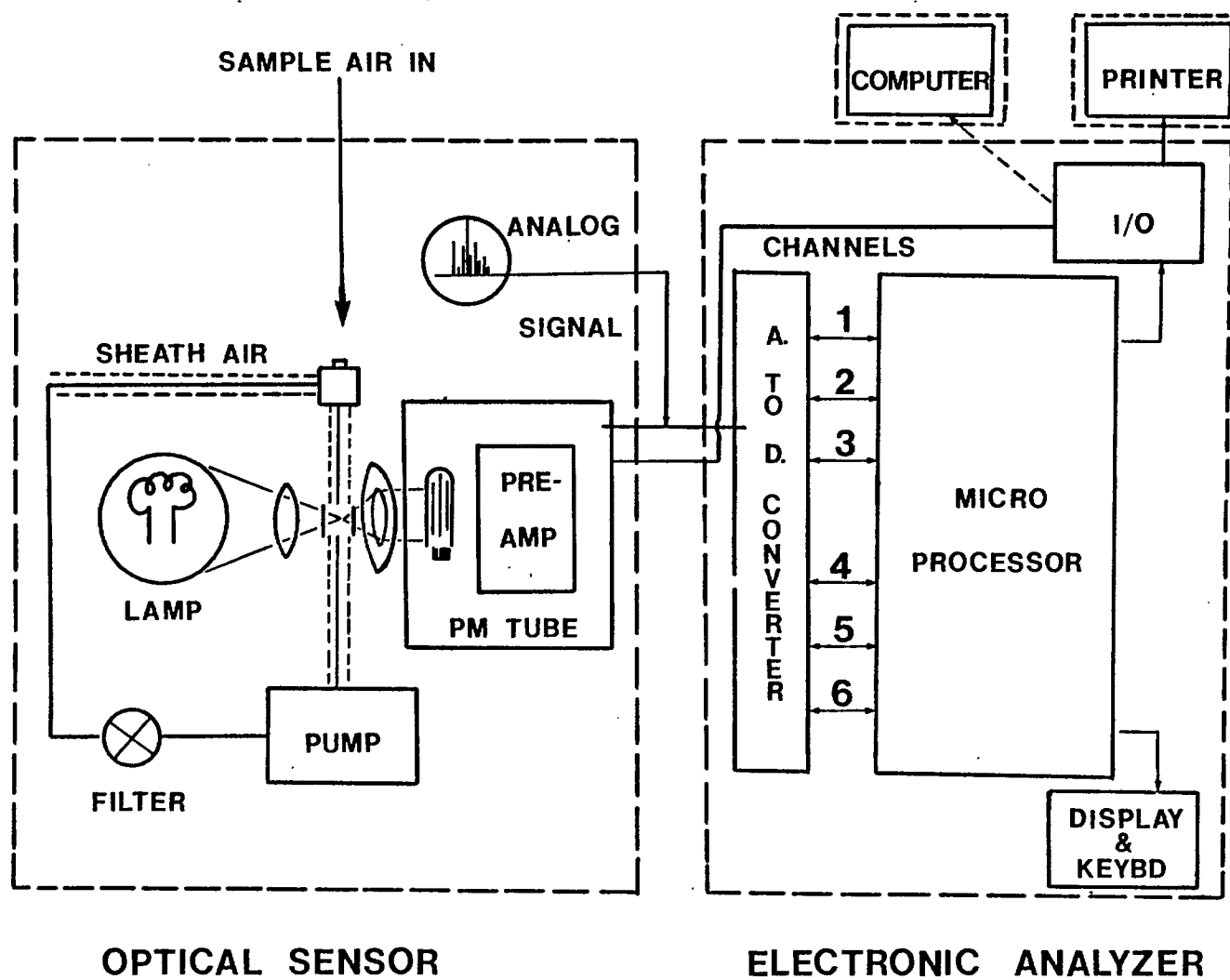


Fig. 1 - Original system configuration of a HIAC/ROYCO model 4102 aerosol counting instrument.



particle counter. The system configuration (Figure 1) consists of an optical sensor, electronic analyzer, output device and optional input/controlling device. Basically, the system functions as follows: an airstream is drawn through the optical sensor, which converts scattered light from particles in the airstream into electronic pulses, then the analyzer counts and sizes each particle's pulse into one of six diameter groups and the count and size data are logged on a computer or printer.

#### SYSTEM OPTICS

The 4102 system is a near forward scattering light instrument with sheath optics (Figure 2). Light from a standard tungsten filament or quartz halogen source is focused through a defining aperture and passes as a sharply defined beam through a sensitive volume. The aerosol drawn into the 4102 passes through the small sensitive volume (0.5 x 1.0 x 2.0 mm), where each particle of the aerosol scatters a pulse of light over a large solid angle. The near forward component of the scattered light is collected and relayed to a photo-multiplier (PM) tube which converts it to an electronic pulse. A light trap collects and absorbs direct light passing through the aerosol when no particles are present.

The typical dynamic range of a near forward scattering technique detector is 40:1, which corresponds to an 0.5 to 20  $\mu\text{m}$  diameter detection range.

#### SYSTEM ELECTRONICS AND INPUT/OUTPUT

The 4102 electronics and input/output options are shown in Figure 1. The electronic pulses from the PM tube ( $\sim 40 \mu\text{s}$  duration) pass through the analog to digital converter to the microprocessor. Here the pulses are counted and sized according to amplitude into 1 of 6 threshold diameter groups. The microprocessor is also responsible for numerous other operations, including controlling input/output modules, internal communications and self-

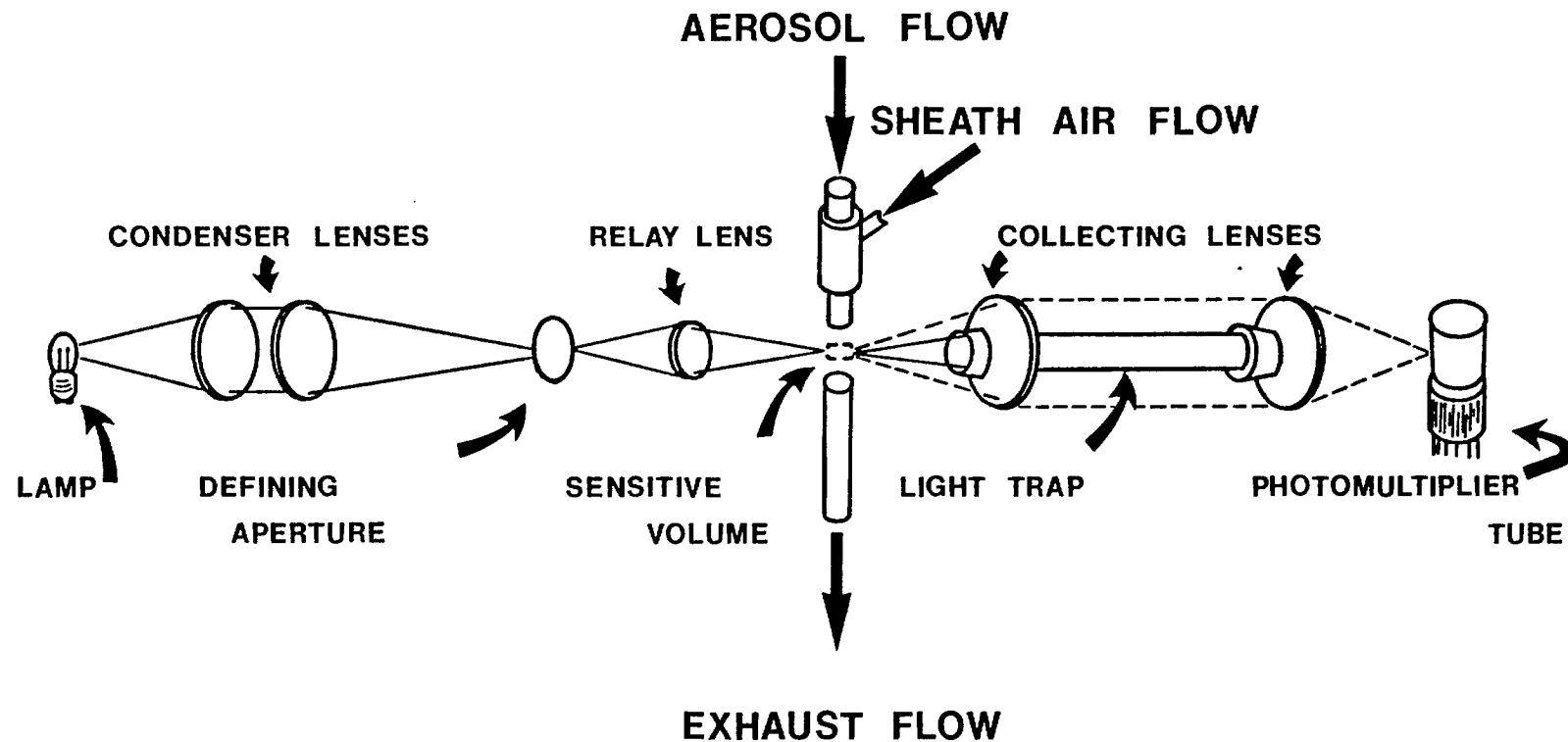


Fig. 2 - The optical system of the HIAC/ROYCO 4100 series of near forward light scattering instruments.

checking of the system.

The input/output modules communicate with the external devices. These may be purely passive data printers, or interactive controlling/data logging computers.

#### SYSTEM PNEUMATICS

The 4102 pneumatic system draws 2.8 L/min (0.1 cfm) from the inlet (Figure 3). This airstream is contained by a 32 L/min column of sheath air. A 0.45  $\mu\text{m}$  absolute filter ensures the sheath air is particle free and able to prevent particles from contaminating lenses in the system.

Figure 3 also depicts a diluter that may be incorporated at the inlet port as it now exists. This again contains an absolute filter. The inclusion of a diluter was one of the major modifications to the system.

#### 4102 LIMITATIONS AND SPECIFICATIONS

The 4102 in its unmodified state has limitations when considering it for use in an underground environment.

The maximum concentration limit of  $4 \times 10^5$  counts/L/min, or total count of  $1 \times 10^6$  counts may be insufficient for some mining operations and locations.

The 4102 system does not accommodate any memory for data storage. Although the system program functions are non-volatile, the data is volatile and could be readily lost during power failure. In addition, the system cannot perform multiple runs and upload data from a remote site.

The 4102 is not readily portable as purchased. It consists of three boxed elements and is not suited to harsh handling. Unmodified, it may be susceptible to stray electro-magnetic noise and is 110 VAC dependent.

Despite the above limitations, of all the near forward light scattering instruments being manufactured, this unit can measure the highest concentration. It has adjustable and programmable sampling, delay and

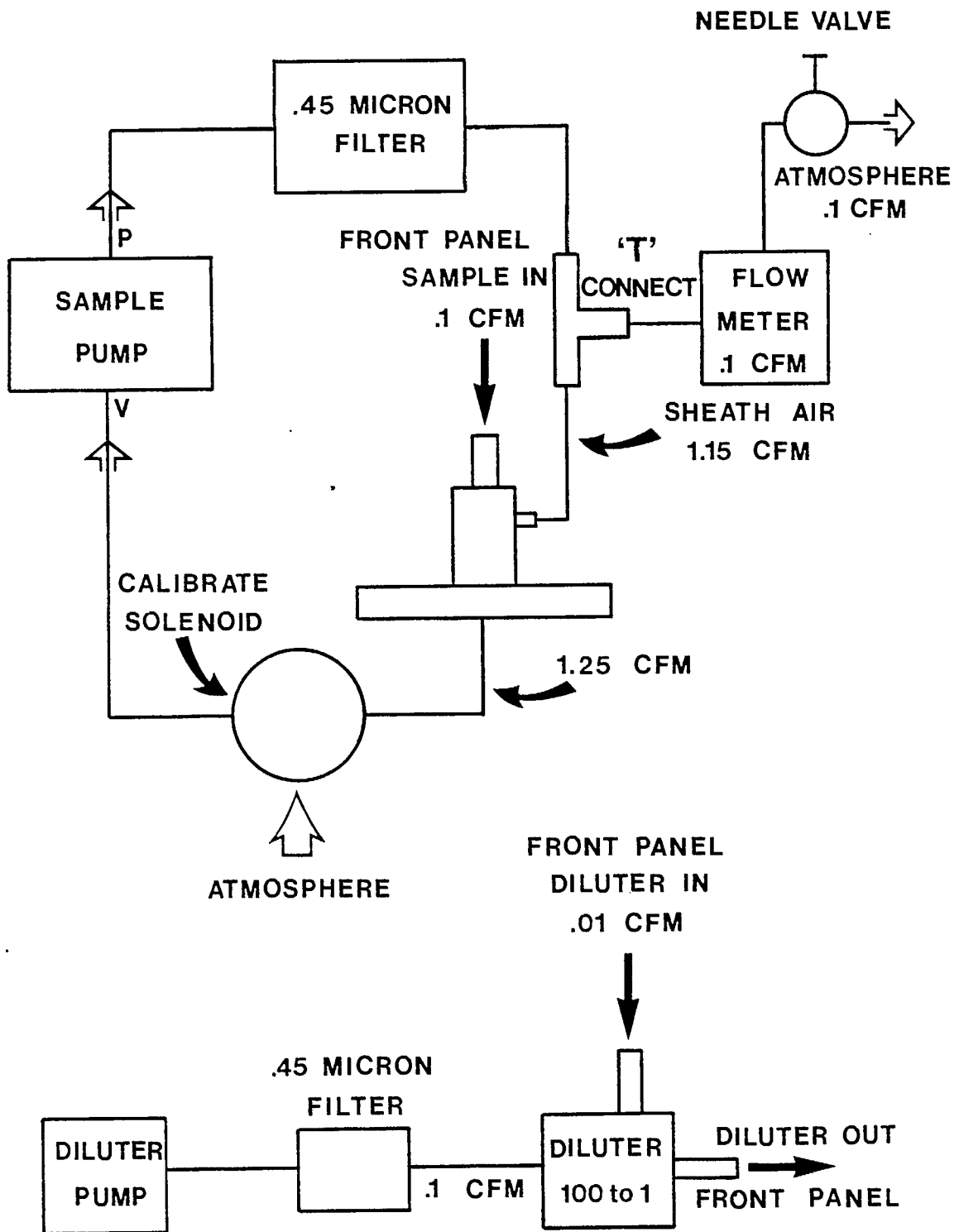


Fig. 3 - The HIAC/ROYCO pneumatic system and optional diluter.

stabilization times, it is a true six-channel analyzer and contains numerous programmable functions. The 4102 is already user friendly, has a membrane keyboard and RS-232 communications port for computer control and data logging facilities.

Most of the above limitations have been removed through extensive modifications and development of software and hardware to control the system.

#### CALIBRATION STANDARDS AND TECHNIQUES

Primary calibration of light scattering instruments is generally performed with monodispersed spherical latex particles (5). The size distribution property reported is the equivalent optical diameter based on the projected area of a spherical particle of known refractive index.

For correlating between instruments intended to monitor a polydispersed environment a secondary calibration procedure is also utilized (6).

#### MODIFICATIONS OF A MODEL 4102 PARTICLE COUNTING SYSTEM TO PERMIT ITS USE IN MINING ENVIRONMENTS

Generally, the areas of modification to the 4102 system were: repackaging for portability and to provide general protection, redesigning power requirements and usage, providing automatic/remote data logging and control capabilities and fabricating an optional high efficiency battery power supply and charger.

#### ELECTRICAL AND ELECTRONIC MODIFICATIONS

Repackaging necessitated the relocation of most of the circuit boards and wiring harnesses, and removal of most of the external wiring. Additional filters were also required to reduce line noise.

Various interlocking switches, relays and time delay circuits were included. These were required to ensure a correct start-up sequence, allow remote activation of pumps when controlled by an external computer and to

smooth the high instantaneous current provided by the remote power supply inverter.

For survey areas where 110 VAC is unavailable it was also necessary to design and fabricate a high efficiency and rugged inverter with rechargeable batteries. The power packs consisted of three 12 V batteries and also required a custom charging system.

#### PNEUMATIC MODIFICATIONS

As shown in Figure 2, the main change to the pneumatics was the inclusion of an optional venturi style diluter. The present flow disc in the venturi port provides a dilution ratio of 100:1. The dilution air is prefiltered and the airstreams mix under turbulent conditions.

#### MODIFICATIONS FOR COMPUTER INTERFACING AND CONTROL

To optimize the use of the aerosol counter extensive work was performed to allow remote control and data logging from a portable self-contained hand held computer (a MEMO unit). This provided a non-volatile memory that could store the data from numerous tests.

Specific software also had to be written for communications and file management between both the MEMO and the particle counter, and between the MEMO and an IBM PC or compatible computer.

Once the data is on a PC it can be readily included in an electronic spreadsheet, such as Lotus 1-2-3\*, with minimal restructuring. The following section shows examples of trials of the particle counter that have been analyzed with a spreadsheet. The optimum presentation of the data has not yet been finalized, the examples produced here are the standard output of Lotus 1-2-3\*.

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\*Trade Mark of Microsoft Inc.

## FIELD STUDIES USING THE MODIFIED PARTICLE COUNTER IN MINING ENVIRONMENTS

To date, the particle counters have been employed in five underground tests, and each occasion has been valuable in showing minor modifications necessary to produce the optimum units. The studies were performed in the following locations:

1. Two evaluations of the counters in a conveyor way where broken ore was being transported from a crusher to an interim storage bunker (7). One of these specifically looked at dust transportation and/or sedimentation.
2. Two investigations in an underground ore crushing room (8,9), one of which was the evaluation of the particulate removal efficiency of a wet filtration unit attached to the crusher.
3. One evaluation of a wet filtration unit attached to an orepass into which broken rock is dumped from train cars (10,11,).

In most of the investigations two particle counters have been used, and the following sections present some of the results from the evaluation of a water type collector at two different mining operations. The type of dust collector being assessed was a 'water scrubber', the Mark III Precipitaire. In both series of evaluations the particle counters were analyzing the air entering and exhausting the collector.

THE EFFECTIVENESS OF A WATER TYPE COLLECTOR AT REMOVING DUST  
GENERATED AT AN OREPASS

The optical particle counters had the following minimum thresholds for their six size ranges: 0.5, 1.5, 3.0, 5.0, 10.0 and 15.0  $\mu\text{m}$ ; they sampled continuously at 2.8 L/min, counted for 30 sec in each minute and used no dilution. The counters were controlled locally through the membrane keyboard and data were logged on a printer. The dust collector was also evaluated on a gravimetric basis, concurrently, using two-stage impactors.

Figures 4 to 9 show selected results from the optical counters. These

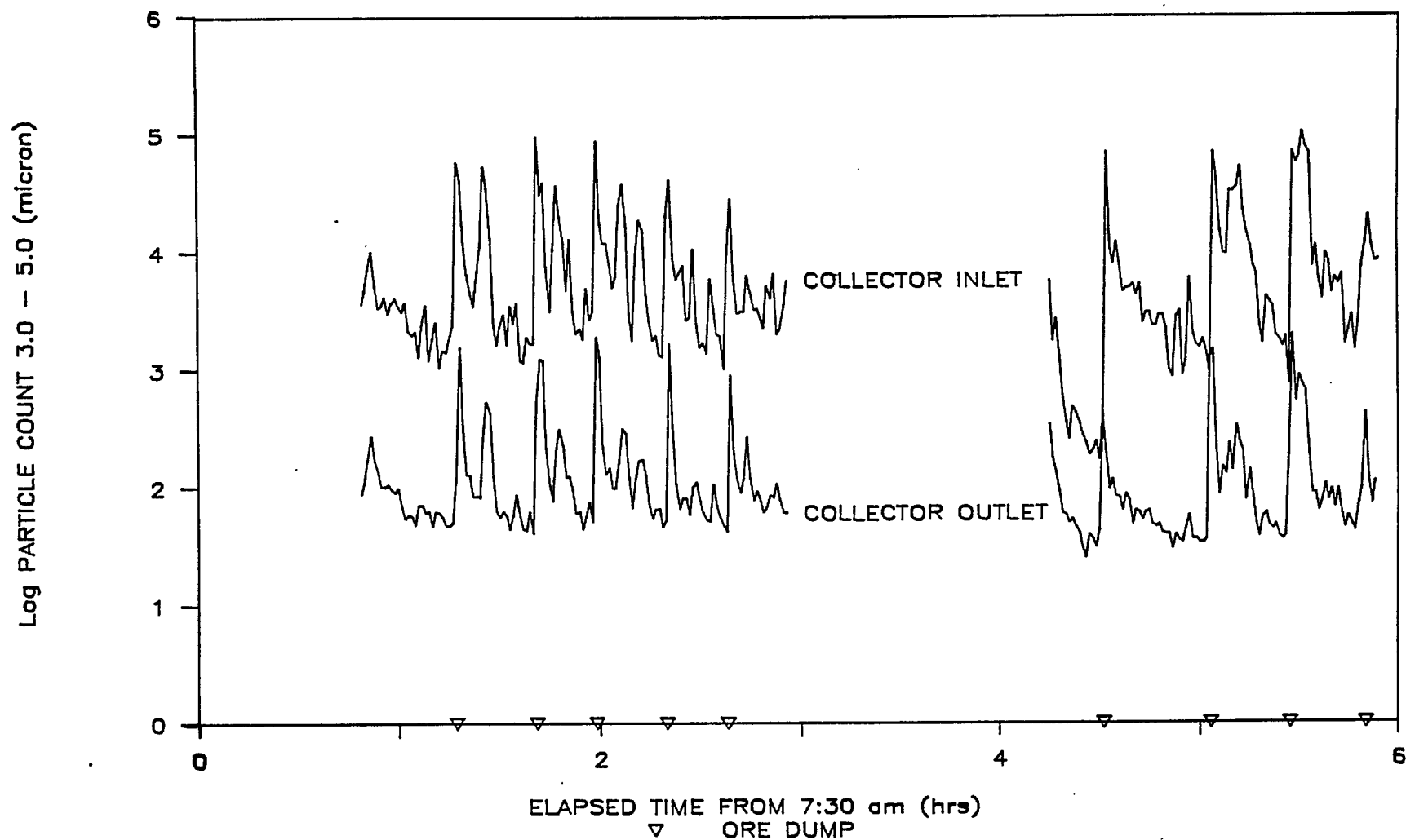


Fig. 4 - Optical particle counts at the inlet and outlet of a wet dust collector at an orepass during dumping operation for 3.0 to 5.0  $\mu$ m diameter particles.



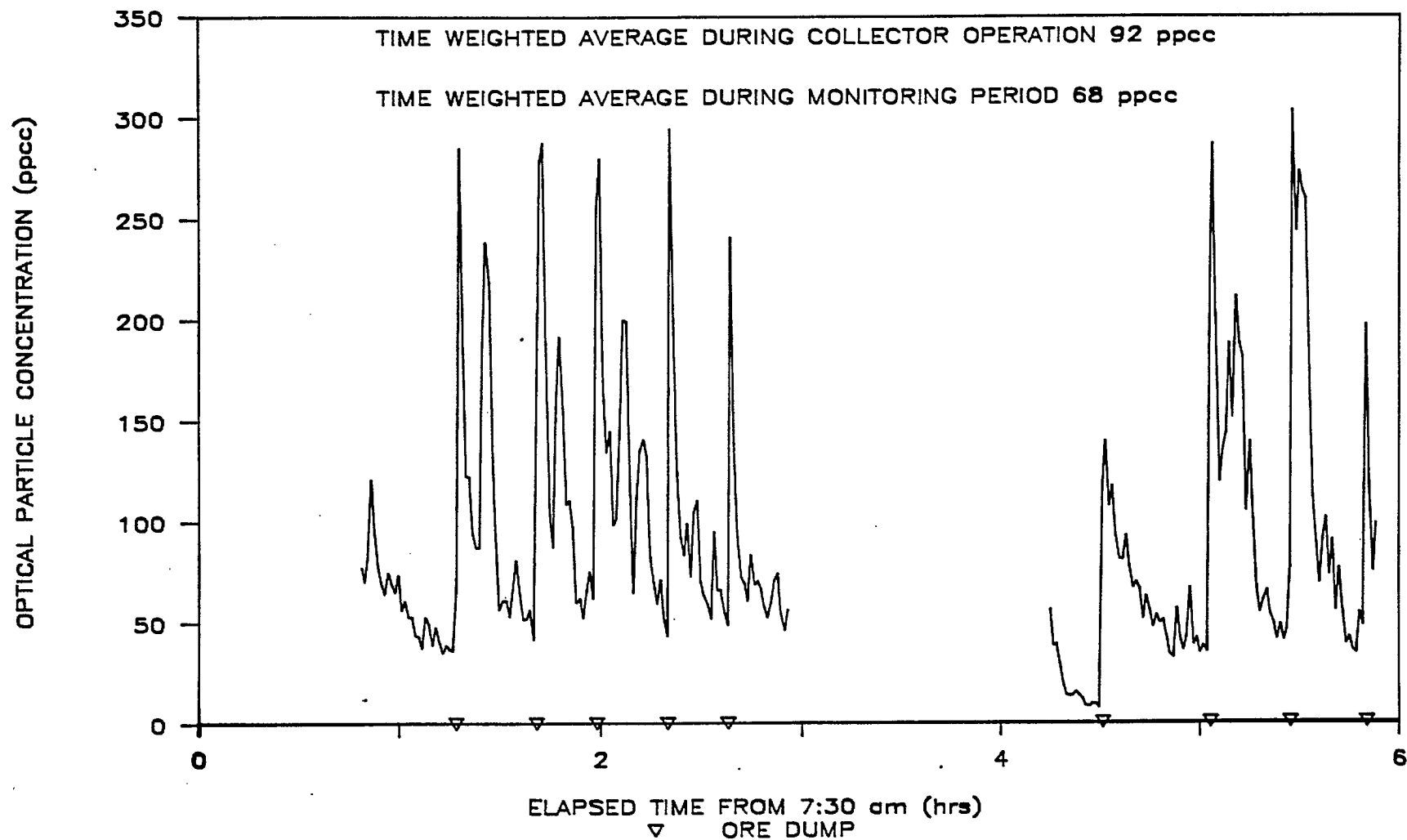


Fig. 5 - Total optical particle count concentration at the orepass dust collector outlet.

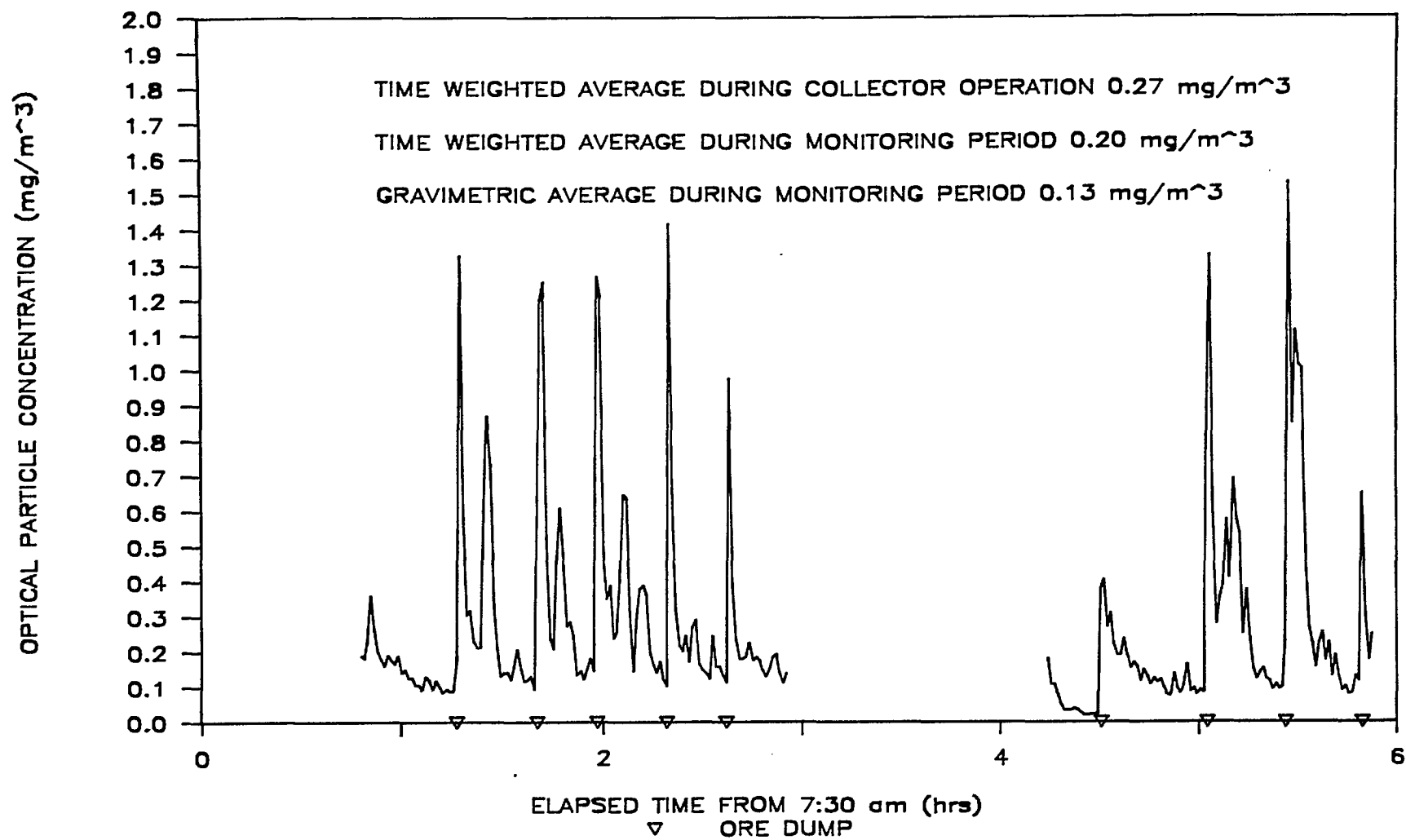


Fig. 6 - Optically derived mass concentration for the orepass dust collector outlet.

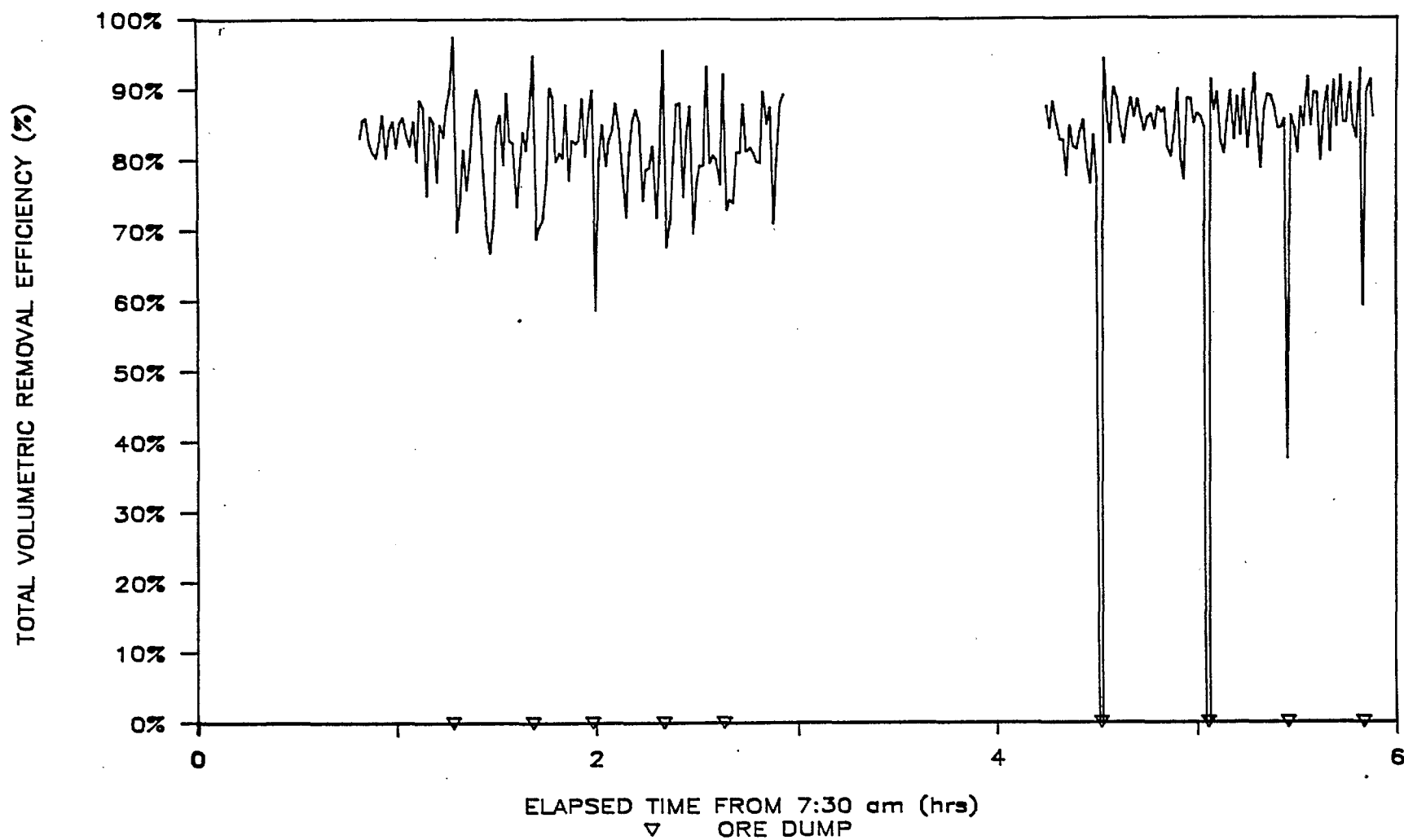


Fig. 7 - Optically derived total particle volumetric removal efficiency for the orepass wet dust collector.

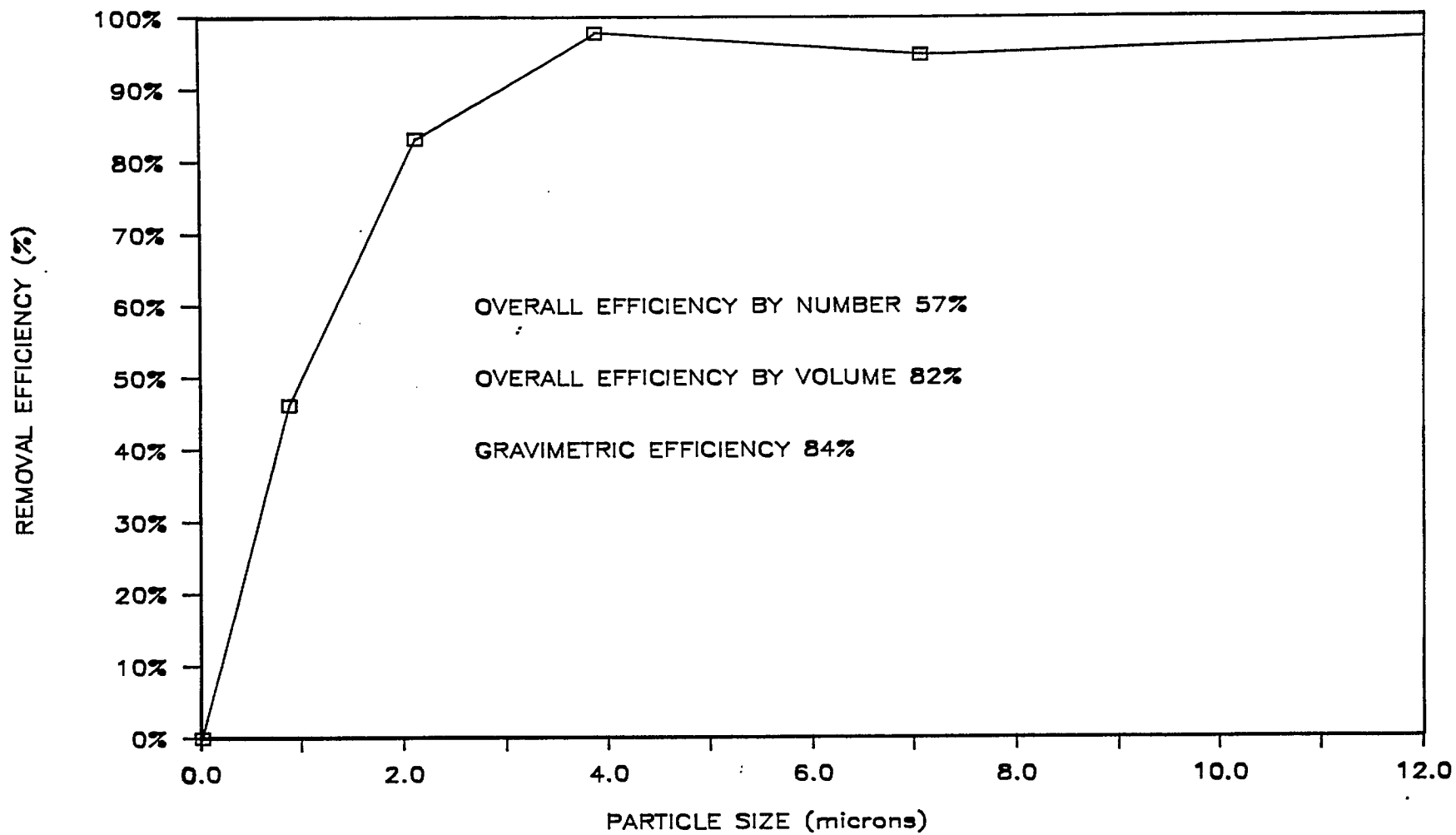


Fig. 8 - Optically derived size differentiated particle removal efficiency curve for the orepass wet dust collector.

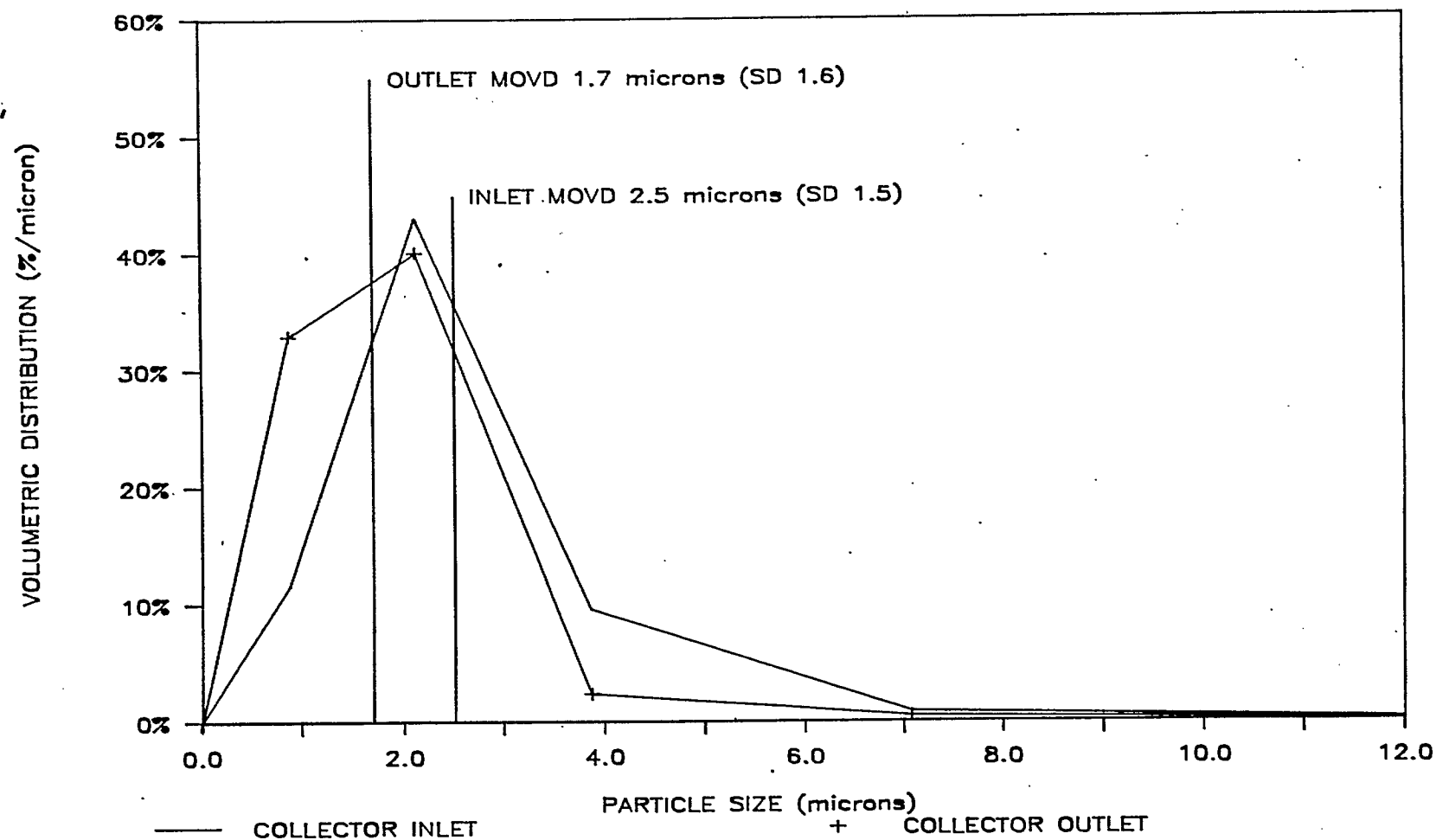


Fig. 9 - Optically derived differential inlet and outlet aerosol size distributions at the orepass dust collector.

range from the basic raw data for a single channel to derived results on converting the count readings into mass.

#### General Dust Conditions

Figure 4 shows the basic time history of the number of particles in the 3.0 to 5.0  $\mu\text{m}$  size range as measured at the collector inlet and outlet. The good vertical separation of the two inlet and outlet traces is representative of the good collection efficiency of the unit at this size range. Similar traces could be drawn for the other five size ranges.

The primary peaks of the time history traces all correspond with ore dumping operations. During the first half of each trace there are distinct secondary and tertiary peaks, at about 7 minute intervals.

On occasion, the inlet counter became saturated with particles and resulted in coincidences in the sensing volume. This caused lower counts in the smaller size ranges and higher counts in the larger size ranges. As a result of this, some of the collected inlet data has been omitted when deriving individual size efficiencies of the collector and TWA values. The diluter was not used as the 100:1 ratio was too extreme. No saturation was encountered at the outlet counter and this trace can be assumed to be fully representative of the conditions at the collector exhaust.

In mining, dust exposures are normally quantified in terms of concentrations. Optical counter data can readily be converted into particle number concentrations, similar to konimeter results. Also converting volume into mass, data may be compared to those of other optical sensors.

#### Dust Collector Outlet Concentration

Figure 5 gives the time history of the dust collector exhaust concentration in terms of particles per cubic centimetre (ppcc). This is derived from the total particle count, the flow rate, and counting time. Again the trace shows peaks, to a maximum 300 ppcc, occurring at dumping

times. The peaks are relatively short-lived and would bias any assessment if taken in isolation. Between peaks the concentration decays to acceptable levels and produces a TWA of ~70 to 90 ppcc depending on whether a non-operational period is included.

A more extensive treatment of optical counter results through conversion to volumes can provide the outlet trace in gravimetric terms (Figure 6). Here the concentration is in the more typical terms of milligrams per cubic metre ( $\text{mg}/\text{m}^3$ ). This treatment shows peaks of  $1.5 \text{ mg}/\text{m}^3$ , and TWA of ~0.2 to  $0.3 \text{ mg}/\text{m}^3$ . These are significantly higher than those using a gravimetric method and could be the result of: i) omitting a shape factor correction; and ii) not correcting these total masses into their respirable mass concentration.

#### Dust Collector Removal Efficiencies

Through converting both inlet and outlet counts to total volumes it is possible to obtain a time history of the collector's overall efficiency (Figure 7). For the majority of the evaluation period this varied between 70 and 95%. All the values significantly lower than this probably correspond with coincidences occurring in the inlet counter and are not representative.

The efficiency of the collector can also be calculated for each of the six size ranges. Ignoring the occasions of coincidence and saturation in the inlet counter, an overall efficiency curve has been obtained (Figure 8). As is the nature of this type of wet dust collector, it is least efficient in small size ranges and very efficient in larger size ranges. In this instance the optical counters show the collector to be 45% efficient for particles 0.5 to  $1.5 \mu\text{m}$  optical diameter and >95% for particles larger than  $3.0 \mu\text{m}$ .

The particle counters show the collector to have a TWA overall removal efficiency of 82% by volume and 57% by particle number, the latter number seeming low only because of the predominance of small particles. The volume

efficiency compares well with that from a gravimetric method of 84% (10). This comparison is better than for the preceding TWA mass concentration at the outlet as it is not dependent on shape factors.

#### Inlet and Outlet Particle Size Distributions

A volumetric analysis also provides percentage size distributions of the dust clouds entering and leaving the collector (Figure 9). The mean optical volumetric diameter (MOVD) and its standard deviation can be obtained from the cumulative form of the data.

The distributions shown indicate a reduction in the mean diameter as the cloud passes through the collector. This is a pure reflection of the preferential removal of larger particles over smaller ones by the collector.

#### THE EVALUATION OF A WET DUST COLLECTOR AT A CRUSHING OPERATION

The previous test with the optical counters highlighted that few particles of greater than 10  $\mu\text{m}$  were being counted and greater detail was needed at smaller sizes. The optical counter thresholds were redefined as 0.5, 1.5, 2.0, 3.5, 5.0, and 10.0  $\mu\text{m}$ . During this study the counters were operated in their fully automatic mode with computer control and data logging. The sampling flow rate was 2.8 L/min with no dilution, and the units counted for 48 sec in each 2-min period. A gravimetric analysis was also performed on the dust collector using 8-stage cascade samplers (8).

Figures 10 to 15 depict some of the results from the dust collector evaluation, as produced using standard spread-sheet software. Excepting Figure 10, which has a smaller size range, the remaining diagrams may be directly compared with the previous evaluation.

#### General Dust Conditions

Figure 10 presents the basic time history, on a two minute base, of particles counted both at the inlet and exhaust of the collector for the 3.5 to 5.0  $\mu\text{m}$  size range. In comparison to the dumping operation the crushing



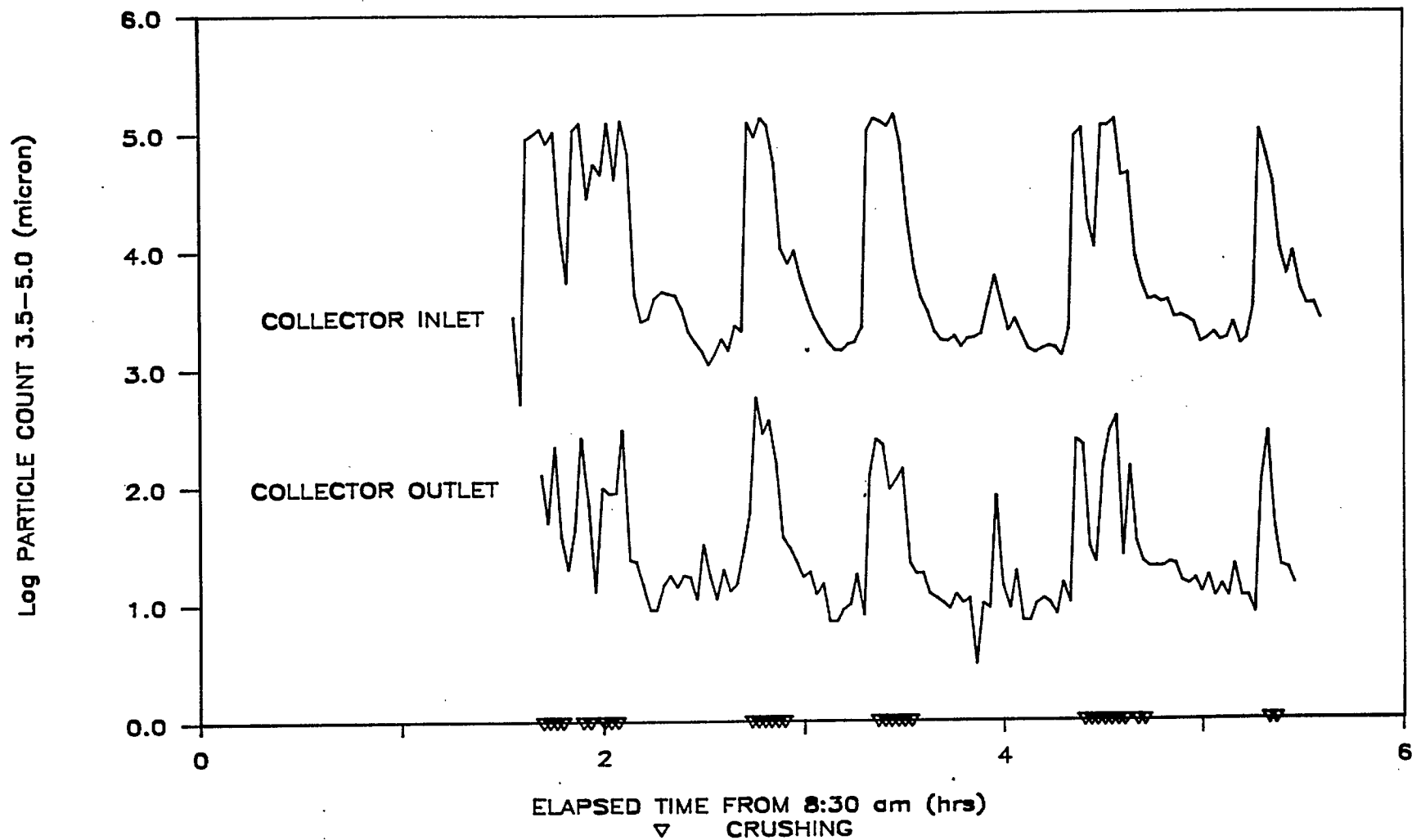


Fig. 10 - Optical particle counts at the inlet and outlet of a wet dust collector at a crushing operation for 3.5 to 5.0  $\mu$ m diameter particles.

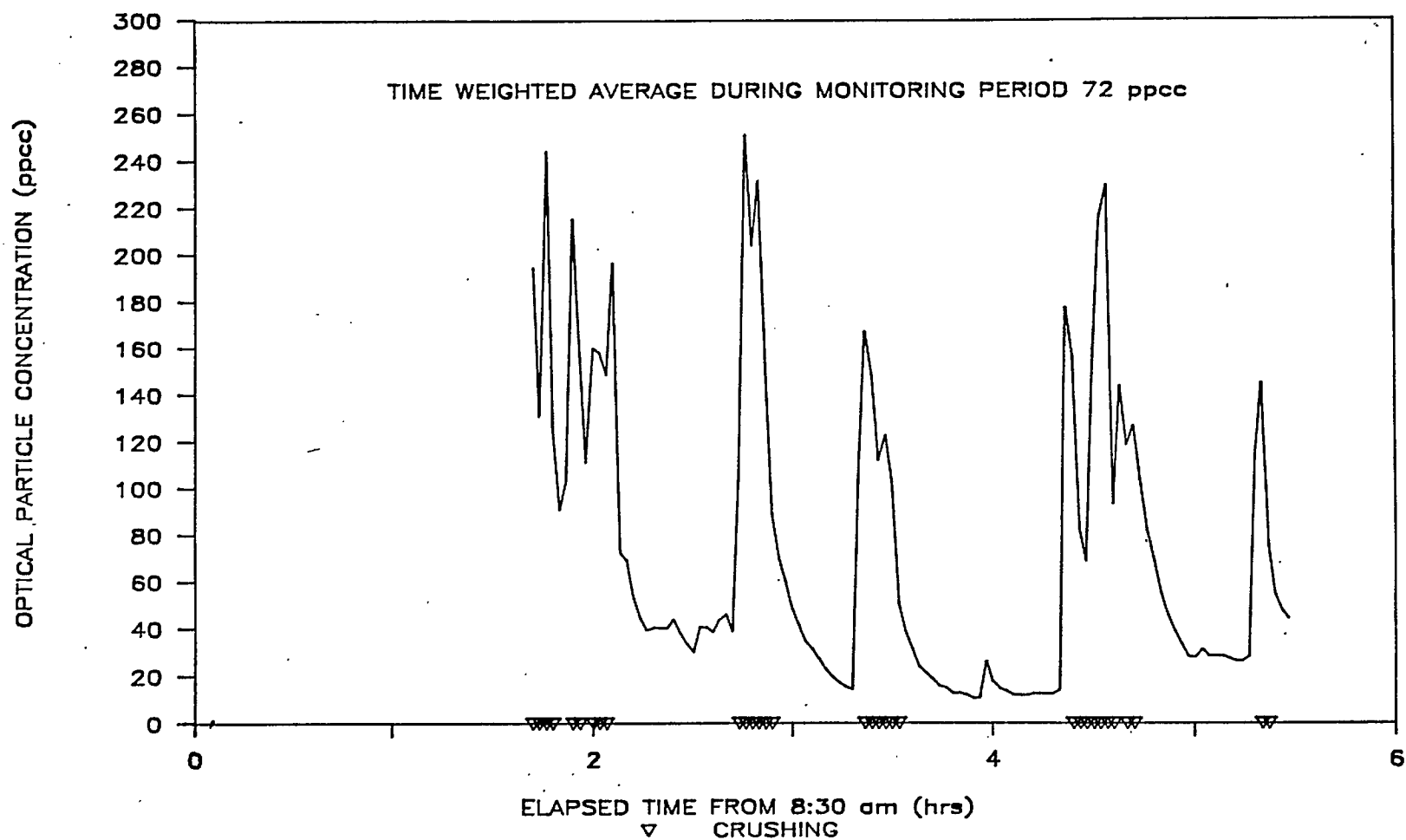


Fig. 11 - Total optical particle count concentration at the crusher dust collector outlet.

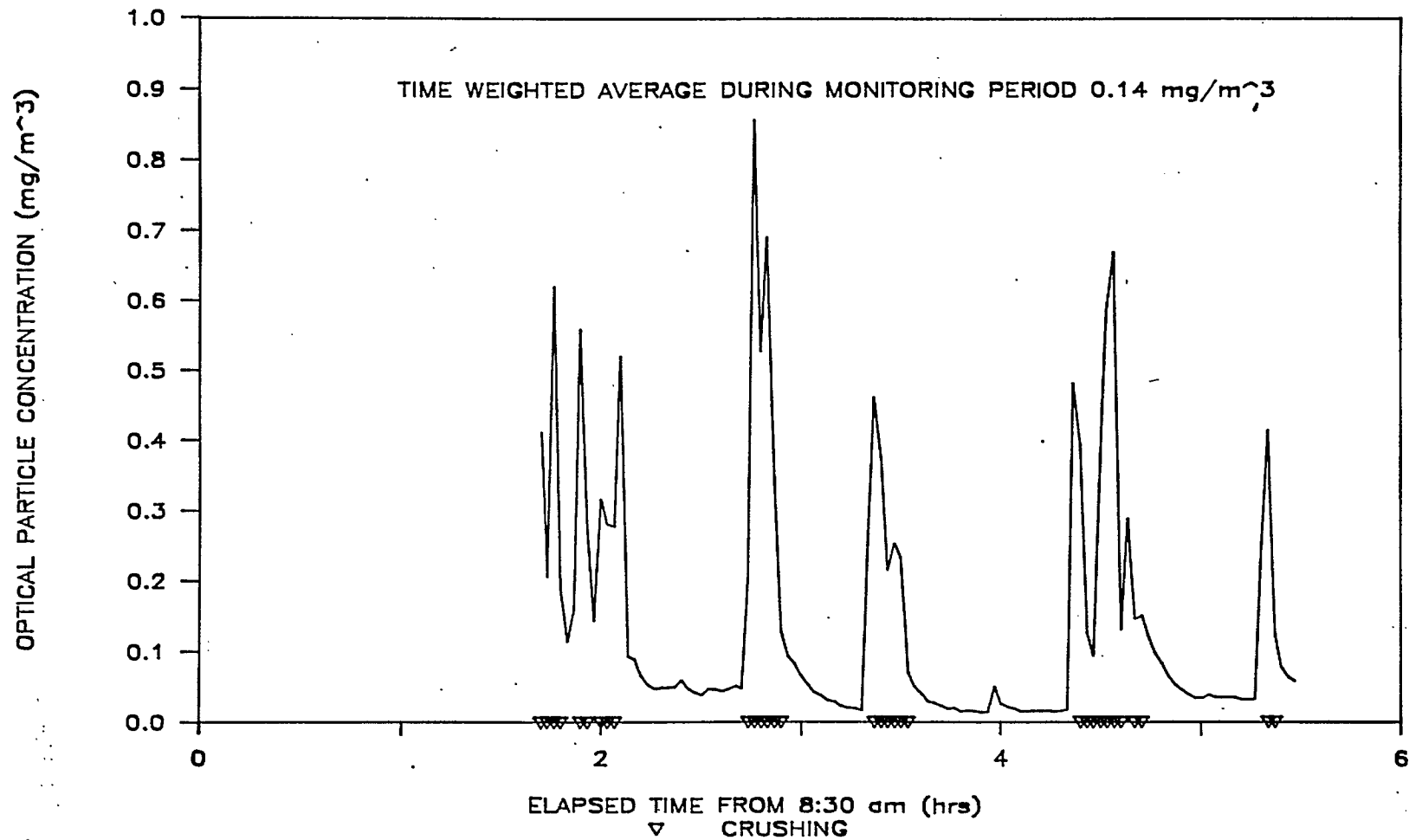


Fig. 12 - Optically derived mass concentration for the crusher dust collector outlet.

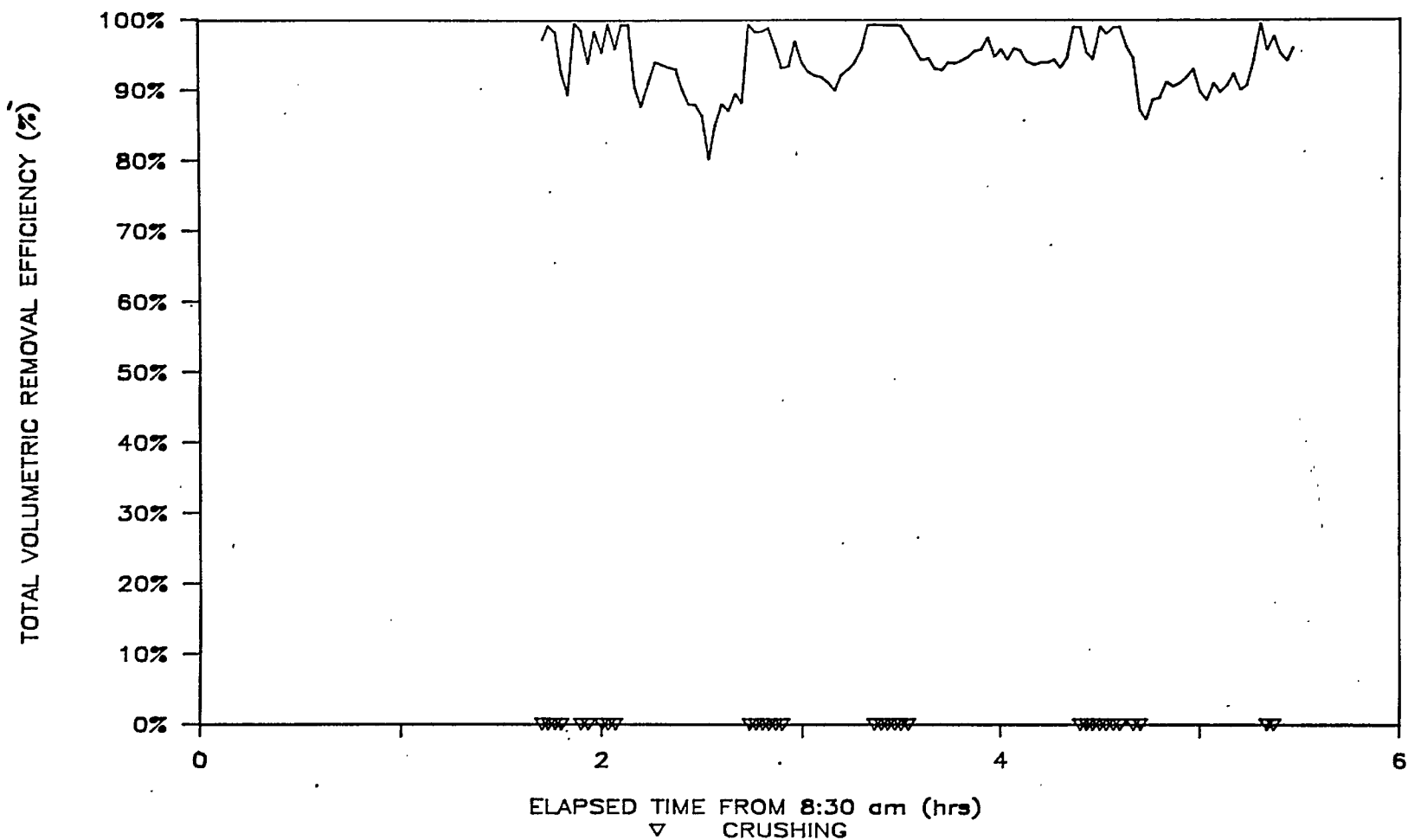


Fig. 13 - Optically derived total particle volumetric removal efficiency for the crusher wet dust collector.

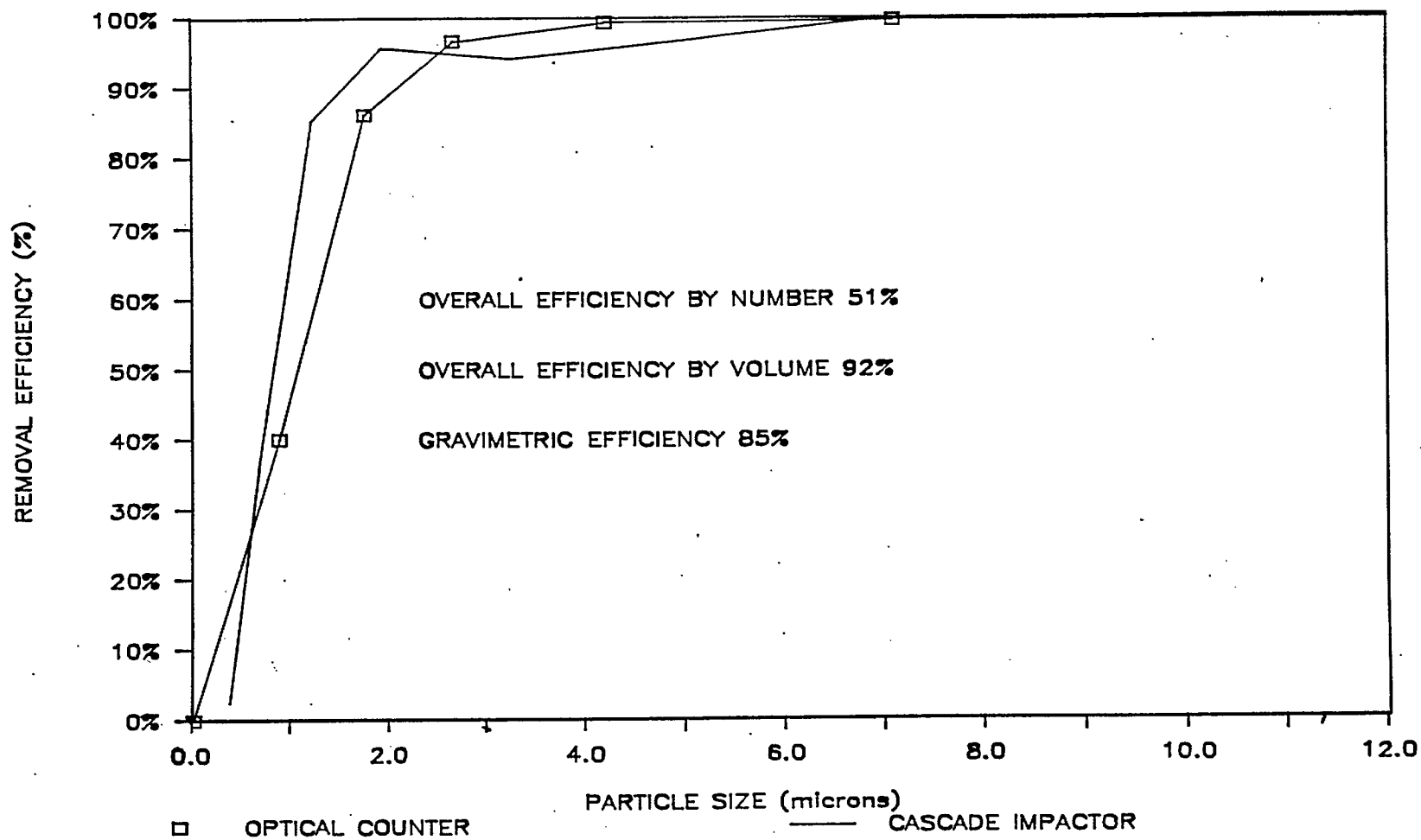


Fig. 14 - Optical and gravimetric derived size differentiated particle removal efficiency for the crusher wet dust collector.

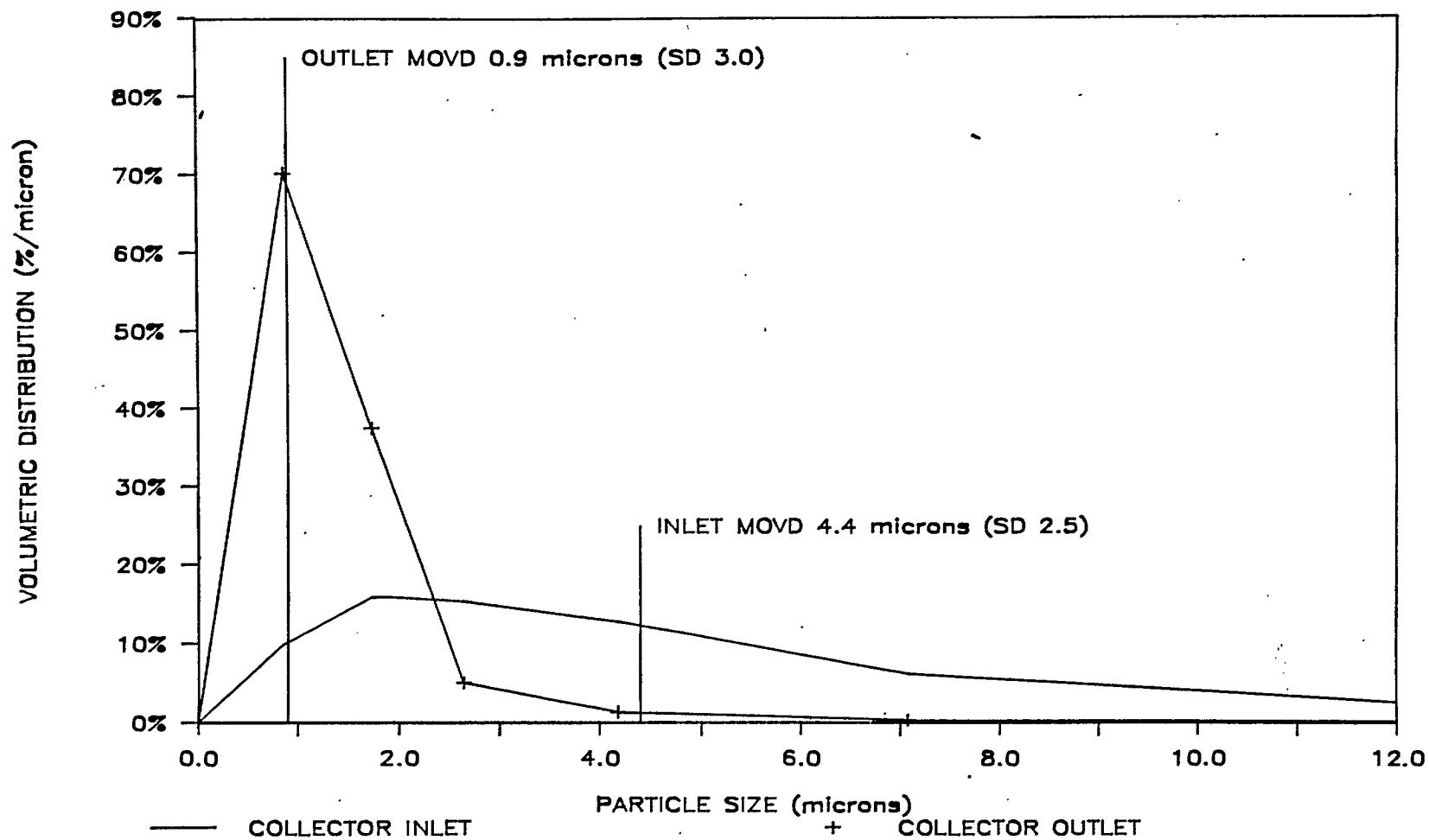


Fig. 15 - Optically derived differential inlet and outlet aerosol size distributions at the crusher dust collector.

operation lasts considerably longer, and this is reflected in the duration of the peaks. In this instance the peaks rapidly decay both in the inlet and outlet on the cessation of crushing. This demonstrates that the collector and its infrastructure are well designed to minimize the crusher contribution of dust to the mining atmosphere.

As with Figure 4, the good vertical separation of the two traces is indicative of the collector's efficiency at this size range. Again the inlet counter became saturated on occasion, but the dilution option was not used because it made the unit too insensitive at other times.

#### Dust Collector Outlet Concentrations

The total numerical count and converted gravimetric concentration exhausted from the collector are presented as a time history in Figures 11 and 12. This collector's exhaust air is cleaner than with the previous unit at the orepass: a) the TWA concentrations were reduced from 98 to 72 ppcc or from 0.27 to 0.14 mg/m<sup>3</sup>; and b) the maximum concentrations were reduced from 300 to 250 ppcc, or from 1.5 to 0.85 mg/m<sup>3</sup>.

#### Dust Collector Removal Efficiency

The time history total volume removal efficiency trace for the unit (Figure 13), shows variations between 80 and virtually 100% removal. No significant low values and the generally higher overall efficiency of this unit is a function of larger particles being more numerous.

Figure 14 shows the collector efficiency by size range. This unit seems more efficient in all ranges, however, for the large sizes this can be attributed to calculating with larger initial inlet numbers. Also shown is the collection efficiency of the unit as derived with cascade samplers and the two curves show reasonable agreement.

For this wet collector, the optical counters show it to be >86% efficient at removing particles larger than 2.0  $\mu\text{m}$  and >96% efficient at 3.5

$\mu\text{m}$  and larger. Overall the particle counters gave a removal efficiency of 92% by volume and 51% by number, while the gravimetric samplers exhibited the unit to be 85% efficient at collecting particles.

#### Inlet and Outlet Particle Size Distributions

The optically derived percentage size distributions of the clouds entering and leaving the collector are distinctly different. Figure 15 shows the inlet distribution to be broad with a large MOVD, whereas the outlet has a small MOVD comparable with that from the orepass unit. This significant reduction in mean diameter emphasizes the collector preference for removing large particles and leaving an aerosol more concentrated in smaller particles to be exhausted.

### DISCUSSION AND CONCLUSIONS

The development of a portable computer controlled multi-size range real-time aerosol counter for underground use has been successful. The two HIAC/ROYCO 4102 optical particle counters, as modified by Mono Instruments Ltd., have been proven to work under mining conditions and be able to count typical high dust concentrations.

Through investigations and counter trials to date, the only shortcoming of the instruments is the dilution unit. Two trials of the counters, in association with dusty mining operations, proved to produce aerosols too concentrated for the units to measure at their normal sampling flow rate. However, on dilution, at 100:1 ratio, the units could readily handle the concentration, but detail for particles larger than  $3.5\mu\text{m}$  was limited. This can easily be corrected by changing the air regulating orifice in the diluter. The optimum dilution ratio is being finalized and will probably be ~20:1.

The data manipulation and presentation performed on a PC, still needs improvement. At present the analysis of the large data files generated is very



cumbersome and time consuming. Until protocols for data analysis and presentation have been finalized and the associated program macros completed, all decisions have to be made by the analyst and most data manipulation operations made through the keyboard.

Field trials with the particle counters have demonstrated the unit's versatility and possible applications in future work. The trials on the collectors show how the data from the counters can be presented in six different formats depending on requirements. The main advantage of the units is their ability to provide real-time information immediately on the particle counts at different sizes. This is easily converted to particle concentration as measured by konimeters. Through numerical methods the data can also provide the mass concentration and the mass size distribution on a real-time basis and in terms of a time-weighted average.

The dust collector study demonstrated how the unit can be used to assess dust removal methods and their efficiency dependence on size. It also provides valuable information on the character of dust producing operations. This includes: dust mass distribution; dust production duration; how long the operation affects an area after its cessation; and how efficiently ventilation and suppression, or removal methods, are at controlling the dust contribution to the mine atmosphere. Such information is essential, firstly to gain a greater understanding of dust and its control in the mining environment, and secondly, as a consequence to reduce the inhalation health risks and workers exposure.

For example, consider the described investigation of two identical water type collection units operating at different dust producing operations. Here the optical counters have shown the collector overall mass removal efficiency to vary from 82% at an oredump up to 92% at a crusher, purely because the crusher produces a coarser dust and the collectors removal

efficiency is size dependent. Although not the case here, a collector only 82% efficient may not be good enough for its designed duty. Therefore, consideration must be given to the size distribution of the product to be removed before employing such a water type collector, and this can be readily provided by a particle counter.

It is expected that the particle counters will prove invaluable as an engineering tool in future dust studies performed by the Mining Research Laboratory, Elliot Lake.

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