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VENTILATION REQUIREMENTS FOR GRINDING, BUFFING, AND POLISHING OPERATIONS

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Mechanical finishing
Air circulation

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ABSTRACT

Criteria have been developed for the design and operation of ventilation systems used with industrial grinding, buffing, and polishing equipment. These criteria are based on the requirement that equipment operators not be exposed to concentrations of airborne particulate materials exceeding the threshold limit values for these materials. Ventilation criteria have been developed for each of nine classes of equipment which include most types of industrial equipment in current use. The criteria were formulated from analytical models of particle transport processes around grinding equipment and were verified by measurements of ventilation system performance. Both the analysis and the measurements have revealed the existence of an optimum ventilation condition for each type of equipment. At this condition, maximum ventilation effectiveness is achieved at minimum ventilation flow rate. Ventilation systems in current use, when operated at the optimum ventilation condition, are found generally to provide effective control of inert particulate materials.

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The investigation was conducted by the Environmental Research Group of IKOR Incorporated under the direction of Dr. E. Karl Bastress. Mr. Albert E. Nugent, Jr., conducted the performance measurement task with the assistance of Mr. Lawrence J. Griffin. Mr. John M. Niedzwecki conducted the performance analysis task.

Substantial support was provided in this program by the Norton Company of Worcester, Massachusetts. The Norton Company provided grinding test facilities for use in the measurement of ventilation system performance, and also provided consultation in grinding technology. The Norton Company support in grinding technology was directed by Mr. Frederic S. Gibb with the assistance of Mr. Leonard J. Piccinino, Mr. James A. Seymour, and Mr. Donald E. Blomquist of the Grinding Wheel Division. Participation in polishing and buffing technology was directed by Mr. Dirck Olton of the Coated Abrasives Division.

Information on grinding, buffing, and polishing equipment and abrasive materials was provided freely by many manufacturers of this equipment and these materials.

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1. INTRODUCTION

1.1 Objective

This report presents the results of an investigation of the design and performance of ventilation systems used for the control of dust generated by industrial grinding, buffing, and polishing equipment (referred to in the remainder of this report as GBP equipment). The objective of the investigation was to formulate criteria for the design and operation of ventilation systems used with GBP equipment. The criteria are intended to prevent the exposure of GBP equipment operators to excessive concentrations of airborne dust.*

Because of the diversity of types of GBP equipment and the operations performed with this equipment, the investigation was directed toward one segment of GBP operations which involves the majority of GBP equipment operators. The operations which were investigated directly include all dry abrasive machining and processing of metals. However, the criteria which have resulted from the investigation are considered to be applicable also to the abrasive machining of non-metals. Orientation of the investigation toward dry processing of metals was considered necessary in order to achieve an adequate depth of understanding of the subject and to derive reliable ventilation system design criteria.

1.2 Approach

The formulation of ventilation system design and operating criteria, which was the objective of the investigation, was achieved by means of an approach involving three distinct steps as follows:

a. Classification of GBP equipment and operations.

b. Measurement of ventilation system performance

c. Formulation of ventilation system design and operating criteria.

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*Program purpose and scope of work, as specified in contract, are presented in Appendix H.

In the classification step, various types of GBP equipment in current use were reviewed and divided into classes according to their ventilation system design requirements. Each equipment class includes machines which require ventilation systems of the same general configuration, and hence, which can be designed according to the same criterion. In the classification step, GBP operations also were categorized principally in accordance with the materials being processed and their toxicological activity levels. The classification step served to reduce the large number of GBP equipment types to a reasonable number of classes for which ventilation criteria could be developed.

In the measurement step, procedures were developed for measuring the performance of ventilation systems in terms of the exposure of equipment operators to airborne dust. These procedures were utilized to determine the effectiveness of ventilation systems used with each of the classes of equipment defined in the previous step. The measurement step provided ventilation system performance data which served as a basis for the formulation of ventilation system design criteria.

In the criteria formulation step, analyses were conducted of the transport mechanisms which affect the movement of dust particles generated by GBP equipment. These analyses provided a basis for a mathematical model of the breathing zone concentration of dust particles and the dependence of this concentration on the design and operating characteristics of the machine and its ventilation system. The breathing zone dust concentration model was used to correlate the data from the measurement step for each class of GBP equipment. The data correlations were used subsequently in the formulation of ventilation system design and operating criteria. The resulting criteria are presented in this report in a format similar to that used in the Industrial Ventilation Manual (Ref 1).

1.3 Report Contents

In the remainder of the body of this report, the procedures used in the classification, measurement, and criteria formulation steps are described, and the principal results of the investigation are summarized. The procedures and results are described in more detail in a series of appendices found at the end of the report. An additional appendix is included which contains a bibliography of references which have been found to be relevant to the subject of the investigation.

2. GRINDING, BUFFING, AND POLISHING EQUIPMENT AND OPERATIONS

2.1 GBP Equipment

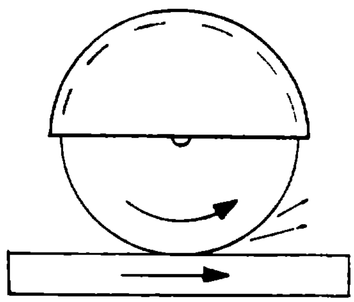
This investigation has been concerned with equipment used in three categories of abrasive machining and processing: grinding, buffing, and polishing. The term grinding has been interpreted in this investigation as including operations involving the use of bonded abrasive wheels, or "hard-wheel" grinding. The term buffing has been interpreted as including operations involving the use of circular buffs of fabric combined with loose abrasive materials applied in a liquid or grease carrier. The term polishing has been interpreted as including operations involving the use of abrasive-coated fabrics used in the form of belts, discs, or wheels, otherwise referred to as "coated-abrasive" operations. As mentioned previously, the investigation has been directed primarily toward grinding, buffing, and polishing of metals.

Specific types of machines in each category generally are designated by the types of operations they perform such as surface grinder, internal grinder, or cutting-off machine. Other types of machines are designated by the configuration of the machine such as pedestal grinder, disc grinder, or portable grinder. To conduct an investigation of ventilation requirements, it has been necessary to define a different classification system based upon the configurations of ventilation equipment used with the various types of machines. This ventilation-oriented classification system has been used effectively as a basis for formulating ventilation system design criteria. However, in order to relate the criteria to the machine designations used in industry, it is necessary to relate the ventilation classification system to the more commonly used machine designations. This relationship is presented in Table I. It is observed from the table that all types of GBP equipment have been separated into nine classes based upon their ventilation equipment requirements. The characteristics of the classes of machines which dictate the ventilation system design are indicated schematically in Figure 1. The rationale for defining the classes and assigning various machine types to the classes is discussed in Appendix A.

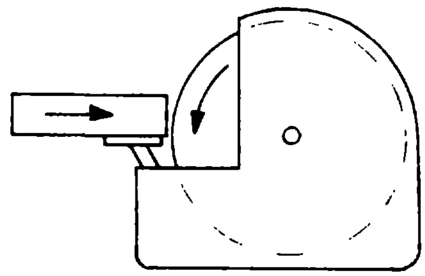
Table I

Classification of GBP Equipment

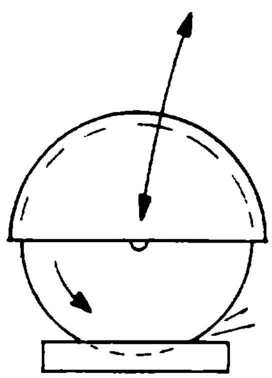
Equipment Classes based on Ventilation System Design	Equipment Types included in Classes
1. Surface-Type Grinders	Surface Grinders Roll Grinders Snaggers Slab and Billet Grinders
2. Pedestal-Type Grinders	Pedestal Grinders Bench Grinders Floorstand Grinders Tool Grinders
3. Abrasive Cutting-Off Machines	Abrasive Cutting-Off Machines
4. Internal Grinders	Internal Grinders
5. Disc Grinders and Polishers	Single Spindle Disc Grinders Double Spindle Disc Grinders Disc Polishers
6. Pedestal-Type Polishers and Buffers	Wheel and Drum Polishers Backstand Idler Polishers Buffing Lathes
7. Belt Grinders and Polishers	Belt Grinders and Polishers (using flat belt surface)
8. Portable GBP Machines	Portable Grinders Portable Polishers Portable Buffers
9. Complex Machines	Multiple-Belt Polishers Multiple-Head Buffers



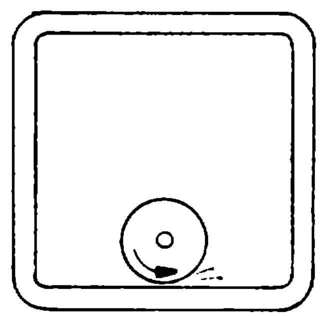
1. SURFACE-TYPE GRINDERS



2. PEDESTAL - TYPE GRINDERS

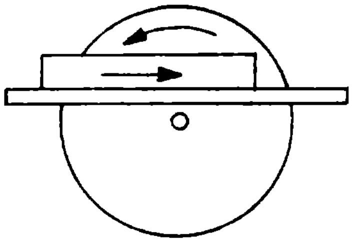


3. ABRASIVE CUTTING-OFF MACHINES

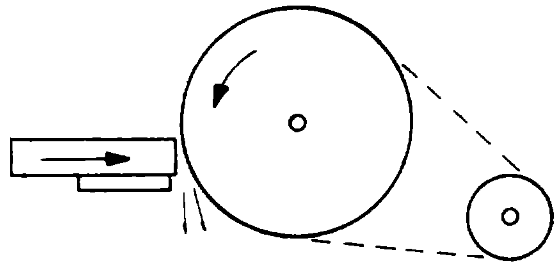


4. INTERNAL GRINDERS

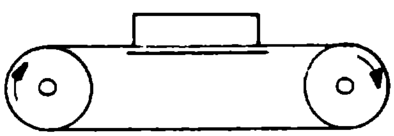
FIGURE 1 - SCHEMATIC DIAGRAMS OF GR[illegible]



5. DISC GRINDERS & POLISHERS



6. PEDESTAL-TYPE POLISHERS & BUFFERS



7. BELT GRINDERS AND POLISHERS

(VARIABLE)

8 AND 9. PORTABLE AND COMPLEX MACHINES

FIGURE 1 (CONTINUED)-SCHEMATIC DIAGRAMS OF GBP EQUIPMENT CLAS- -S

2.2 Ventilation Systems Used with GBP Equipment

2.2.1 Conventional Ventilation Systems

A ventilation system used for control of dust, fumes, vapors, or gases from industrial processes is essentially an air extraction system which withdraws contaminated air from the site of generation of the contaminant. The system consists of a hood which is located near the process and through which the contaminated air is drawn, a conveying duct which carries the contaminated air from the process site, an air mover, and usually an air cleaning device which removes the contaminant from the air. In this investigation, we are concerned only with the design and location of the hood, and the air withdrawal or ventilation rate. Criteria for the design and operation of the other components of the ventilation system are well-developed and are not peculiar to GBP equipment.

A number of attempts have been made to classify ventilation hood designs for general use and for application to GBP equipment in particular (Refs 2, 3, and 4). Classification schemes are based primarily upon the degree to which the hood encloses the source of the contaminant. For this investigation, the authors have adopted a hood classification system similar to that defined by Baturin (Ref 2). Three classes of hood designs are defined as follows:

a. Enclosure or Booth
b. Shaped Collector
c. Captor Hood

An enclosure or booth, as the names imply, is a hood design which partially or completely encloses the source. In the case of GBP equipment, the enclosure may enclose the entire machine, or just that portion of the machine which generates dust, i.e., the grinding wheel or belt. A captor hood, in contrast to an enclosure, does not enclose the machine at all, but is a simple air inlet mounted in close proximity to the dust source. A captor hood induces a flow of air at the dust source which "captures" the particles and entrains them in the ventilation flow. A shaped collector is a hood design intermediate between enclosures and captor hoods. A shaped collector is designed to conform to the shape of the dust source and may partially enclose the source.

It is clear that the distinctions between these hood types are somewhat arbitrary, and in actuality, the transition from enclosure to shaped collector and to captor hood is continuous. However, the design and operating criteria for the various hood classes and their performance characteristics differ markedly, and so it is necessary to distinguish between them.

There also exists a type of ventilation hood referred to as a "low-volume-high-velocity" hood. This hood type consists of a small size hood located close to the point of dust generation and, in some cases, designed to conform closely to the configuration of the grinding machine (Ref 5). Because of its close proximity to the dust source, the ventilation rate required for effective dust control is less than with hoods of conventional size. The authors do not consider the low-volume-high-velocity hood as a unique class but rather a simple extension of the conventional captor hood or shaped collector to hoods of small size. Since the low-volume-high-velocity hood functions in a manner similar to a captor hood, its design-performance relationship can be expected to be similar to that of captor hoods. Consequently, neither a separate classification nor design criterion is considered necessary for low-volume-high-velocity hoods.

Generally speaking, enclosures and booths provide the best ventilation performance in terms of reliability and economy. Dust particles controlled by an enclosure are not susceptible to random air currents in the vicinity of the machine, and the ventilation rate required for effective dust control is less for a well-designed enclosure than for other hood classes. At the other extreme, a captor hood is least reliable and economical. Relatively high ventilation rates are required to achieve effective dust control and the dust capture process may be rendered ineffective by local air currents caused by movements of the machine or its operator. However, the captor hood offers the distinct advantage of maximum freedom of movement about the machine. Hence, from the standpoint of machine utilization, captor hoods are favored and consequently are in widespread use with GBP equipment.

The applicability of the various hood types to the nine classes of GBP equipment is indicated in Table II. Enclosures or booths are considered to be applicable to all types of machines, and are the only hood type applicable to the complex machine class. Shaped collectors and captor hoods are not universally applicable because of machine characteristics which limit the use or effectiveness of these hood types. Typical designs for these hood classes are indicated schematically in Figure 2 for the various equipment classes.

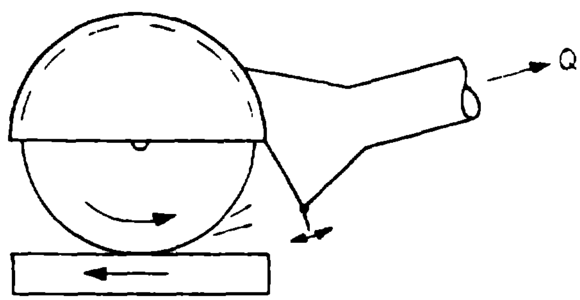
Shaped collectors can be used with most types of machines. With some grinding machines, the shaped collector is integral with the grinding wheel guard. With a polishing or buffing machine, the shaped collector generally is designed to partially enclose the belt or buff and serves also as a guard to protect the operator against belt breakage or workpiece snagging. Certain other machines - notably internal grinders and disc grinders - present severe limitations on the location of ventilation hoods. With these machines, the grinding wheel cannot be enclosed effectively since a large portion of the wheel surface is used in the grinding process. Hoods have been designed for these machines, as shown in Figure 2, which essentially are complex captor hoods designed to conform to the grinding machine contour. Because of the contoured design used with these hoods, they have been classified here as shaped collectors.

As indicated in Table II, captor hoods are considered applicable only to surface-type grinders and pedestal-type polishers and buffers. Captor hoods are not applicable to pedestal-type grinders as their use is precluded by the requirement for a grinding wheel guard which nearly encloses the wheel. Captor hoods are not applicable to machines such as disc grinders because the flow of swarf (grinding

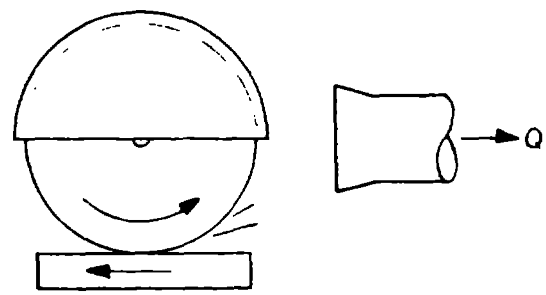
Table II

Classification of GBP Equipment and Ventilation Hoods

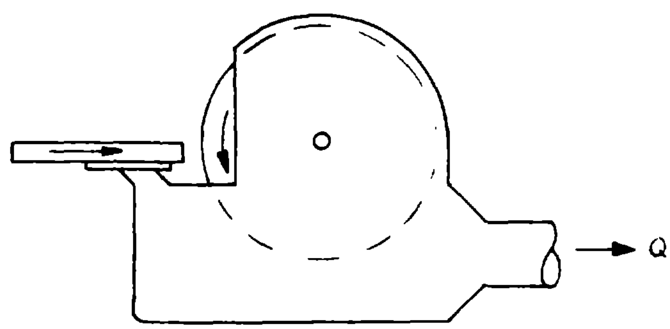
Equipment Class	Ventilation System Class		
	Enclosure or Booth	Shaped Collector	Captor Hood
1. Surface-Type Grinders	Applicable	Applicable	Applicable
2. Pedestal-Type Grinders	Applicable	Applicable	Not Applicable
3. Abrasive Cutting-Off Machines	Applicable	Applicable	Limited Applicability
4. Internal Grinders	Applicable	Applicable	Not Applicable
5. Disc Grinders & Polishers	Applicable	Applicable	Not Applicable
6. Pedestal-Type Polishers & Buffers	Applicable	Applicable	Applicable
7. Belt Grinders and Polishers	Applicable	Applicable	Not Applicable
8. Portable GBP Machines	Applicable	Applicable	Not Applicable
9. Complex Machines	Applicable	Not Applicable	Not Applicable



1A. SURFACE - TYPE GRINDERS WITH SHAPED COLLECTOR

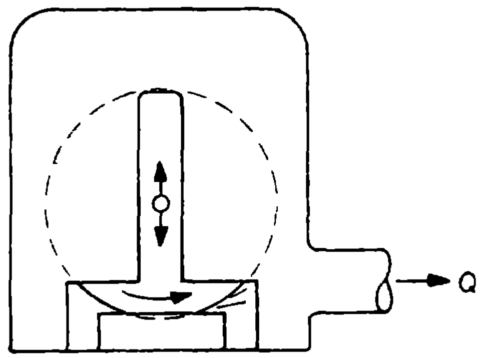


1B. SURFACE - TYPE GRINDER WITH CAPTOR HOOD

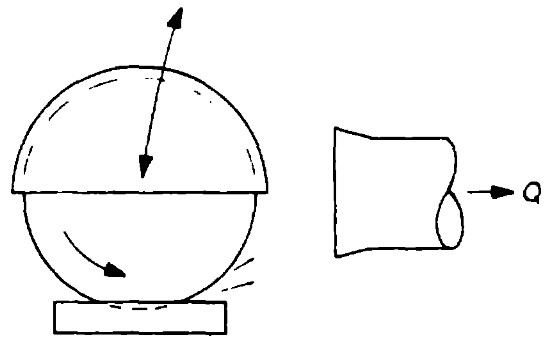


2. PEDESTAL - TYPE GRINDER WITH SHAPED COLLECTOR (HOOD IN GUARD)

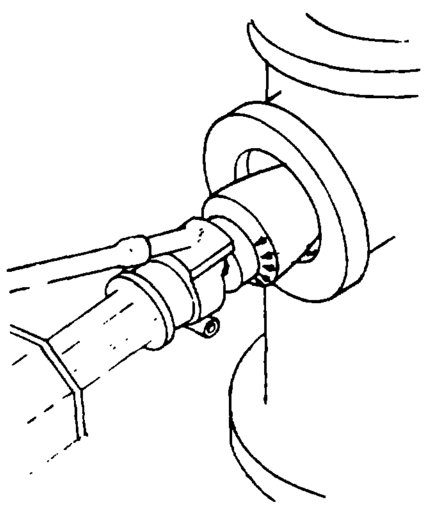
FIGURE 2- SCHEMATIC DIAGRAM OF [illegible] VENTILATION HOODS



3A. ABRASIVE CUTTING-OFF MACHINE WITH SHAPED COLLECTOR

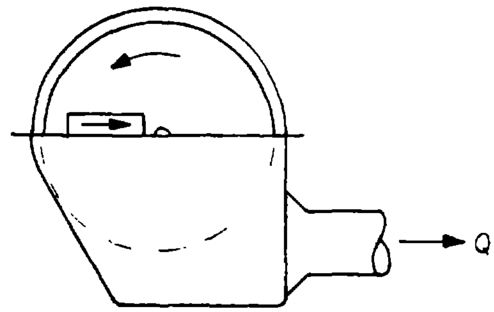


3B. ABRASIVE CUTTING-OFF MACHINE WITH CAPTOR HOOD

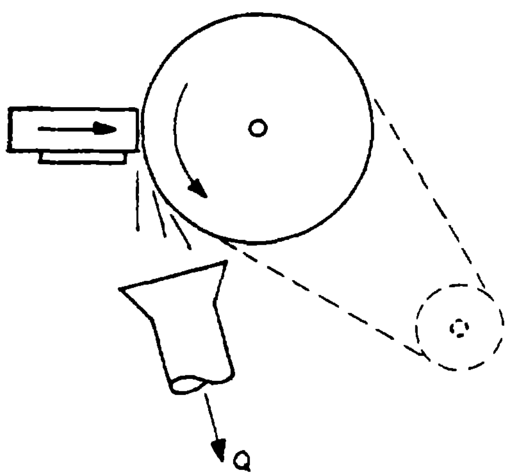


4. INTERNAL GRINDER WITH SHAPED COLLECTOR

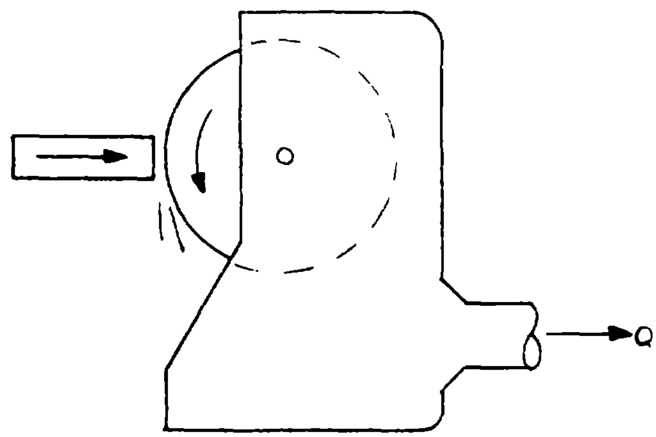
FIGURE 2 (CONTINUED) - SCHEMATIC DIAGRAM OF GBP EQUIPMENT AND VENTILATION HOODS



5. DISC GRINDER OR POLISHER WITH SHAPED COLLECTOR

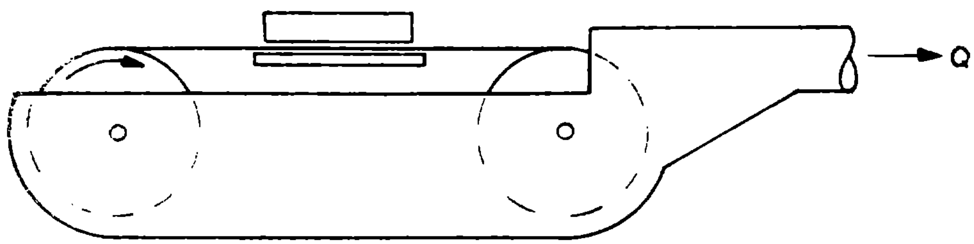


6A. PEDESTAL-TYPE POLISHER OR BUFFER WITH CAPTOR HOOD

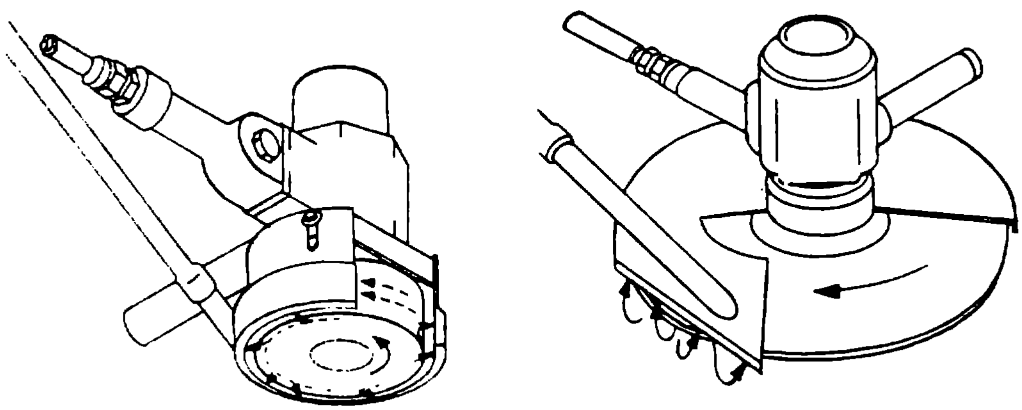


6B. PEDESTAL-TYPE POLISHER OR BUFFER WITH SHAPED COLLECTOR

FIGURE 2 (CONTINUED) - SCHEMATIC DIAGRAM OF GRP EQUIPMENT AND VENTILATION HOODS



7. BELT GRINDER OR POLISHER WITH SHAPED COLLECTOR



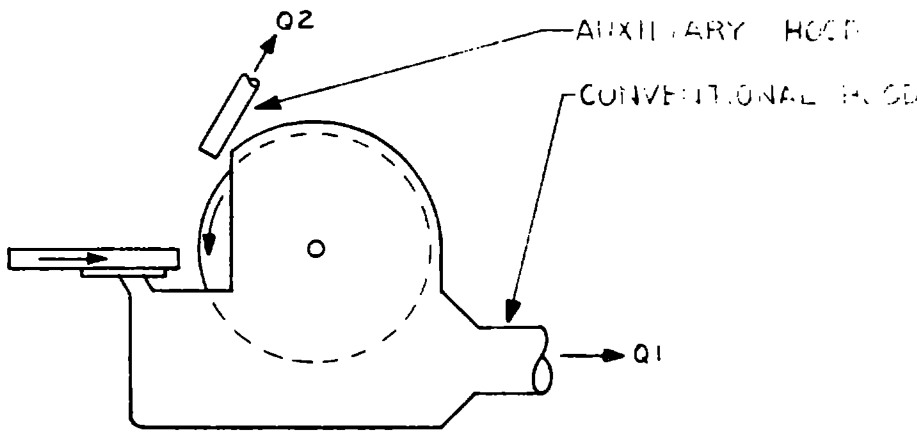
8. PORTABLE GRINDING OR POLISHING MACHINES WITH SHAPED COLLECTORS

FIGURE 2 (CONTINUED) - SCHEMATIC DIAGRAM OF GBP EQUIPMENT AND VENTILATION HOODS detritus) is not well-defined, and are not applicable to machines such as internal grinders because the hood would interfere with the movement of the workpiece. Captor hoods have a limited applicability to abrasive cutting-off machines in that only relatively large hoods can be used because of the movement of the abrasive wheel and the changing direction of swarf flow.

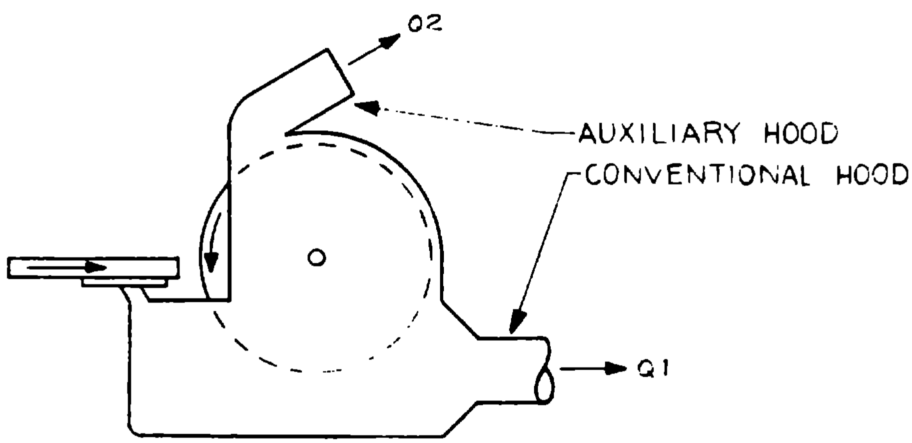
The combined classification of GBP equipment and ventilation hoods shown in Table II identifies the machine-hood combinations for which design and operating criteria are required. However, further distinctions must be made with respect to the operations performed with the various types of GBP machines.

2.2.2 Auxiliary Ventilation Systems

The term "auxiliary ventilation system" is used here to indicate an additional ventilation hood used in conjunction with a conventional hood to obtain improved control of breathing zone dust concentration. Investigations of the effectiveness of auxiliary ventilation systems applied to pedestal-type grinders have been conducted by the British Cast Iron Research Association (Ref 6). Two different auxiliary ventilation hood configurations tested by BCIRA are shown in Figure 3. Both hoods are designed to capture dust particles which escape from the conventional hood mounted in the grinding wheel guard. The first configuration, termed Dusgard, consists of a separate captor hood located outside the guard and above or behind the grinding point. The second configuration, which was designed for use with a specific grinding machine, consists of a second hood incorporated in the grinding wheel guard. The auxiliary hood is installed at the top of the guard adjacent to the guard opening. Both configurations have been reported to be effective in reducing dust concentrations in the operator's breathing zone when used in conjunction with the conventional ventilation systems. However, the authors have not been able to obtain data indicating the actual degree of additional control achieved with either of these systems.



(A) BCIRA "DUSGARD" DUST CONTROL SYSTEM FOR PEDESTAL TYPE GRINDERS



(B) BCIRA SYSTEM OF DUST CONTROL FOR RICHARDS HIGH-SPEED GRINDER

FIGURE 3 - AUXILIARY VENTILATION SYSTEMS USED WITH GRINDING EQUIPMENT

Auxiliary hoods have been recommended for use with backstand idler coated-abrasive machines for improved dust control over that obtained with a conventional captor hood (Ref 7). In this case, the auxiliary hood is located near the idler to capture dust particles leaving the abrasive belt at that location.

2.3 GBP Operations and Ventilation Requirements

2.3.1 Operations

Operations performed by GBP equipment cover a very broad spectrum. However, from the standpoint of controlling airborne dust levels, the principal factor of concern is the nature of the dust particles generated by the operation. Since the largest fraction of the total dust generated by GBP operations is removed from the workpiece, it is logical to classify GBP operations primarily in terms of workpiece materials and, to a lesser degree, in terms of the constituents of the abrasive tools.

A review of literature on GBP equipment and applications has revealed no correlation between equipment types and workpiece materials. It can be inferred from this lack of correlation that all types of equipment are equally applicable to all of the materials which can be processed by GBP equipment. An indication of the wide variety of materials processed by grinding equipment is indicated in Table III which is based on information provided by the Grinding Wheel Division of Norton Company. Literature on coated-abrasive equipment (e.g., Ref 8) indicates that this equipment is used to process an equally wide range of material types. Thus, it is safe to assume that GBP operations involve all solid materials of importance to industry, and that a classification of operations as a guide to ventilation requirements must include all such materials.

Table III

Workpiece Materials - Dry Grinding Operations

A. Abrasive Cutoff

1. Metallics

a. Ferrous Metals - General

(1) Steels
(2) Irons

b. Heat Resisting Alloys

(1) Iron, Nickel, or Cobalt Base

c. Refractory Metals and Alloys

(1) Columbium, Tantalum, Molybdenum, Tungsten

d. Nonferrous Metals

(1) Aluminum and Alloys
(2) Beryllium
(3) Copper and Alloys
(4) Magnesium and Alloys
(5) Nickel and Alloys
(6) Titanium and Alloys
(7) Zinc and Alloys

2. Nonmetallics

Asbestos	Gypsum Board	Stone (Marble, Limestone, Slate)
Brake Lining	Porcelain	Refractory Furnace Liners
Brick	Rubber	
Carbon	Ceramic Tile	
Concrete	Wallboard	
Fiberboard	Plastics	

B. Floorstand, Pedestal and Bench Stand Grinders

1. Metallics - primarily irons and steels, but also includes aluminim alloys and copper alloys.

C. Tool Grinding and Cutting

1. High speed steels

2. Cemented carbides and oxides

   a. containing various amounts Co, WC, TiC, TaC, and mixtures of $Al_2 0_3$ and TiO

3. Cast cobalt - chromium-tunsten alloys

4. Alumina-based ceramics

D. Portable Grinding (ex. cut-off) and Hand-Held Swing Frame Snaggers

1. Primarily castings and forgings of iron, steel, brass, bronze, aluminum, magnesium, and titanium.

Table prepared from information supplied by the Grinding Wheel Division of Norton Company.

2.3.2 Ventilation Requirements

Requirements for the performance of ventilation systems used with GBP equipment are based primarily on the control of dust concentrations in the breathing zone of the equipment operator. If one of the conventional ventilation system configurations is used to accomplish control of breathing zone dust, it is reasonable to expect that hazards to other personnel in the vicinity of the equipment also will be eliminated. Such hazards may not be eliminated, however, if unconventional means of dust control are employed to protect the operator such as the use of fans or reliance on natural air currents, as in outdoor operations, to carry equipment-generated dust away from the operator's breathing zone. Thus, in defining the ventilation requirements for various GBP operations, it is implicit that these requirements are to be met by means of a conventional type of ventilation system.

The classification of GBP operations proposed is based on a division of workpiece and abrasive materials into three classes according to their toxicological activity. The classification system is presented in Table IV and its derivation is discussed in Appendix B. Class I includes the majority of GBP operations which are performed with inert workpiece and abrasive materials. Classes II and III include operations with toxicologically active workpiece or abrasive materials, Class II materials having threshold limit values greater than one-tenth that of total inert dust, and Class III materials having TLV's less than one-tenth the total inert dust TLV*. Examples of materials included in Classes II and III are listed in Table IV.

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*The baseline dust concentration actually used to classify Class II and Class III materials in Table IV is 2/3 the total inert dust TLV contained in the current Occupational Safety and Health Standards, or 10 mg/m^3. The use of this dust concentration as the basis for the design of standard ventilation systems for inert dust control provides a margin of safety to allow for the presence of background inert dust in concentrations up to 5 mg/m^3

Table II

Classification of GBP Operations

Operations Class	TLV* Ratio	Operations Included	Ventilation Requirements
I	1.0	All operations with inert workpiece, abrasive, and abrasive support materials.	Standard ventilation systems.
II	0.1 to 1.0	Grinding, buffing or polishing of copper, chromium, or nickel	(1) Auxiliary ventilation system combined with standard system, or (2) Totally enclosed ventilation system.
III	Less than 0.1	(1) Grinding, buffing, or polishing lead, cobalt silver, or beryllium (2) Grinding sand castings (3) Grinding with wheels containing lead or silica (4) Buffing with silica abrasive	(1) Totally enclosed ventilation system, and (2) Respiratory apparatus for personnel within enclosure.

*Ratio of threshold limit value of dust generated by operation to 2/3 the TLV for total inert dust or 10 mg/m^3.

In defining ventilation requirements here, and in formulating ventilation system design criteria later, an approach has been adopted which orients the design and performance requirements toward the control of inert or Class I materials. With this approach, baseline or standard ventilation system design and operating criteria will be defined for inert dust control, and special or non-standard criteria will be defined for control of active dusts. An alternative approach might universally require ventilation performance adequate to maintain dust levels below the TLV's for active materials. However, since most GBP operations are conducted with inert materials, this approach would result in unnecessary expenditures for ventilation equipment installation and operation in the majority of GBP equipment applications. It will also be observed later in this report that effective control of toxicologically active dusts cannot be achieved by certain types of ventilation systems which are in widespread use and which are capable of controlling inert dust.

Using this approach to defining ventilation requirements, systems suitable for the control of inert dust are designated as "standard" systems and are so indicated in Table IV. Control of Class II materials, which are moderately active, will require augmentation of standard ventilation systems. Control of Class III materials will be possible only with the most effective ventilation systems which are well-designed booths or total enclosures.

3. VENTILATION SYSTEM PERFORMANCE MEASUREMENT

3.1 Measurement Procedure

A procedure was developed for measuring concentrations of total and respirable dust in the breathing zones of GBP equipment operators. The procedure is based on the use of an IKOR Portable Air Quality Monitor for continuous measurement of dust concentrations and the use of a NIOSH personal sampler for calibration of the IKOR AQM. A detailed description of the procedure is presented in Appendix C.

The IKOR AQM is an electronic instrument which provides a continuous, real-time measurement of particulate concentration in an extracted gas sample from either an exhaust stack or an ambient environment. The use of the continuous monitor allowed breathing zone dust concentrations to be made with frequent changes in grinding operations and ventilation rates. The dust concentrations measured with the IKOR AQM could be correlated with similar measurements made with the NIOSH sampler so that the IKOR AQM data could be converted to NIOSH-equivalent data.

3.2 Measurement Program

The purpose of the measurement program was to measure total and respirable particulate concentrations at the operator breathing zone for each of the types of GBP equipment described in Section 2 of this report. The ventilation flow rates were varied in order to make measurements at maximum and minimum flow and at several flow rates in between if possible. It was thought that the measurement of particulate concentrations at the different ventilation flows would allow comparison with the existing allowable concentrations and would thus permit new criteria to be developed if required.

3.2.1 The Test Program

The test program consisted of three distinct sections: (1) testing at IKOR (2) testing at the Norton Company in Worcester, Mass., and (3) testing at the Norton Company in Troy, New York.

3.2.1.1 Testing at IKOR Incorporated

The purpose of the testing at IKOR was to develop the instrumentation and procedures required to measure the particulate concentrations during short time intervals. Long test periods would have been impossible due to GBP equipment operator fatigue and due to limitations on the total testing which could be accomplished during the program. It was decided that each individual measurement should not take more than about 3-5 minutes for manually operated GBP equipment and about 5-10 minutes for automatic GBP equipment. It was hoped that this could be accomplished with both the IKOR and the NIOSH personal sampler operating at a 9 liter per minute flow rate. The testing at IKOR, however, proved that it was not possible to obtain a sufficient gravimetric sample with the NIOSH unit during such short time periods nor to obtain a sufficient signal on the IKOR AQM at such a low flow rate. It was therefore decided to operate the AQM at 17.5 cubic feet per minute and to use the 9 liter per minute NIOSH sampler as a calibration standard over a half-hour or hour period on each GBP machine.

The measurement procedures were used to measure ventilation system performance on two machines in the IKOR laboratory. These machines are described in Table V.

3.2.1.2 Testing at the Norton Company, Worcester, Mass.

At the Grinding Wheel Division of the Norton Company in Worcester, Massachusetts, a variety of grinding wheel equipment was tested. Each piece of equipment had its own ventilation system usually installed as part of the wheel guard or mounted separately directly

Table V

Grinding Machines used at IKOR, Incorporated (Burlington, Mass.) for Measuring Ventilation System Performance

Equipment Class	Machine Description	Wheel Diameter (inches)	Surface Velocity (Surface feet per minute)	Hood Type
Pedestal Type Grinders	Floorstand	7	3300	Shaped Collector
Belt Grinder	Belt Grinder	5 1/2	3170	Shaped Collector

in the path of the swarf coming from the grinding wheel. For example, see Figure 4, the S-3 Surface Grinder. The ventilation flow rates could be varied by adjusting the butterfly-type valves in the vent ducts. The general categories and specific types of GBP equipment tested at this location are listed in Table VI. Figures 4 through 10 illustrate some of the types of GBP equipment tested at Norton Company in Worcester, Massachusetts.

3.2.1.3 Testing at the Norton Company, Troy, New York

Ventilation system performance tests were conducted with coated-abrasive equipment at the Coated Abrasives Division of the Norton Company at Troy, New York. Additional tests with buffing equipment also were conducted at this location. The coated-abrasive equipment generally had ventilation systems which could be used in measuring ventilation performance. However, the buffing equipment and certain pieces of coated-abrasive equipment were not ventilated so that tests were conducted with these machines to determine dust concentrations without ventilation.

The machines on which tests were conducted are described in Table VII. A few of the machines also are shown in Figures 11 and 12.

3.3 Measurement Results

3.3.1 Performance of Conventional Ventilation Systems

The results which will be discussed in this section are some of the most significant results obtained in this program. A more extensive description of the data obtained is presented in Appendix C.

Figure 13 shows the typical shape of the ventilation performance curve which was observed for each class of GBP equipment. The figure indicates the breathing zone dust concentration as a function of ventilation rate. There exists a steep descent of the concentration as the ventilation flow is increased until at some point (approximately 250 CFM

Table VI

Grinding Machines Used at Norton Company (Worcester) for Measuring Ventilation System Performance

Equipment Class	Machine Description	Wheel Diameter (inches)	Surface Velocity (Surface feet per minute)	Hood Type
Surface-Type	Swing Frame	16	8790	Captor
Grinders	BDA Wheel Tester	7	10260	Captor
	Mounted Portable	6	9260	Captor
	S-3 Surface Grinder	7	5860	Captor
Pedestal-Type	Floorstand	28	11830	Shaped Collector
Grinders	Bench	12	8800	Shaped Collector
Cutting-Off	Tabor	20	12040	Captor
Machines	Delta	10	6020	Shaped Collector

Table VII

GBP Machines used at Norton Company (Troy)
for Measuring Ventilation System Performance

Equipment Class	Machine Description	Wheel Diameter (inches)	Surface Velocity (Surface feet per minute)	Hood Type
Pedestal-Type Polishers and Buffers	Belt Grinder	14	6600	Shaped Collector
	Flap Wheel	14	6090	Shaped Collector
	Buffing Wheel	16	6700	none
	Buffing Wheel	12	5030	none
Portable Machines	Portable Disc Grinder	9	11780	Booth
	Swing Frame Belt Polisher	6	5500	Booth

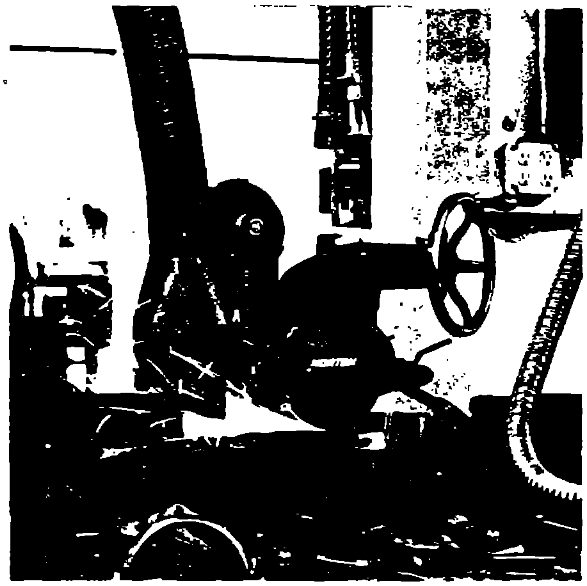

FIGURE 4. S-3 SURFACE GRINDER WITH CAPTOR HOOD

FIGURE 5. SWING FRAME GRINDER WITH CAPTOR HOOD

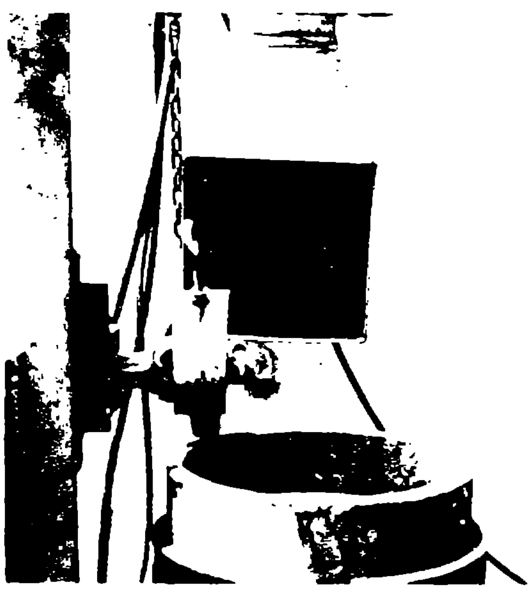

FIGURE 6. MOUNTED PORTABLE GRINDER WITH CAPTOR HOOD

FIGURE 7. BDA WHEEL TESTER WITH CAPTOR HOOD

FIGURE 8. BENCH GRINDER WITH SHAPED COLLECTOR

FIGURE 9. FLOORSTAND GRINDER WITH SHAPED COLLECTOR

FIGURE 10. TABOR CUTOFF WHEEL WITH CAPTOR HOOD

FIGURE 11a. BELT GRINDER WITH SHAPED COLLECTOR

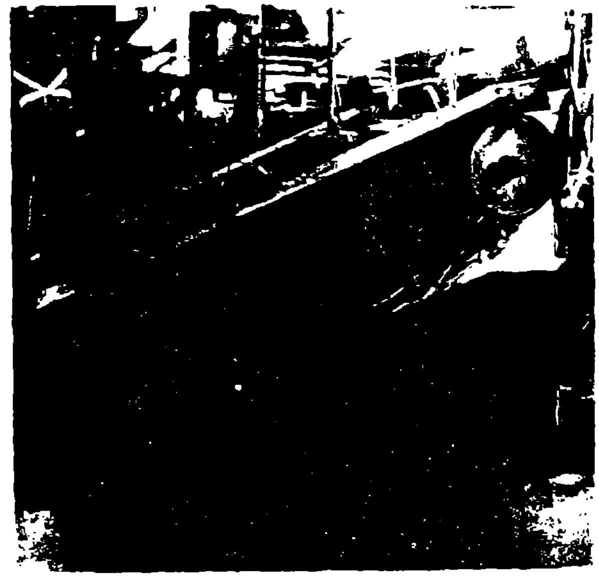

FIGURE 11b. BELT GRINDER WITH SHAPED COLLECTOR OPEN

FIGURE 12a. SWING FRAME BELT POLISHER WITH BOOTH

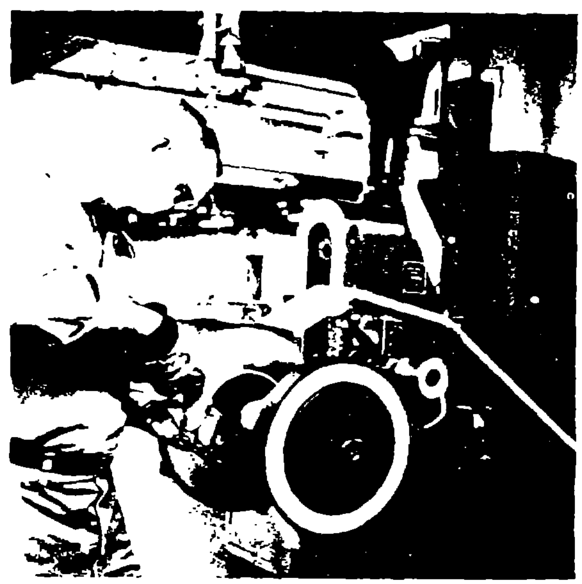

FIGURE 12b. BELT POLISHER WITH NO VENTILATION

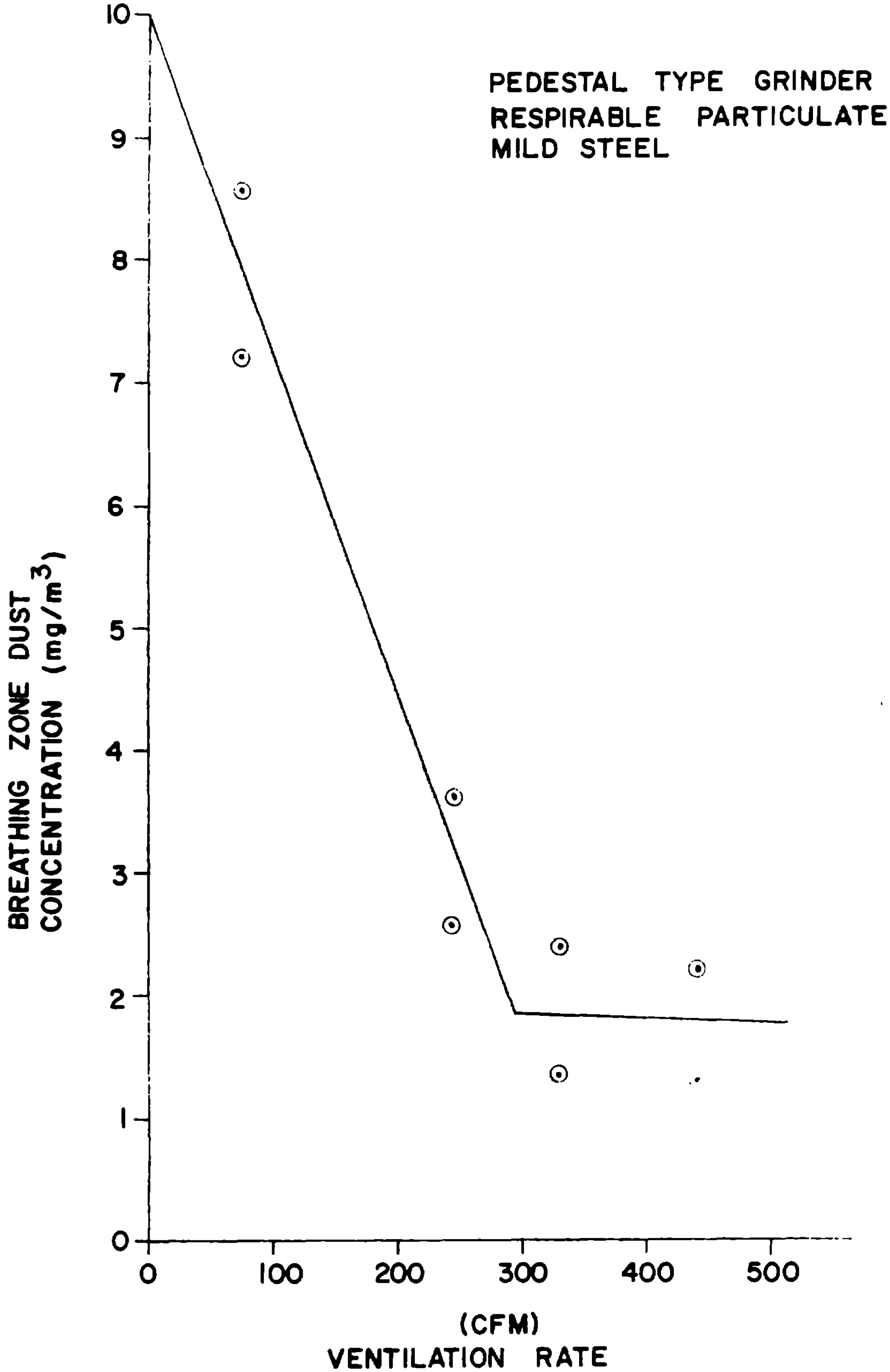

Figure 13 Typical Ventilation System Performance

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in this example) any further increase in flow through the normal ventilation system of the machine will have a minimal effect on concentration. This two-segment curve is characteristic of all the ventilation systems which were studied.

3.3.2 Performance of Auxiliary Ventilation Systems

A limited series of tests was conducted to evaluate the effectiveness of auxiliary ventilation hoods used in combination with conventional ventilation systems. The auxiliary hoods were located to capture fine particles not readily captured by the conventional hoods. The particle motion analysis, which is discussed in the next section of this report, indicated that fine particles generated by grinding are not captured directly, but instead pass around the grinding wheel or belt in the boundary layer of air. These particles are stripped off the tool surface by collision with the workpiece, and therefore are released to the environment near the grinding point. The effectiveness of the conventional ventilation system in capturing particles released at this point is less than in capturing particles which leave the tool surface with an initial velocity in the general direction of the ventilation hood.

The auxiliary ventilation systems utilized were composed of two shop-type vacuum cleaners with nozzles of 1 inch diameter. The flow rate through each nozzle was approximately 60 cubic feet per minute. See Figure 14 for the positioning of the nozzles.

Tests of auxiliary ventilation hood performance were conducted with one and two auxiliary hoods operating. These tests indicated that a reduction in breathing zone dust concentration can be obtained with one hood operating, but the use of a second hood does not improve ventilation performance further. Tests were conducted on a 12-inch bench grinder with a variety of workpiece materials and with one auxiliary hood operating with a flow rate of 60 cfm. The increase in ventilation effectiveness provided by the auxiliary hood is indicated in Figure 15. This figure, which is typical of the results obtained with all workpiece materials, indicates that

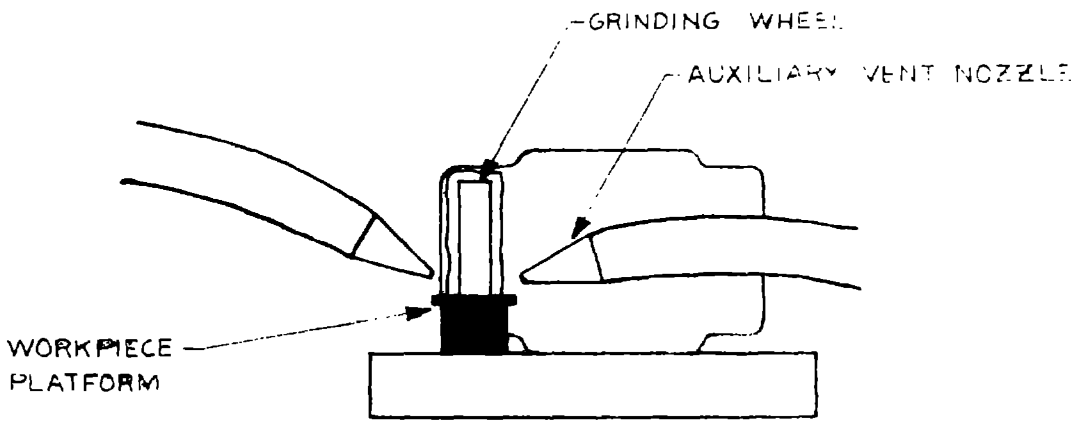

Figure 14   Auxiliary Vent System on Bench Grinder (Front View)

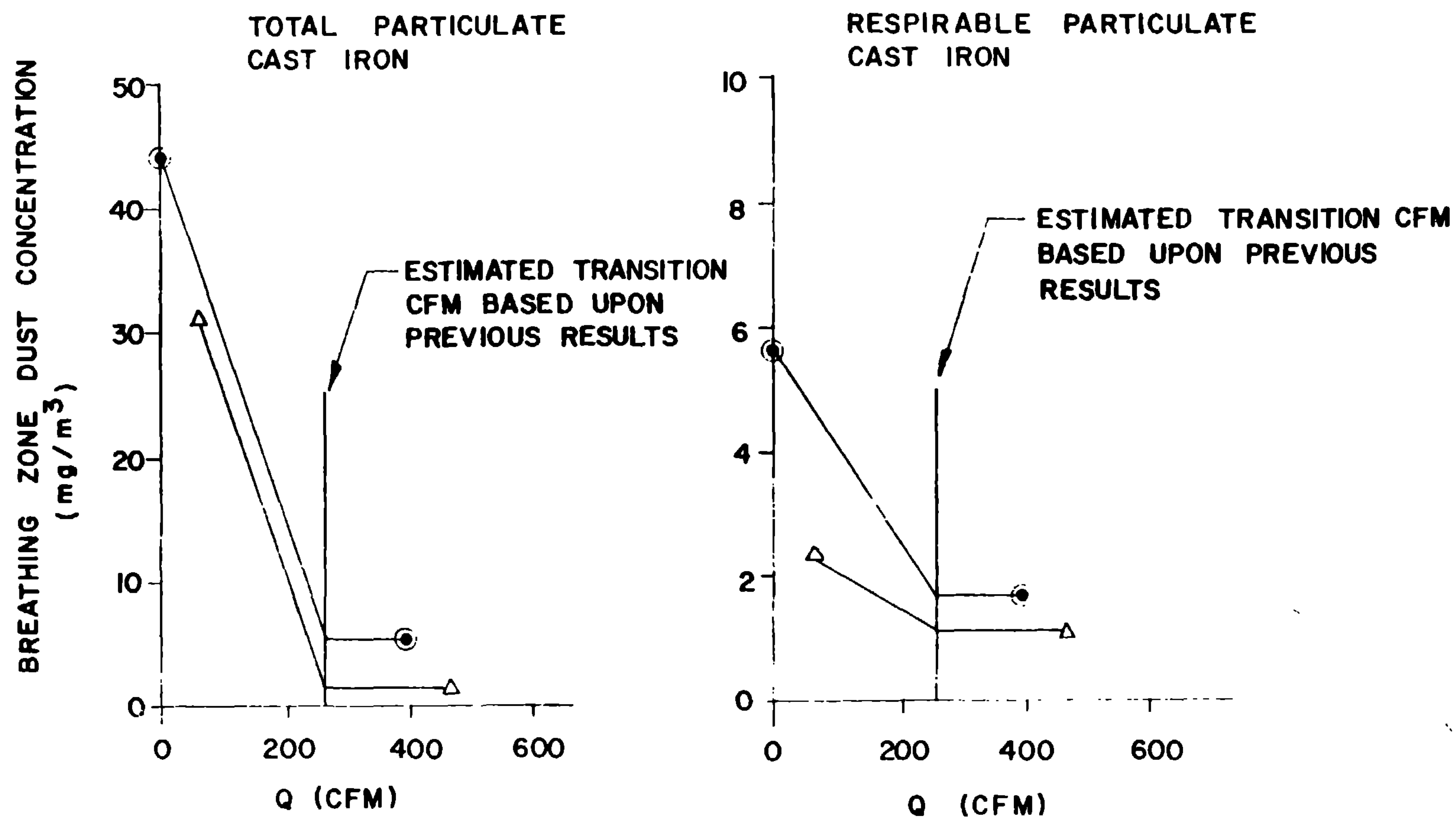

Figure 15

Ventilation System Performance Data
12" Bench Grinder W/Auxiliary Captor Hood (2,800 RPM)

(•) - Auxiliary Captor Hood - Off
Δ - Auxilairy Captor Hood - On

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the auxiliary hood provides a reduction in breathing zone dust concentration which remains approximately constant over the full range of flow rate through the conventional ventilation hood. At high ventilation rates where maximum effectiveness of the conventional hood was being achieved, the additional reduction in breathing zone dust concentration provided by the auxiliary hood ranged between 30 and 70 percent. This range of performance was achieved with only a small increase in total ventilation rate and with no attempt to optimize the location or configuration of the auxiliary hood. It is reasonable to expect, therefore, that even greater reductions in dust levels could be achieved through optimization of the design and operating characteristics of the auxiliary hood.

3.3.4 Material Effect

The grinding of different workpiece materials did affect the concentration levels as may be seen from Figure 16. The same grit grinding wheel was used for each of the three tests described in the figure. Note that the typical two-segment curve is obtained for 1018 steel but that the concentrations obtained for the aluminum workpiece are essentially zero. The result for titanium indicates one very high concentration and one very low concentration at the low ventilation rate. The high concentration point is due to the use of a new abrasive belt for this particular measurement. Titanium is a soft metal and the belt readily becomes filled with the metallic particulate. A new belt therefore generates much more particulate than a used belt.

It is concluded from these results that the nature of the workpiece material and the character of the abrasive tool surface influence the rate of particle generation. However, the general shape of the ventilation performance curve and the location of the transition point do not change.

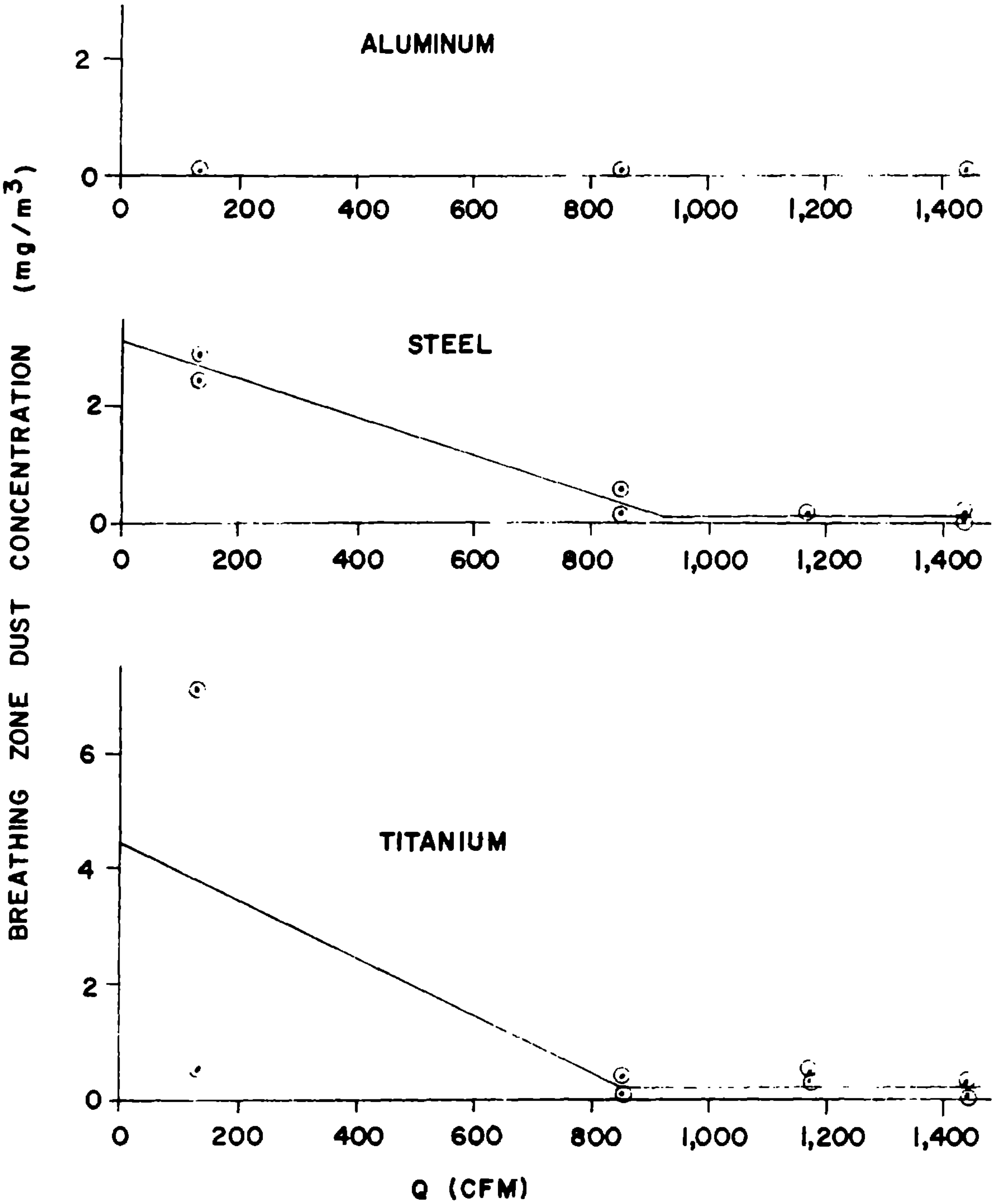


Figure 16

Effect of Workpiece Material
On Respirable Particulate Levels
(Belt Grinder)

4. VENTILATION SYSTEM PERFORMANCE ANALYSIS

4.1 Particle Motion Analysis

4.1.1 Regions of Particle Flow

The mechanism of particle motion in and about the vicinity of GBP equipment is, when viewed as a single process, quite complex. However, the problem can be simplified by viewing the process of particle transport as being composed of several independent processes which can be explored separately and then combined to obtain a final representation or model of the overall process. Using this approach, it is necessary to define specific flow regions around the GBP equipment. Referring to Figure 17, it can be seen that three flow regions have been defined. Region I encompasses a flow region in which the particles are subject to a velocity field which is totally controlled by the abrasive tool of the GBP equipment, that is, the grinding wheel, belt, or buffing wheel. Region II includes the flow field generated by the ventilation system. The extent of Region II is dependent upon the strength, location and dimensions of the ventilation system. The remainder of the flow field not encompassed by Regions I and II is defined as Region III. The diffusion of particles which have escaped Regions I and II takes place in Region III.

The development of models for the three flow regions has required a combination of analytical and experimental work. After reviewing the available literature it was apparent that only Region II had been sufficently documented and that Regions I and III had to be explored.

4.1.2 Development of Models For Specific Flow Regions

4.1.2.1 Region I

4.1.2.1.1 Air Velocity Profiles

Experiments to study Region I were directed at obtaining a profile of the velocity gradient in that region and to study how the profile is altered by varying the wheel speed, diameter, thickness and surface roughness. Because of the wide range of variables to be studied it was decided that for flexibility and safety, aluminum discs would be substituted for

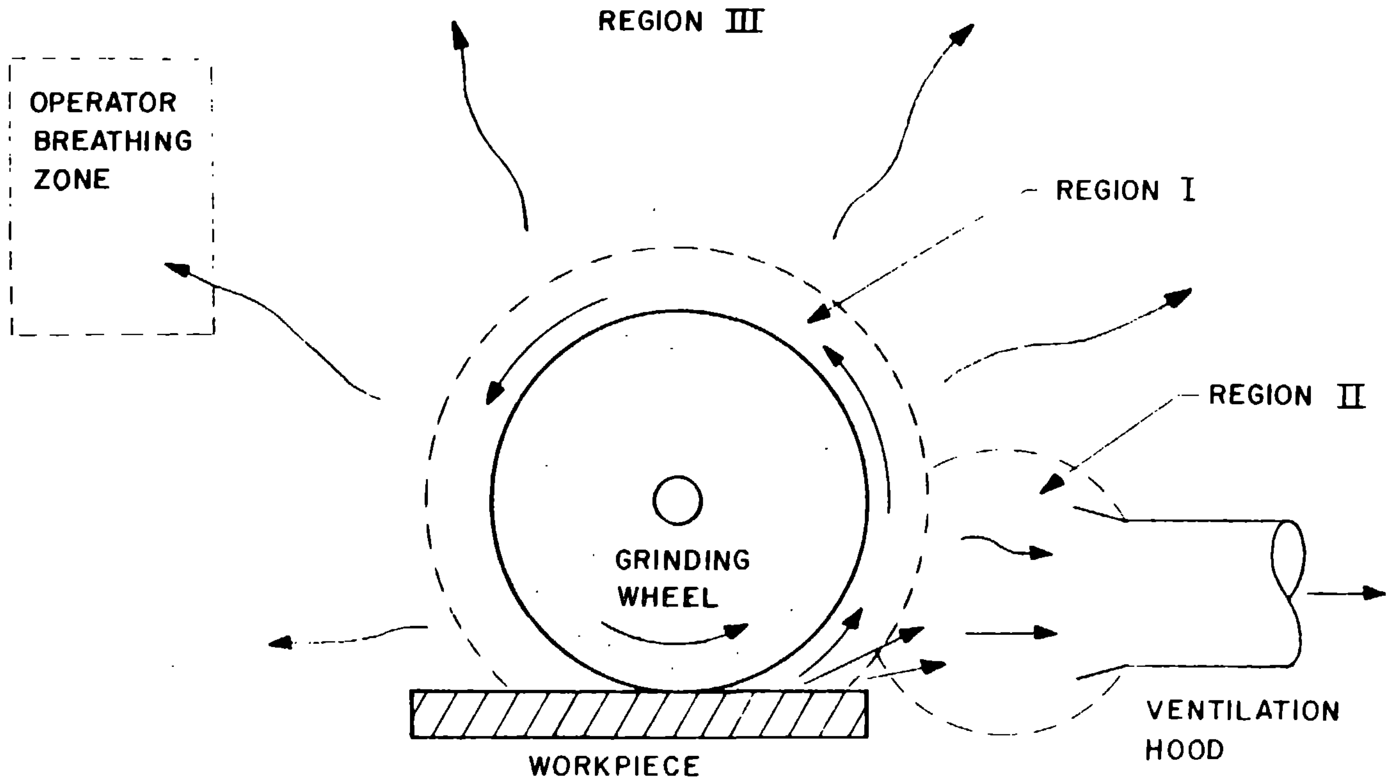


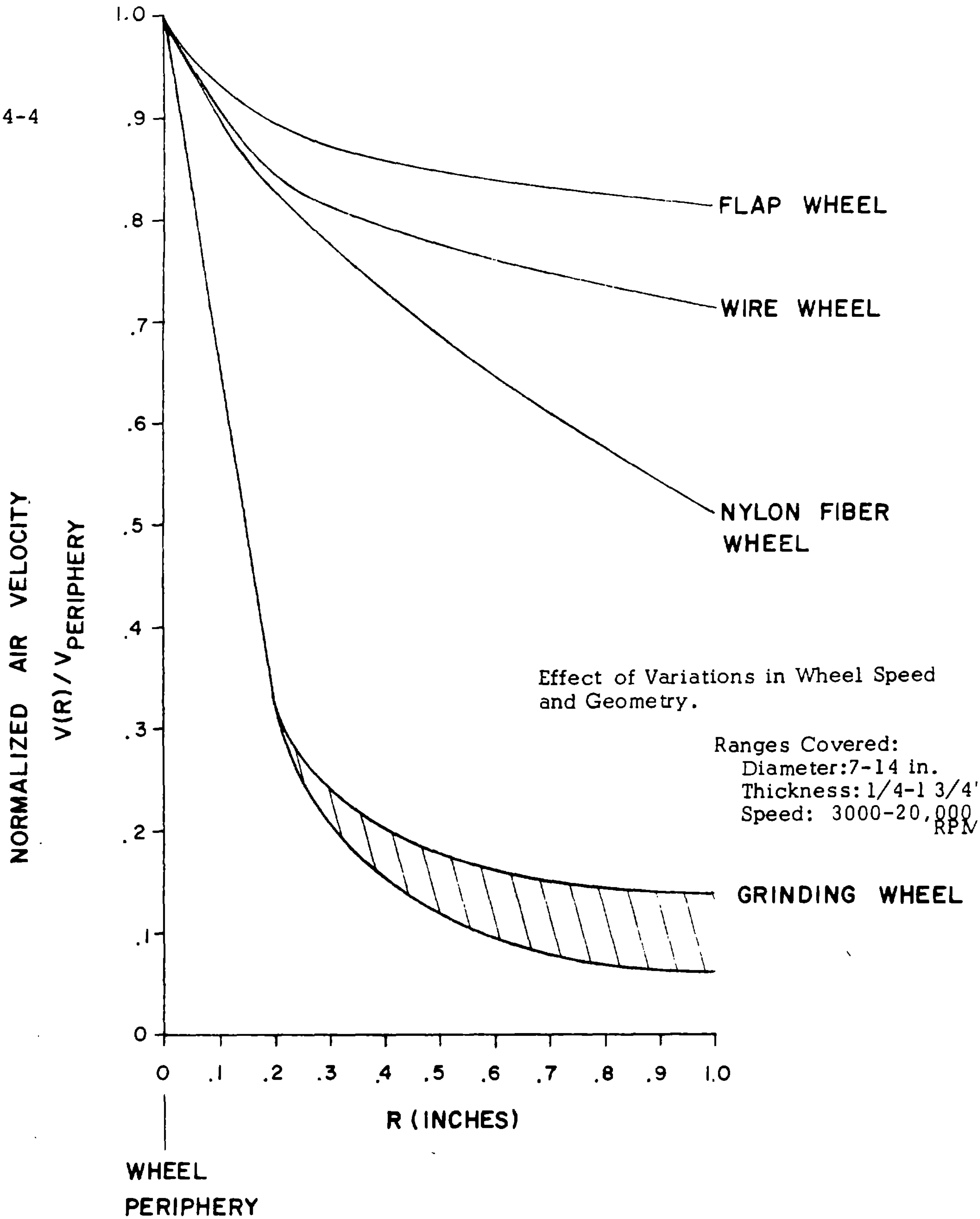
Figure 17

DUST FLOW REGIONS: SURFACE - TYPE GRINDER actual grinding wheels. However, for comparison several grinding wheels and a wire wheel were also examined. The velocity profile measurements were conducted in the IKOR Laboratory.

The velocity measurements were made using a standard alnor velometer with the probe of the velometer mounted on a camera tripod. The probe could be rotated to obtain the maximum velocity reading at each measurement point, and the camera tripod was mounted on a sliding track allowing consistent measurement patterns to be followed. With this method, air velocity measurements could be made up to a distance of 0.2 inches from the wheel surface. The velocity profile near the wheel surface was assumed to vary linearly from the value measured at the closest measurement point to the wheel peripheral velocity.

To provide a base of comparison for all of the experimental results, the individual velocity profiles from each experiment were normalized with respect to the peripheral velocity of the grinding wheel during the experiment. Once all of the data were normalized, the effects of varying the wheel geometry and velocity were examined by superposition of the data. Referring to Figure 18 the effects of these variations are indicated for the grinding wheel by the shaded area. It is observed that for grinding wheels, the effects of changing speed, diameter, thickness or surface roughness are relatively small. Thus, it was concluded that the wheel surface speed is the principal factor affecting the air velocity profile and that a single, normalized profile can be used to describe the air flows around all grinding wheels. The grinding wheel velocity profile originating at the wheel periphery and continuing along the upper bound of the shaded region was adopted as the universal velocity profile for grinding wheels.

To supplement the data obtained in the lab at IKOR, field test data were obtained which verified the initial test results. For comparison, a flap wheel and a nylon fiber wheel were also examined in field tests. Their normalized profiles are also shown in Figure 18. It is important to note the differences of flow field strength around the various



AIR VELOCITY PROFILES AROUND GRINDING AND POLISHING WHEELS

Figure 18

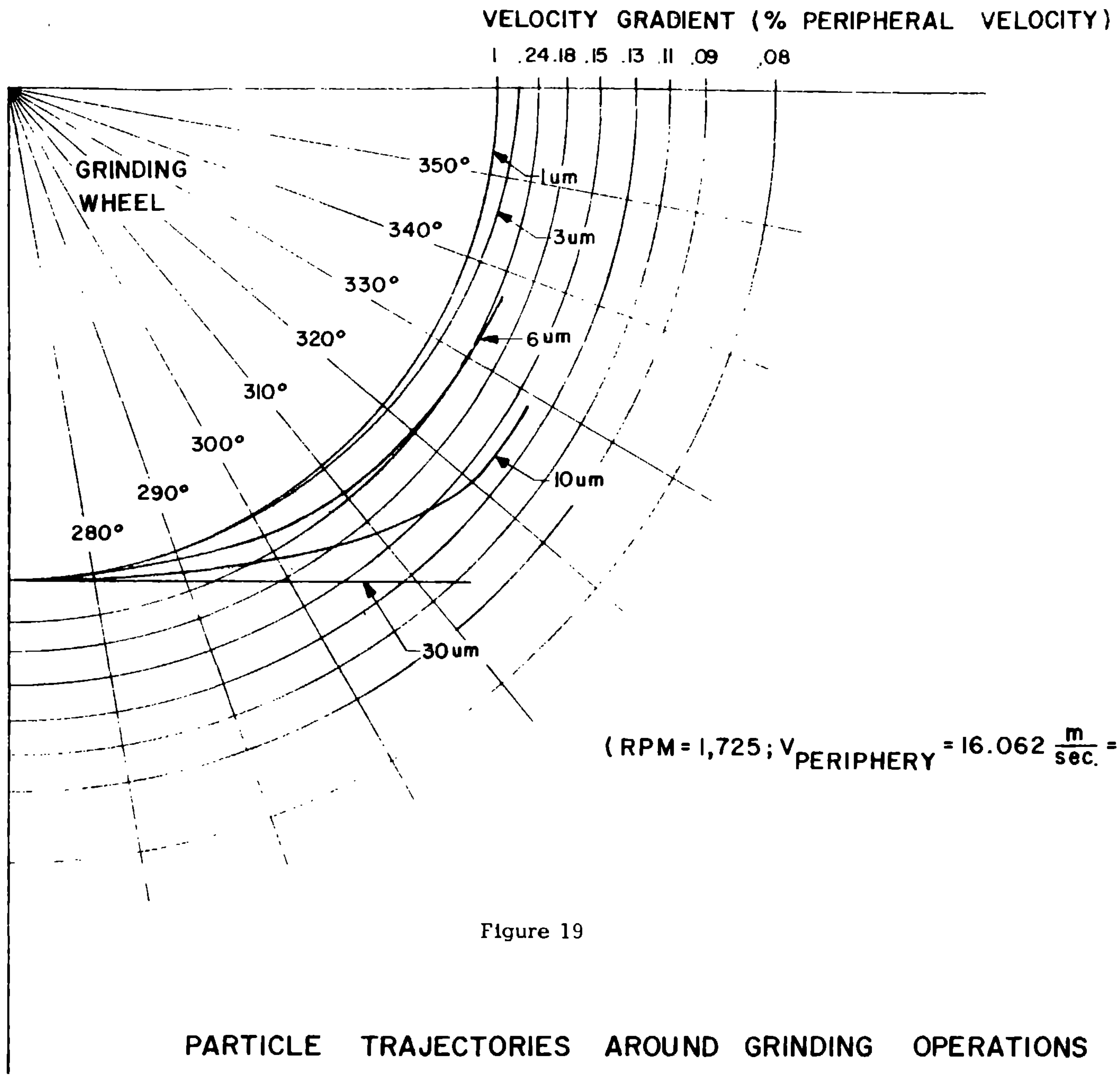
wheels, since the trajectories of small particles are strongly influenced by these profiles.

A number of field tests also were directed at defining the velocity profiles around abrasive belts. Some work concerning the effects of varying grit size and belt velocity has been reported previously (Ref. 9), but no data have been reported on velocity profiles. After reviewing the test data, it appears reasonable to assume the velocity profile above curved belt surfaces is similar to the universal grinding wheel profile. However, an additional velocity component on one edge of the abrasive belt can be expected when the contact wheel is grooved. It is anticipated that the magnitude of the additional velocity component is dependent upon the contact wheel design.

4.1.2.1.2. Particle Trajectories in Region I

To study the motion of particles in Region I, a single particle model was developed. This model combines the experimental results withthe known physicalproperties of the particle and its immediate environment. A complete description of the development of the single particle model can be found in appendix D. Once the single particle model was completed, a computer program was written which allowed us the versatility of changing key parameters in the particle trajectory calculations, (i.e. particle size, particle initial velocities, etc.)

Let us now consider a typical example for the computer program where a wheel is rotating at 1,725 RPM and is grinding a workpiece which has a density of 8 gram/cc. The particles which are created by the grinding start with an initial velocity equal to the peripheral velocity of the wheel. The resulting particle trajectories are shown in figure 19. It is seen that very fine particles (1-3μm) are retained quite close to the wheel periphery at relatively high velocities. This leads us to conclude that these particles cannot be captured by conventional ventilation hoods. Instead, they escape Region I and diffuse with the local air currents after they interact with the workpiece on the other side of the wheel.



(RPM = 1,725 ; $V_{PERIPHERY} = 16.062 \frac{m}{sec.} = 3,161 \frac{ft.}{min.}$)

Figure 19

PARTICLE TRAJECTORIES AROUND GRINDING OPERATIONS

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Other trajectory analyses were conducted for 1μm, 3μm, 6μm and 10μm particles at various wheel speeds. The results showed that, although the particle trajectories shifted further away from the wheel periphery, the 1μm and 3μm particles displayed the same type of behavior as they had at the lower speed.

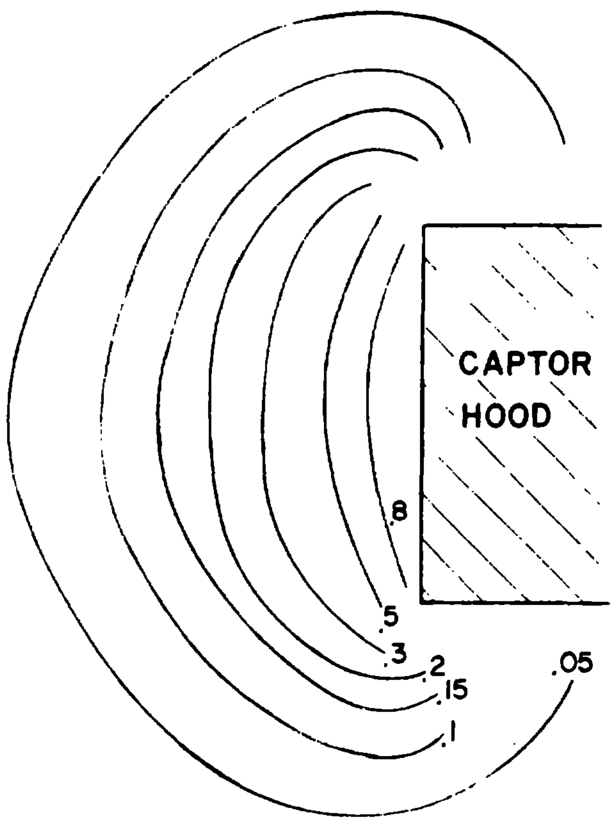
It is concluded in general that particles in Region I are separated into three groups as a result of the inertial and aerodynamic forces acting on individual particles. To a ventilation system these groups present varying degrees of difficulty to capture. The groups of particles will be denoted as fine, intermediate and inertials. Refering to figure 19, the fine particles are those which remain close to the wheel at relatively high velocities. These are the most difficult to capture. The inertial particles are those which traverse Region I with negligible aerodynamic effects, in Figure 19, particle sizes above 30μm. These particles are relatively easy to capture if the hood is located directly in their path. The remaining particles belong to the intermediate group and their capture depends mainly on the performance of the ventilation system.

4.1.2.2 Region II

Velocity profiles for Region II, that is, the flow region dominated by the ventilation hood, have been obtained experimentally by Dallavalle (Refs 10, 11 & 12) and Silverman (Refs 13 & 14). In addition, they have provided approximate expressions for the flow rates necessary to capture particles with a specific hood geometry. The results of their experiments are the basis for all of the analyses involving Region II.

The velocity profile of a circular hood (Ref 15) is shown in figure 20. Note that the magnitudes of the velocity contours are expressed as fractions of the captor hood face velocity. This profile encompasses what we have defined as Region II.

Constant Velocity Contours



(fraction of hood face velocity)

Figure 20
Velocity Profile Around A Circular Hood

To determine the location of the boundary between Regions I and II or a specific wheel and hood configuration, the velocity fields for the two regions are superimposed as shown in Figure 21. This method is approximate in general and fails completely near solid surfaces. However, the method does provide a qualitative insight into the interaction of the wheel and hood flow fields and the probable trajectories of particles passing through the regions. The method also can be used to demonstrate the effects of varying hood design and flow characteristics on the probability of capturing particles released at various locations in the flow fields.

In Figure 21, a locus of points has been constructed at which the velocity profiles of Regions I and II are equal for the condition in which the hood face velocity is equal to the wheel surface velocity. This locus of equal velocity points is denoted as the capture threshold. Particles which cross the capture threshold are assumed to be captured by the hood. Particles which do not cross the capture threshold may either escape or remain in Region I. Those particles remaining in Region I are then transported around the wheel and diffuse with the local air currents upon reaching the top face of the workpiece. Those particles which escape Region I and do not cross the capture threshold either fall to the floor or diffuse with the local air currents of Region III.

The location of the capture threshold can be altered by increasing the ventilation rate and/or by changing the location of the captor hood. Figure 22 has been included for a comparison with Figure 21, the difference being the size of the captor hood and the location of the capture threshold.

The wheel and hood configurations shown in Figures 21 and 22 are realistic in that they represent typical hood configurations used in industrial practice. However, the ventilation rates represented by the condition of the hood face velocity equal to wheel surface velocity are higher than are normally used. Even with these high ventilation rates, the analyses of

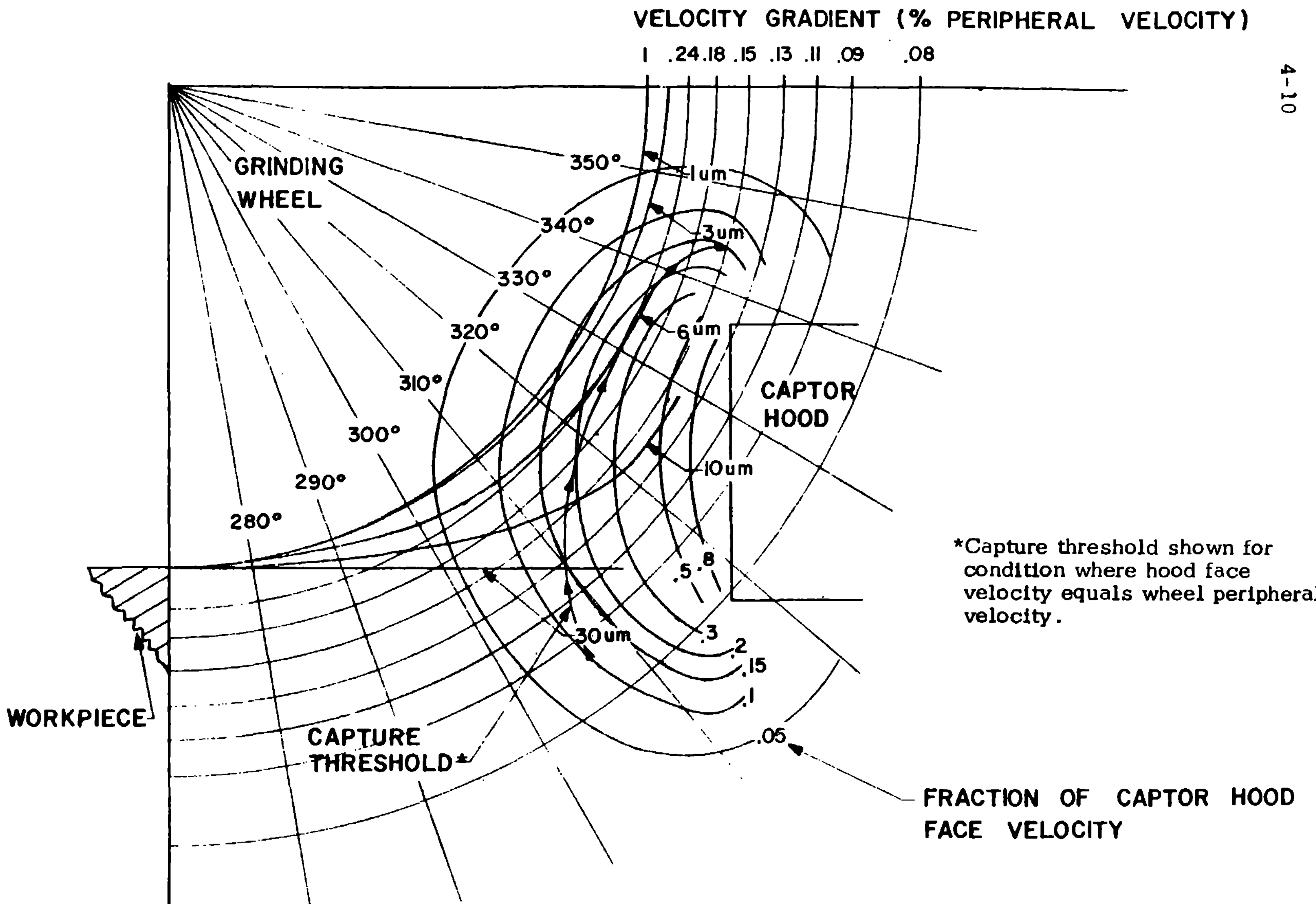


Figure 21

PRIMARY DUST CAPTURE MECHANISM: SMALL CAPTOR HOOD

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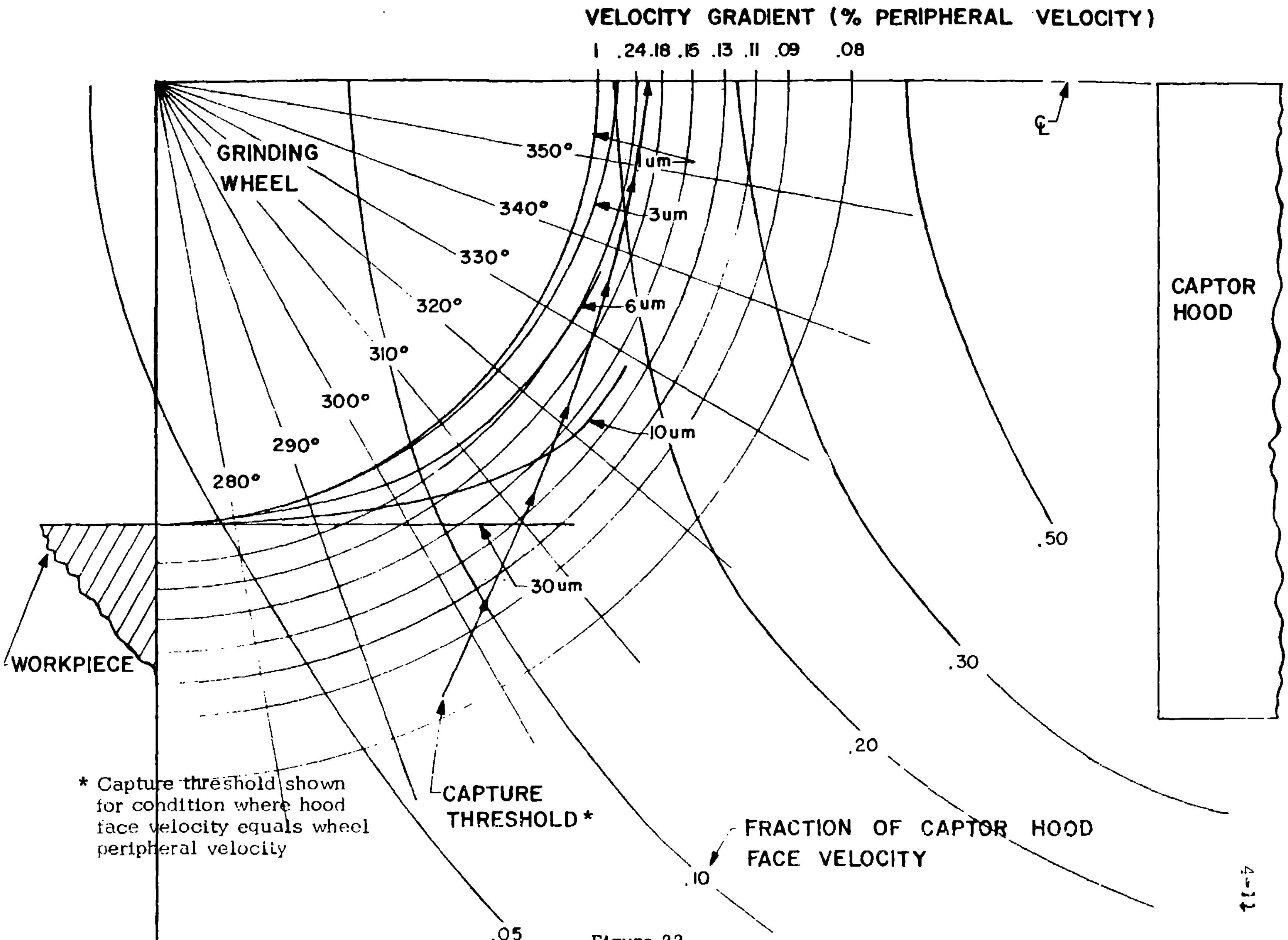

Figure 22
PRIMARY DUST CAPTURE MECHANISM: LARGE CAPTOR HOOD

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capture performance shown in the figures indicate that particles smaller than 6 micrometers in diameter will not be captured directly by the hood. If the particles are stripped from the wheel surface by the workpiece, it can be seen in the figures that they will be released at a point in space where the influence of the hood is relatively small.

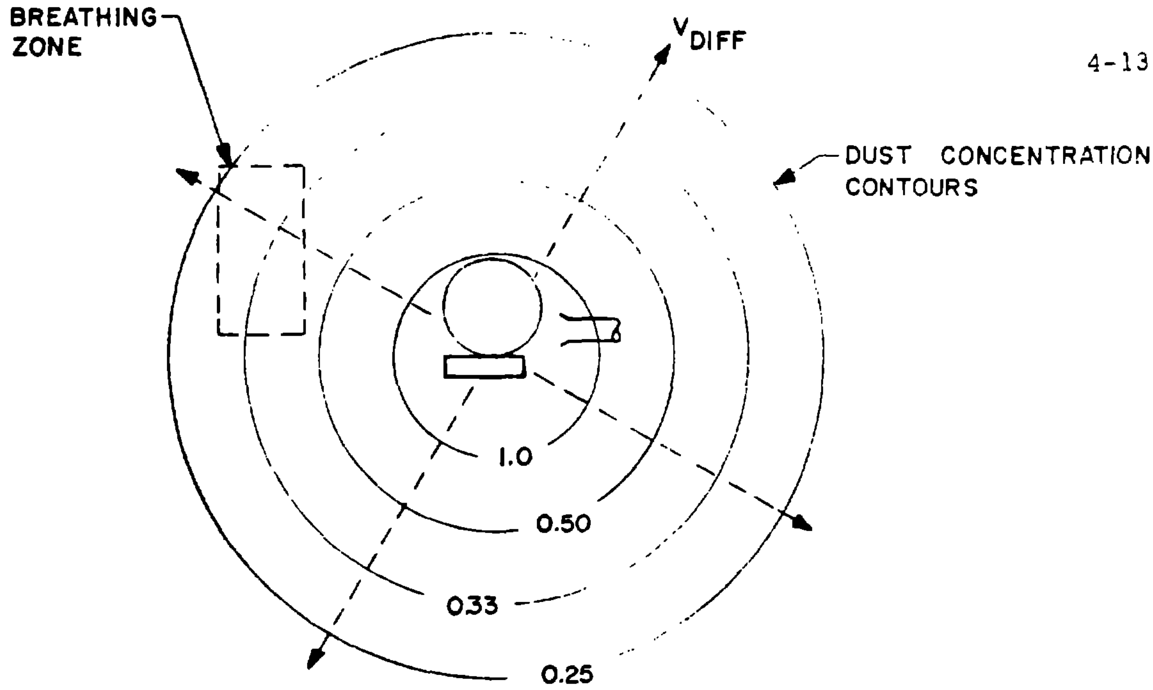
4.1.2.3 Region III

As stated previously, the remainder of the flow field not encompassed by Regions I and II is defined as Region III. Contained within Region III is the operator's breathing zone (OBZ). The OBZ is of particular interest since we are concerned about the exposure of the operator to dust levels generated by GBP operations. The dust in the OBZ is a combination of background dust and dust which has escaped Regions I and II.

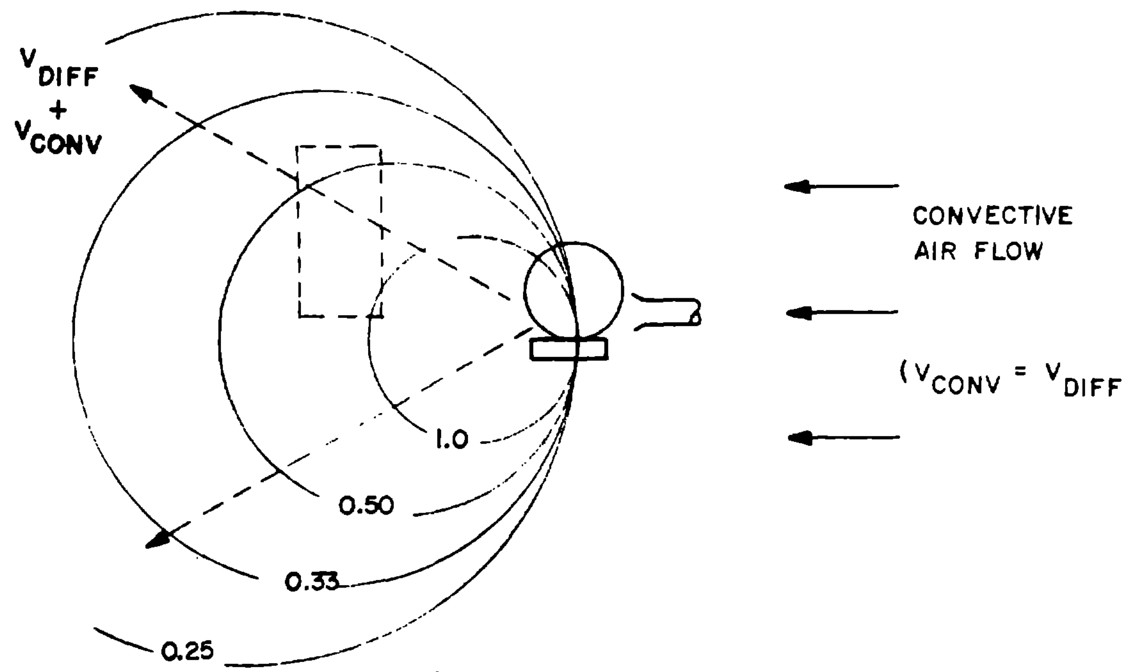
The transport of particles in Region III is considered to consist of an outward flow of particles from the grinding machine. The transport mechanisms are turbulent diffusion and convection resulting from background air currents which exist in the vicinity of the machine, including currents associated with booths installed for dust control. The assumption of a combined diffusion and convection particle transport mechanism in Region III is supported by the results of the measurement program described in Appendix C.

In a still air environment, particle flow in Region III will occur as a result of the turbulent diffusion mechanism alone. Referring to figure 23a, we observe a symmetric pattern for the diffusion of particles in still air based upon some characteristic diffusion velocity. Relative dust concentration levels are shown based on the concentration existing at a distance from the grinding point **equal** to one wheel diameter. In still air, the strength of the dust concentration contours falls off as the inverse of the radius (r). Thus, the dust concentration in the OBZ will generally be less than at points closer to the machine.

Referring to Figure 23b, a convective air current is introduced which is equal in magnitude to the characteristic diffusion velocity. The result is an asummetric shift in the diffusion pattern. In this case the OBZ is subjected to substantially higher dust concentrations. In actual practice, a



(a) DIFFUSION ONLY (STILL AIR)



(b) DIFFUSION + CONVECTION

ESCAPED PARTICLE FLOW FIELDS

Figure 23

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beneficial effect is obtained when the convective velocity created by a booth is strong enough to reduce the particulate concentration in the OBZ. This would correspond to a convective velocity in the opposite direction of that shown in figure 23b.

The influence of a weak convective velocity on the diffusion of particles was demonstrated in this program during ventilation performance tests with a surface grinder. During these tests an air conditioner in the vicinity of the surface grinder was allowed to run during one series of tests and then was turned off for a comparable test series. The resulting concentrations, plotted against the flow rate of the vent, are shown in Fig. 24. A second test series was conducted to investigate the effects of a substantial convective velocity directed into the operator's breathing zone. The results of this experiment are shown in Figure 25. By introducing a substantial convective velocity toward the OBZ, the measured dust concentration increased considerably. These results are in agreement with the previous discussion of the effect of convective flows upon particle diffusion, and serve to verify the diffusion-convection model used to describe Region III.

The effects of convective flow currents on the transport of dust particles in region III is important for two reasons. First, the equipment operator should be aware that convective flows can increase his exposure to airborne dust if the flow is in the direction from the machine toward him. Second, the observed effects of convective flows demonstrate the potential effectiveness of booths and enclosures as dust control systems. Only moderate convective flow velocities are required to prevent the flow of dust to the operator's breathing zone and to convey the dust to an exhaust system.

4.1.3 Overall Particle Flow Model

It has been observed that, as particles are generated by GBP equipment, they experience a size separation process due to the inertial and aerodynamic forces acting upon the individual particles. Particles of different size ranges present varying degrees of difficulty for capture by a ventilation system. In an effort to consolidate what has been learned about the dust flow and capture processes, a flow chart, shown in Figure 26, has been developed. This flow chart shows the alternative flow paths that the particles generated by a GBP operation can follow.

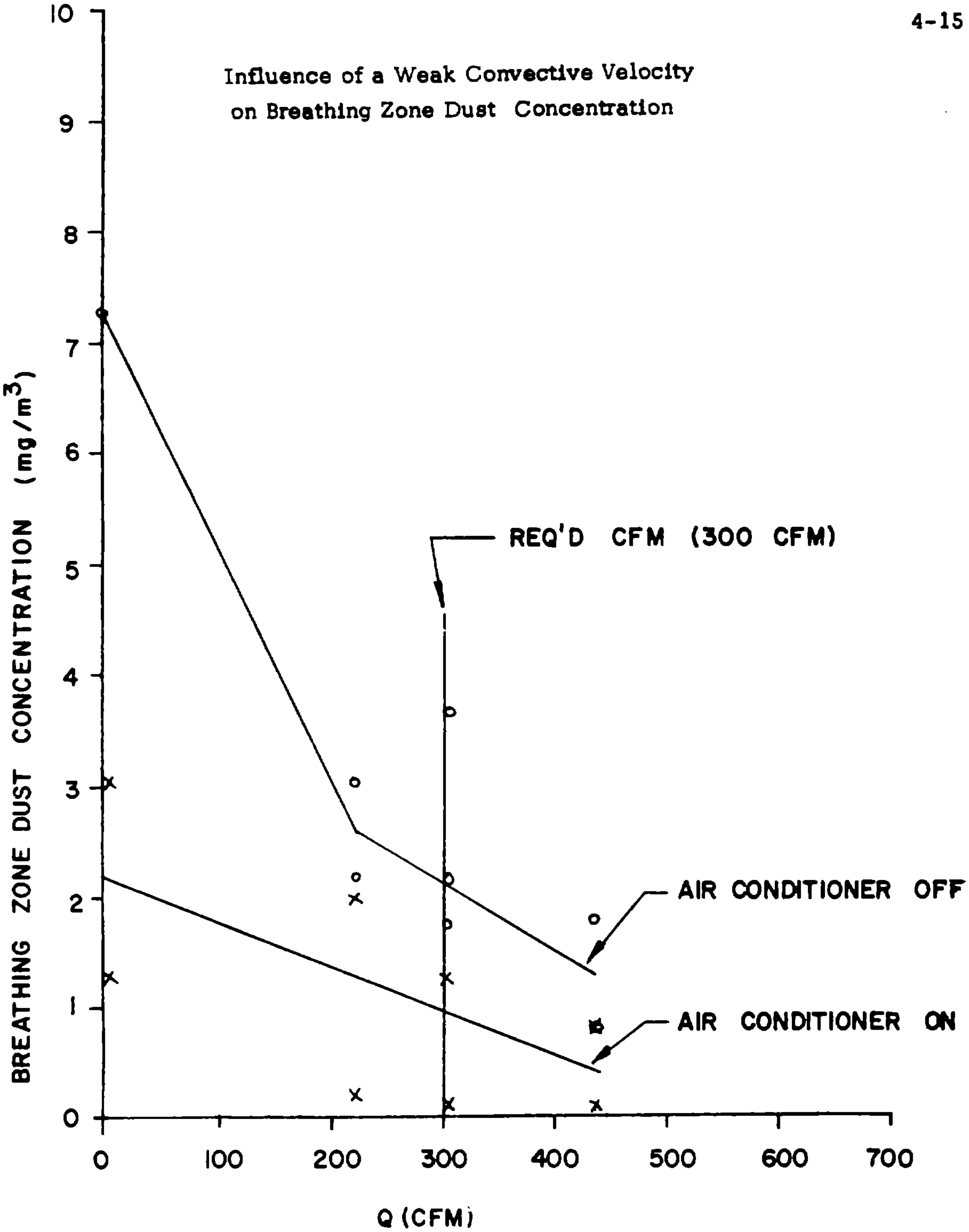

Influence of a Weak Convective Velocity
on Breathing Zone Dust Concentration
BREATHING ZONE DUST CONCENTRATION (mg/m3)
Q (CFM)
REQ'D CFM (300 CFM)
AIR CONDITIONER OFF
AIR CONDITIONER ON
0
1
2
3
4
5
6
7
8
9
10
0
100
200
300
400
500
600
700

Figure 24

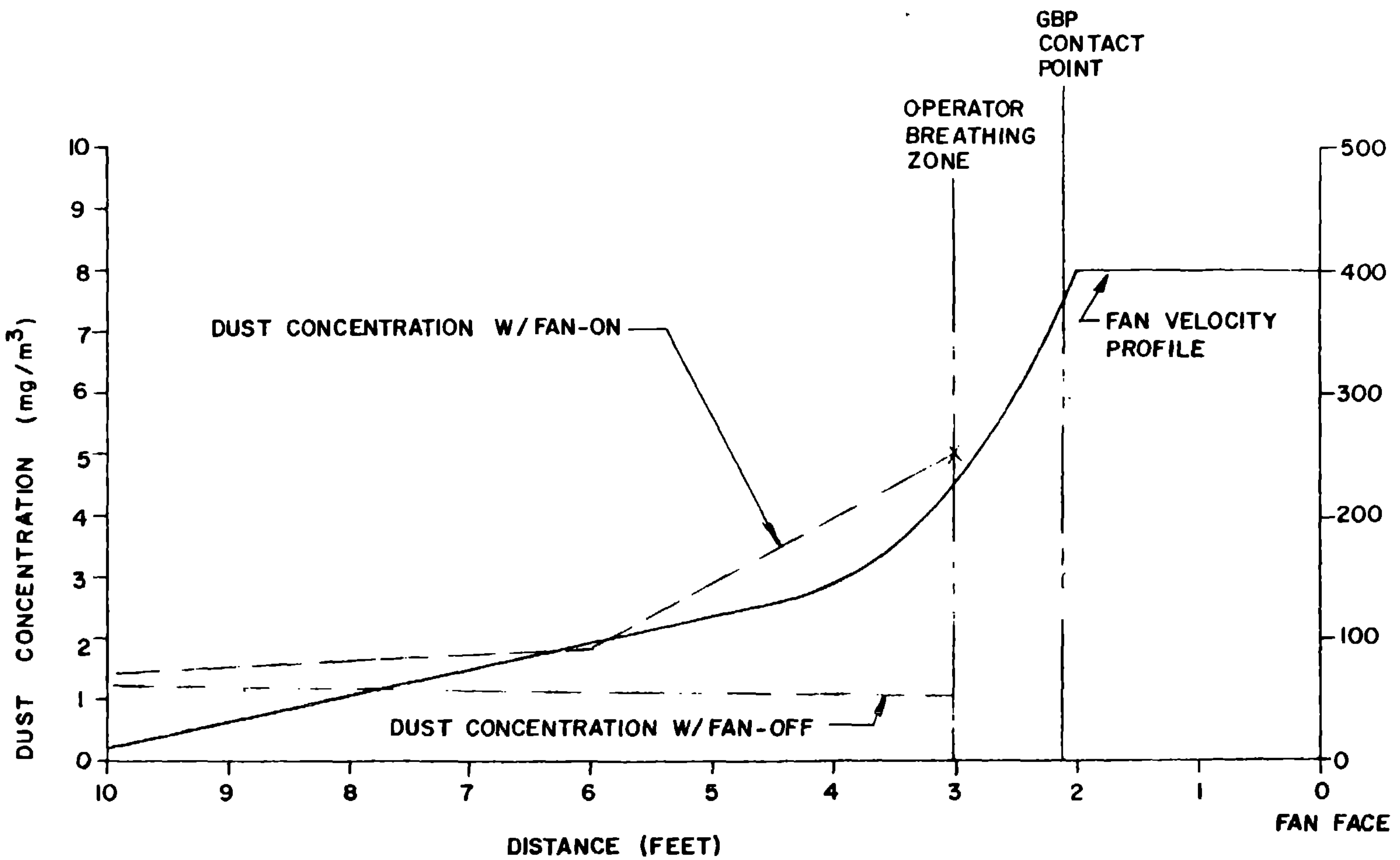


Figure 25

Effects of Convective Air Flow
Directed into the GBP Operator's Breathing Zone

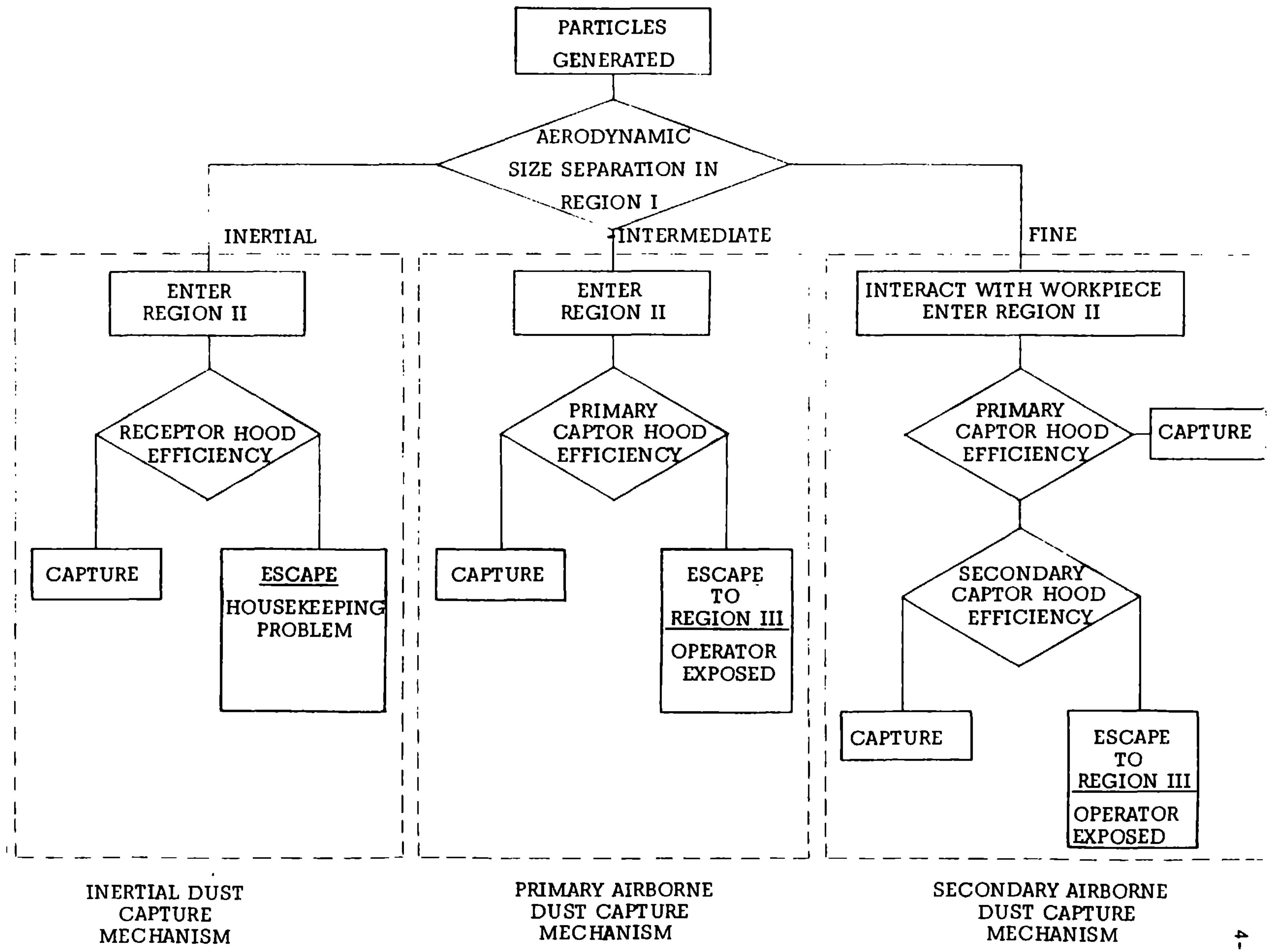


Figure 15 Dust Flow and Capture Processes

Referring to Figure 26, we see that as the particles are generated they experience aerodynamic size separation in Region I. The indvidual particles are separated into three groups classified as inertial, intermediate, and fine particles. For each group of particles there is a corresponding capture mechanism. Within each capture mechanism the particle may either escape or be captured depending upon the type, location and strength of the ventilation system.

Inertial particles, upon leaving Region I, Enter Region II. These particles, propelled by their inertia, can be captured by a receptor hood. Capture or escape from the receptor hood is mainly a problem of locating the hood in the particle flow path. This process has been denoted as the inertial dust capture mechanism.

The particles in the intermediate group enter Region II with a wide range of trajectories. Only those which cross the capture threshold have a high probability of capture. Thus the efficiency of the primary captor hood determines whether the intermediate sized particles are captured or escape to Region III. Some fraction of the particles escaping to Region III are very likely to reach the operator's breathing zone. We call this process of capture or escape for the intermediate sized particles the primary airborne dust capture mechanism.

It has been determined that the fine dust particles are not likely to enter Region II until they are transported around the wheel and interact with the workpiece. If the primary captor hood is large and has a high face velocity, the fine particles may be captured after they interact with the workpiece. Another approach to capturing fine particles is through theuse of a secondary or auxiliary captor hood. If not captured, the fine particles escape to Region III and expose the operator. This process of fine particle capture is termed the secondary airborne dust capture mechanism.

The overall particle flow model serves to identify the various capture mechanisms which can be utilized to control dust particles generated by GBP equipment. These mechanisms are as follows:

a. Capture of inertial particles by receptor hood.
b. Capture of intermediate particles by primary captor hood.
c. Direct capture of fine particles by primary captor hood.
d. Indirect capture of fine particles by primary captor hood after interaction of particles with workpiece.
e. Capture of fine particles by secondary or auxiliary hood.
f. Capture of escaped intermediate and fine particles by convective flow in booth or enclosure.

It is not necessary to employ all of these mechanisms simultaneously to achieve effective dust control. However, one must be aware of the various particle flow processes when ventilation system design and operating characteristics are specified.

4.2 Breathing Zone Dust Concentration Analysis

The nature of the particle transport and capture processes around GBP equipment, as determined by the previous analysis, was used as a basis for formulating a model of the breathing zone dust concentration. The formulation of the model, which is described in Reference 1, involved consideration of three factors: (1) the rate of particle generation, (2) the capture efficiency of the ventilation system, and (3) the distribution of non-captured particles in space. These considerations, accompanied by some simplifying approximations, led to a set of models for breathing zone dust concentration for various classes of equipment. The models are all of the following general form:

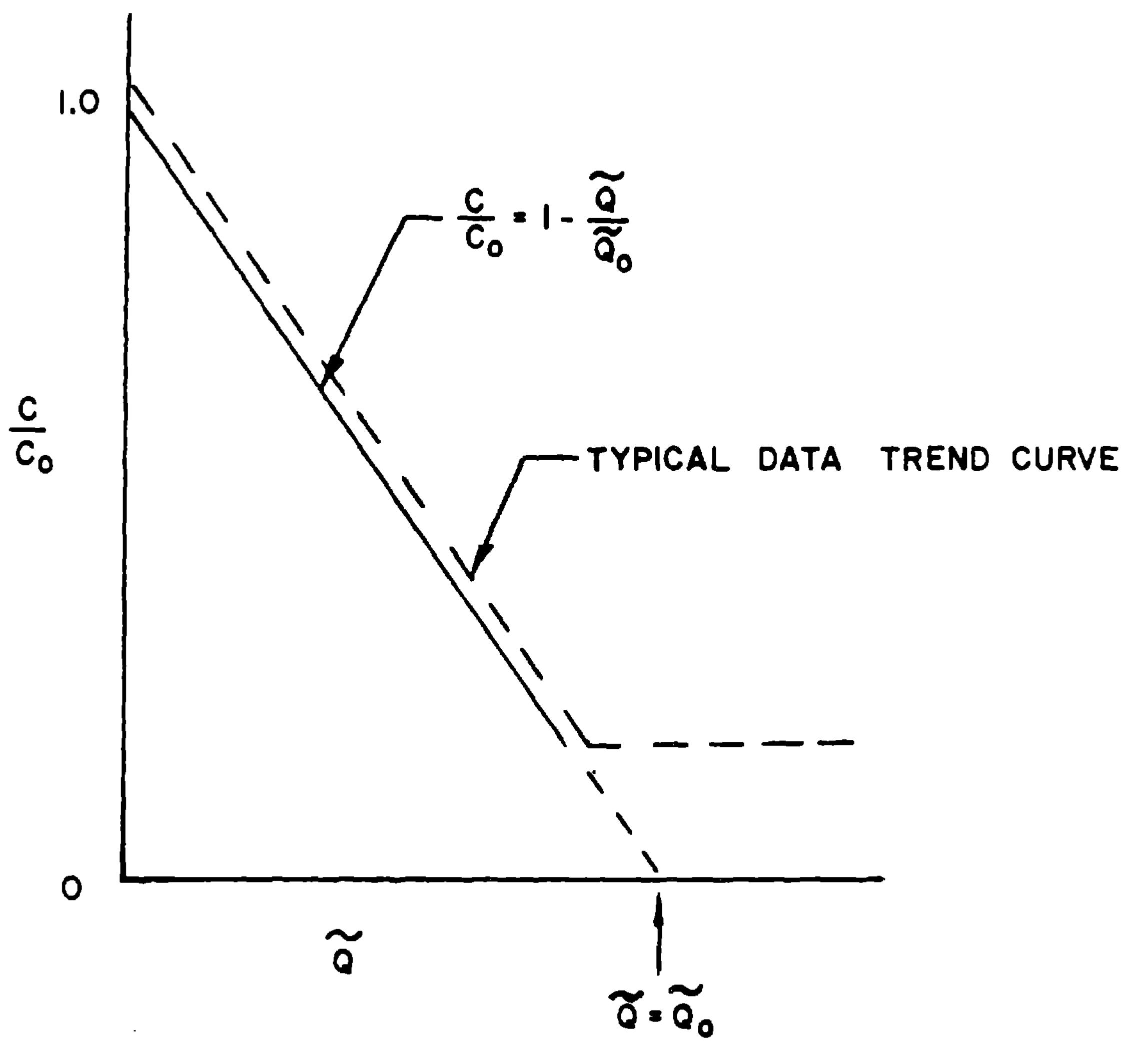
$$\frac{C}{C_o} = 1 - \frac{\tilde{Q}}{\tilde{Q}_o}$$

where C = Breathing zone dust concentration
C_o = Breathing zone dust concentration at zero ventilation rate
$\tilde{Q}$ = Ventilation Parameter
$\tilde{Q}_o$ = Ventilation Index (Value of Q at C = 0)

The general model form is shown graphically in Figure 27.

Figure 27

General Form of Breathing Zone Dust Concentration Model



The ventilation parameter $\tilde{Q}$ is defined differently for each class of GBP equipment. The breathing zone dust concentration model has been applied to four equipment classes: (1) surface-type grinders with captor hoods, (2) pedestal-type grinders with shaped enclosures, (3) pedestal-type polishers and buffers with shaped collectors, and (4) belt grinders and polishers. The ventilation parameters used in these applications of the model are listed in Table VIII.

The ventilation parameter $\tilde{Q}$ is a measure of the capture performance of a specific ventilation hood type used with a specific class of GBP equipment. The parameter is formulated as a dimensionless ratio of the velocity induced by the hood to the particle velocity. This velocity ratio is commonly used in ventilation system design practice as a measure of hood performance (e.g., Ref. 5). In the case of captor hoods, the velocity ratio can be formulated explicitly using the traditional exhaust ventilation formula (Ref 8) to evaluate the hood velocity:

$$V = Q / (10x^2 + A)$$

and the particle velocity is assumed to be proportional to the tool surface velocity. In these cases, the particle capture location, and hence, the point at which the velocity ratio is evaluated, is taken at the abrasive tool (wheel or belt) surface.

In cases where shaped collectors are used, the particle capture locations are not known. In these cases, simple formulations for ventilation parameters are used incorporating equipment design variables which are considered most likely to influence the hood velocity at the particle capture location. The particle velocity is again assumed to be proportional to tool surface velocity.

The ventilation index $\tilde{Q}_o$ is the value of the ventilation parameter $\tilde{Q}$ obtained when the model formula is extended to the point where the breathing zone concentration C is zero. The ventilation index, therefore, defines an optimum value of the ventilation parameter corresponding to maximum particle capture effectiveness per unit volume of ventilation air.

TABLE IV

Breathing Zone Dust Concentration Models

General Form: $\frac{C}{C_o} = 1 - \frac{\tilde{Q}}{\tilde{Q}_o}$

Equipment Class	Ventilation Parameter
Surface-Type Grinders with Captor Hoods	$\tilde{Q} = \frac{Q}{V_s\,(10x_p^2 + A)}$
Pedestal-Type Grinders with Shaped Enclosures	$\tilde{Q} = \frac{Q}{V_s\,D^2}$
Pedestal-Type Polishers and Buffers with Shaped Enclosures	$\tilde{Q} = \frac{Q}{V_s\,D^2}$
Belt Grinders and Polishers with Shaped Collectors	$\tilde{Q} = \frac{Q}{V_s\,W\,L}$

Nomenclature:

C = Breathing zone dust concentration

C_o = BZD Concentration at $Q = O$

$\tilde{Q}$ = Ventilation Parameter

$\tilde{Q}_o$ = Ventilation Index ($\tilde{Q}_o = \tilde{Q}$ at $C = O$)

Q = Ventilation Rate

V_s = Wheel, Belt, or Buff Surface Velocity

X_p = Distance from hood face to wheel surface

A = Hood face area

D = Wheel, Drum, or Buff Diameter

W = Belt width

L = Distance between belt roller centerlines (belt grinders)

4.3 Ventilation System Design-Performance Correlation

The models of breathing zone dust concentration presented in Table VIII have been used to correlate the ventilation system performance data for four equipment classes to which the models are applicable. These correlations are presented in Figures 28, 29, 30, and 31. In each case, a substantial amount of dispersion of the data is observed about each correlation line. However, considering that the data were taken from a number of different machines, the degree of dispersion observed is not surprising. With the surface-type and pedestal-type grinder data, the fits to the correlation curves are sufficiently good to define the curves adequately and to verify the ability of the models to correlate the data from different machines. With the pedestal-type polisher data, the lack of data at low ventilation rates and the fact that all the data were obtained with one machine reduce the confidence level in the location of the correlation curve. Similarly, the belt grinder data also were obtained from one machine so that confidence in this correlation also is somewhat less than for other equipment classes.

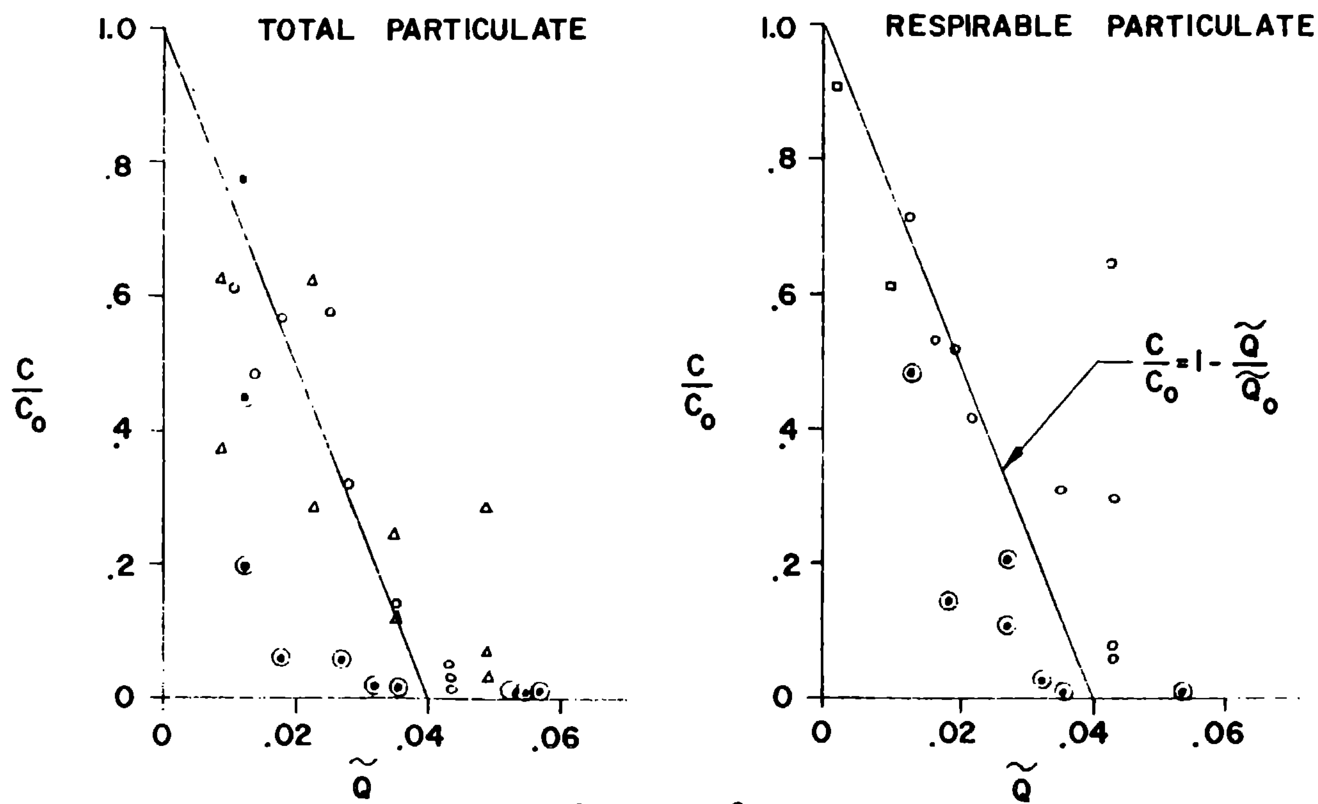
An additional observation worth noting is that for each of the equipment classes, there is no substantial difference between the correlation curves for total and respirable particulates. As a result, the ventilation indices for total and respirable particulates are generally considered to be equal for each equipment class.

4.4 Ventilation System Design Criteria

4.4.1 Control of Inert Dust

4.4.1.1 Captor Hoods and Shaped Collectors

The ventilation performance data correlations from the previous section have been used to formulate ventilation hood design criteria for six equipment classes, and the criteria are summarized in Table IX. Each criterion indicates the ventilation rate required, in terms of machine and hood design characteristics, to achieve optimum ventilation performance. Optimum performance is defined as corresponding to the condition where the ventilation



$$\tilde{Q} = \frac{Q}{V_s(10\,X_p^2 + A)}$$

Figure 28
Correlation of Surface-Type Grinder Data

◉	- 7"	Rough Surface Grinder	w/Cast Steel
○	- 7"	Precision Surface Grinder	w/1045 Steel
□	- 16"	Swing Frame Surface Grinder	w/E4140 Steel
▲	- 6"	Rough Surface Grinder	w/Cast Steel

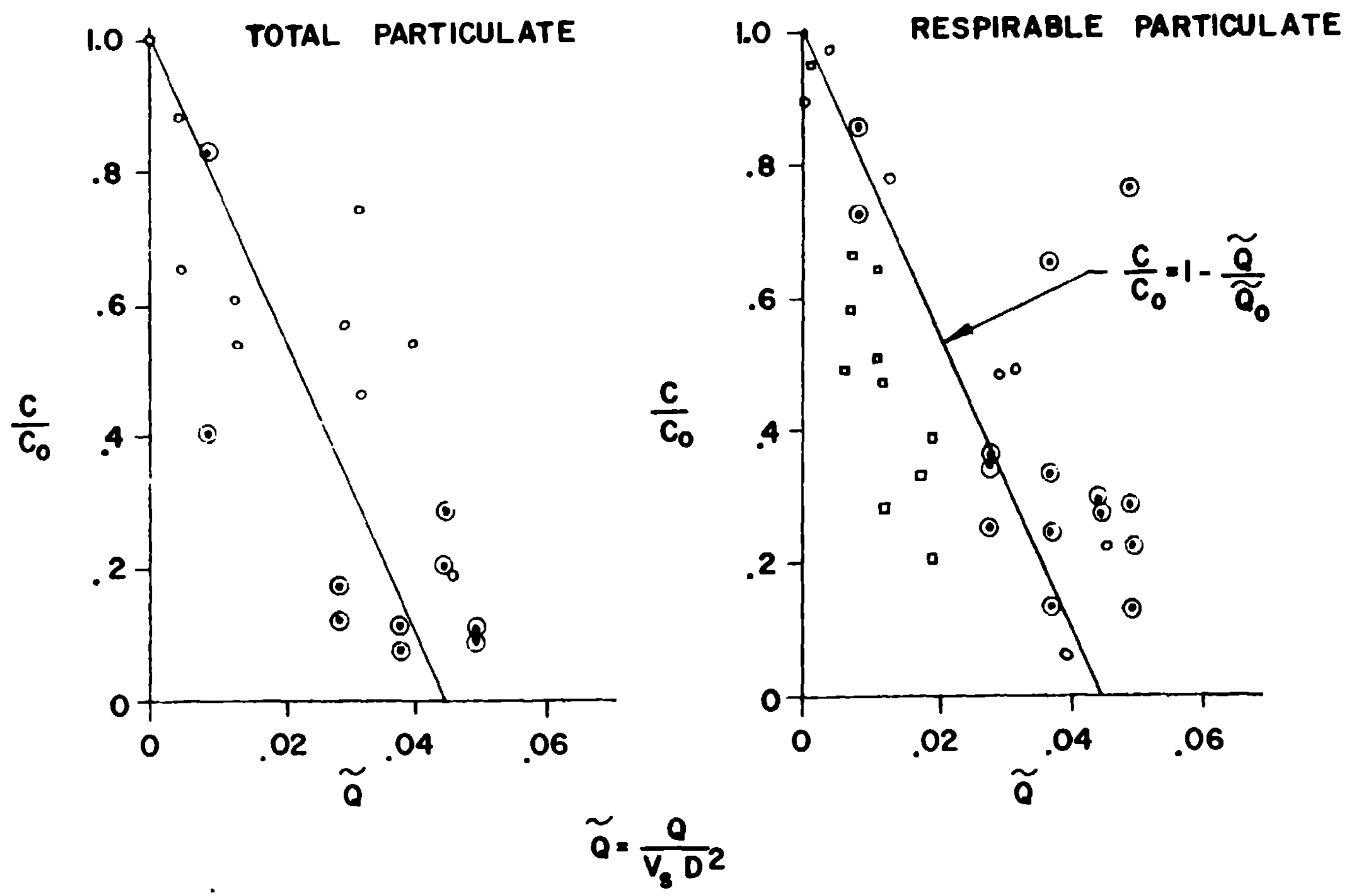


Figure 29

Correlation of Pedestal-Type Grinder Data

⊙	- 12" Bench Grinder	w/1045 Steel & Cast Steel
o	- 10" Pedestal Grinder	w/Mild Steel
▫	- 30" Floorstand Grinder	w/Iron Bar

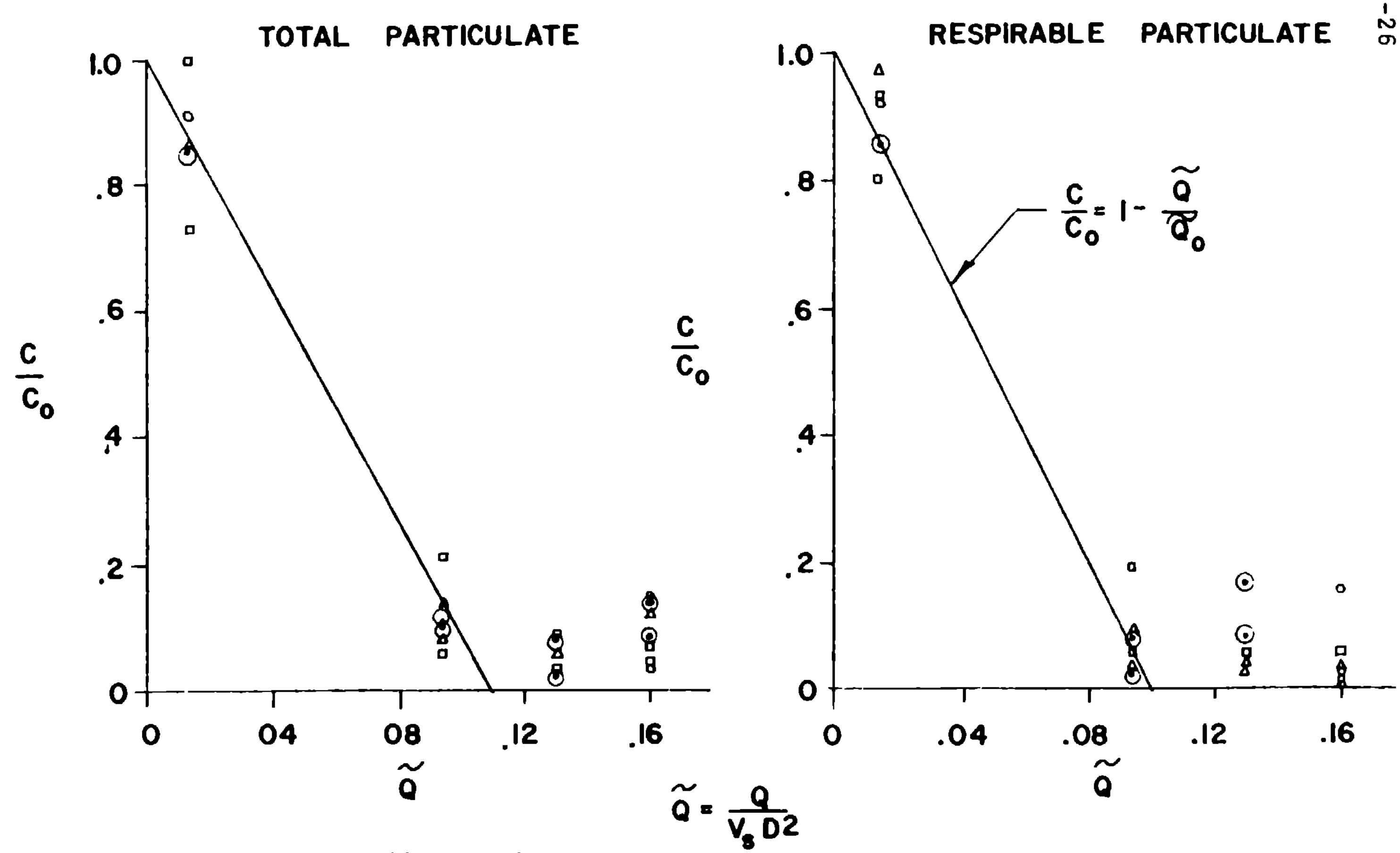


Figure 30 Correlation of Pedestal-Type Polisher Data

⊙ - 36 Grit w/1018 Steel
○ - 120 Grit w/1018 Steel
□ - 80 Grit w/1018 Steel
△ - 80 Grit w/6AL4V Titanium

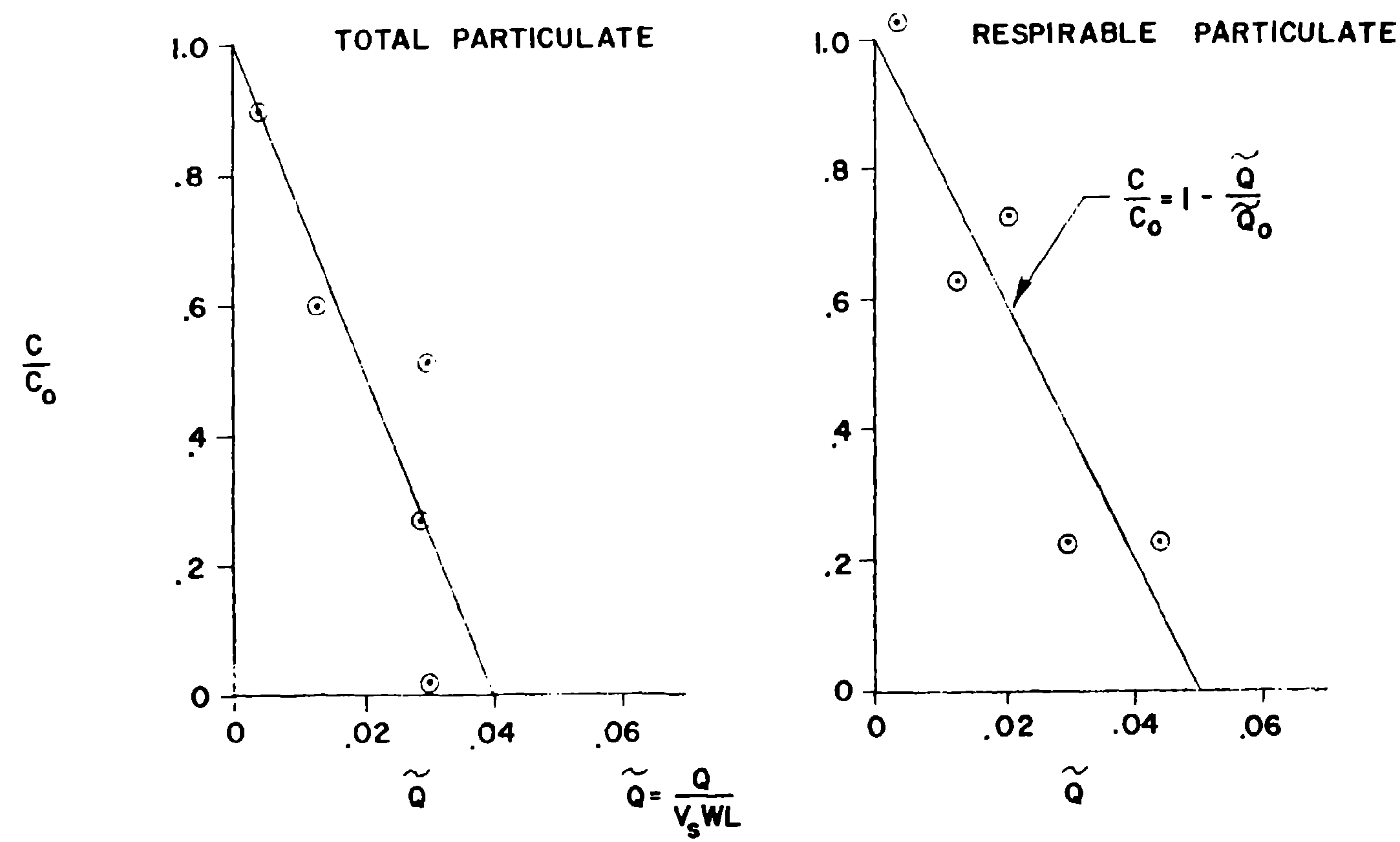


Figure 31

Correlation of Belt Grinder Data
6" Belt Width
V_{5}-3170 SFM

TABLE V

Summary of Design Criteria for Captor Hoods and Shaped Collectors

Equipment Class	Ventilation Hood Design Criterion	Confidence Level
Surface-Type Grinders with Captor Hoods	$Q = 0.04\ V_s\ (10x_p^2 + A)$	High
Pedestal-Type Grinders with Shaped Enclosures	$Q = 0.045\ V_s\ D^2$	High
Pedestal-Type Polishers and Buffers with Shaped Collectors	$Q = 0.045\ V_s\ D^2$	Medium
Pedestal-Type Polishers and Buffers with Captor Hoods	$Q = 0.04\ V_s\ (10x_p^2 + A)$	Medium
Belt Grinders and Polishers with Shaped Collectors	$Q = 0.05\ V_s\ W\ L$	Medium
Abrasive Cutting-Off Machines with Captor Hoods	$Q = 0.04\ V_s\ (10\ x_p^2 + A)$	Medium

parameter $\widetilde{Q}$ is equal to the ventilation index $\widetilde{Q}_o$. At this condition, breathing zone dust concentration will be zero, or nearly zero, and further increases in ventilation rate will produce little or no additional improvement in dust control. These criteria are presented in Appendix F in a format similar to that used in the Industrial Ventilation Manual.

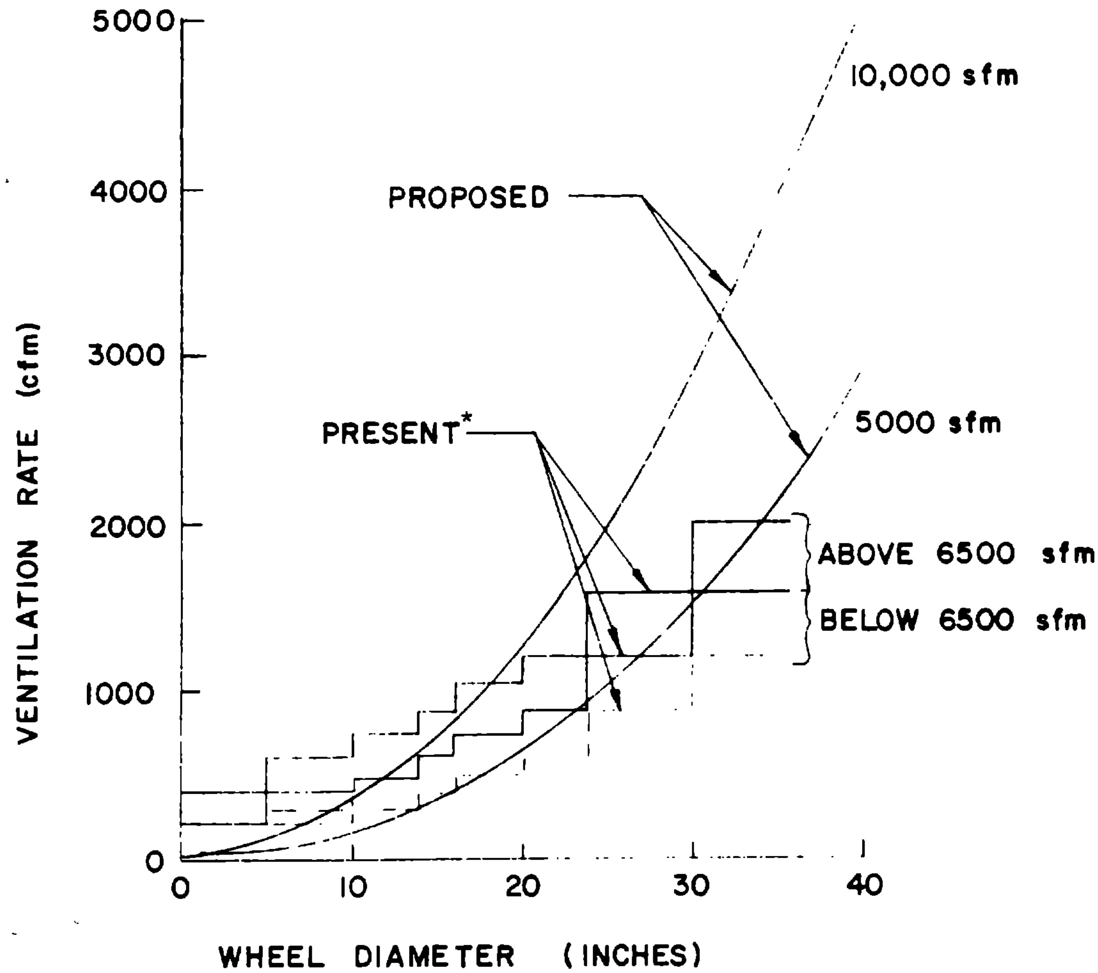
In Table IX, an indication is given of the confidence level associated with each criterion. Confidence in the surface-type and pedestal-type grinder criteria is high because they are based upon models which satisfactorily correlated ventilation performance data from several diverse machines. Less confidence is associated with the other criteria for the following reasons: The criterion for pedestal-type polishers and buffers with shaped collectors actually is taken from the pedestal-type grinder results instead of the data correlation in Figure 30. The criteria for pedestal-type polishers and buffers with captor hoods and abrasive cutting-off machines with captor hoods are taken from the surface-type grinder results. The criterion for belt grinders and polishers is based on data from one machine.

Experience in this program has shown that the above criteria will provide adequate control of inert dust. That is, with the ventilation rates and hood designs prescribed by these criteria, breathing zone dust concentrations will not exceed two-thirds the threshold limit values for total or respirable inert dust, even under prolonged, steady operation of the equipment. Comparisions of the ventilation rates required by the proposed criteria with the rates specified by the Industrial Ventilation Manual are shown in Figures 32 and 33 for pedestal-type grinders and pedestal-type polishers. The ventilation rates required by current practice are similar to those required by the proposed criteria for machines with low surface velocities. However, for large machines with high surface velocities, the proposed criteria require greater ventilation rates than are presently used. General comparisons of required ventilation rates cannot be made for the other classes of equipment because the ventilation criteria are more complex. However, current and proposed ventilation rates are indicated for specific machines in the ventilation performance data in Appendix C. The following qualitative conclusions can be drawn from these comparisions:

Figure 32

Comparison of Proposed Ventilation System Design Criterion
with Present Practice for Pedestal-Type Grinders

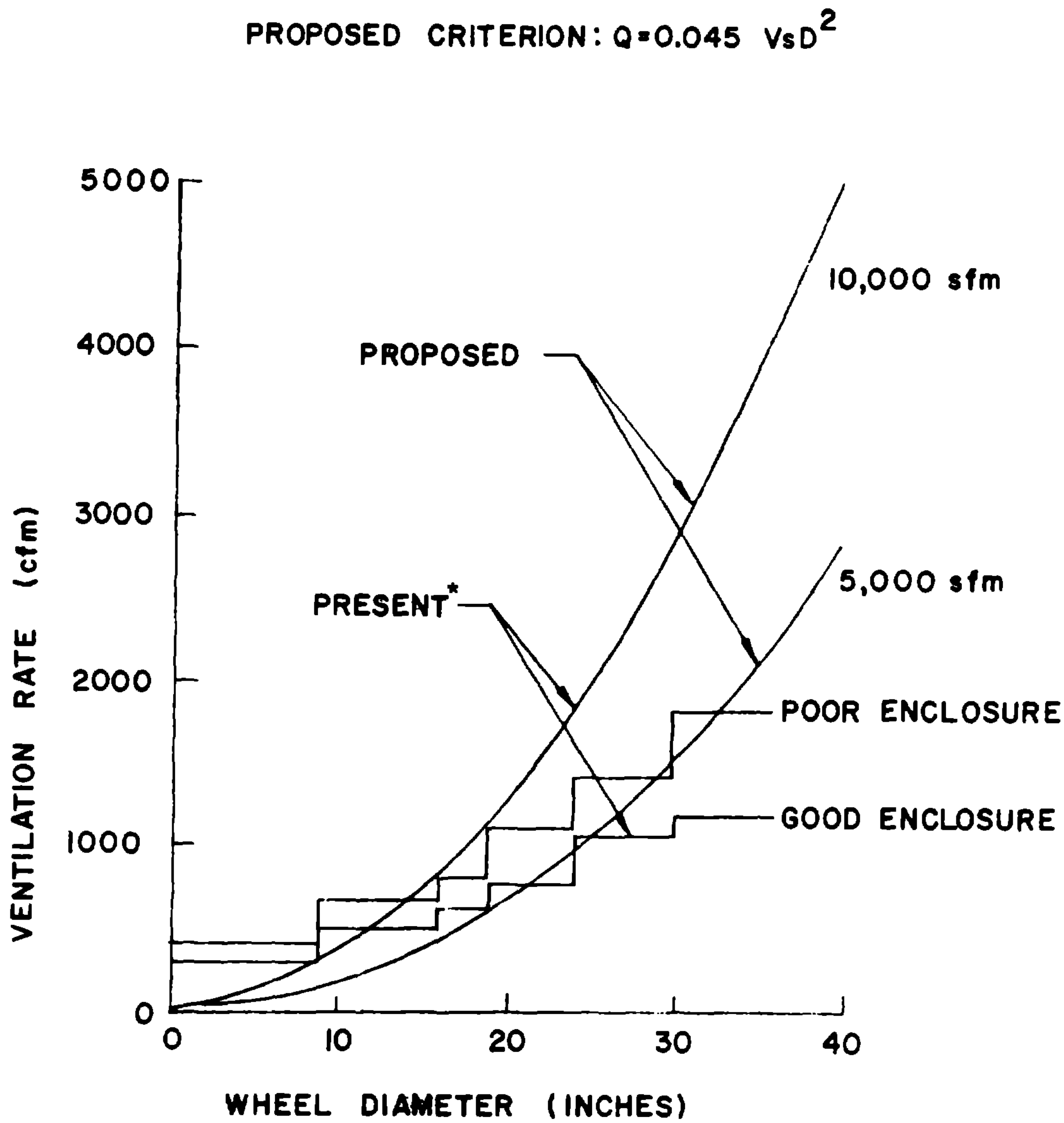
PROPOSED CRITERION: $Q = 0.045\ V_s D^2$



*Recommended Practice, ACGIH - Ventilation rate dependent on quality of enclosure.

Figure 33

Comparison of Proposed Ventilation System Design Criterion
with Present Practice for Pedestal-Type Polishers



*Recommended Practice for Polishing and Buffing, ACGIH

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a. The current ventilation guidelines for surface-type grinders do not adequately specify hood design characteristics. These characteristics affect ventilation performance to the same degree as ventilation rate.

b. The current ventilation guidelines for belt grinders specify ventilation rates which are excessive for small machines.

Design criteria have not been formulated for certain equipment classes for which shaped collectors are applicable. These classes are:

a. Surface-type grinders.

b. Abrasive cutting-off machines

c. Internal grinders

d. Disc grinders and polishers

e. Portable GBP machines

It is recognized that shaped collectors are used for dust control with these machines. However, standardized configurations for these collectors have not been defined so that it is not possible to formulate general criteria for their design and operation.

4.4.1.2 Enclosures and Booths

Measurements of ventilation performance were made for booths used with portable grinding and polishing equipment. The data from these tests are presented in Appendix C. In addition, the practice recommended in the Industrial Ventilation Manual has been reviewed and it appears to be soundly based. This practice specifies face velocities in the range of 100 to 250 fpm for booths and enclosures used with GBP equipment. The lower range of face velocities are suitable when the flow of air and swarf from the machine can be directed consistently away from the enclosure or booth face. The higher velocity range should be used whenever the direction of these flows cannot be controlled. In all ventilation performance tests conducted in this program, the air and swarf flows were directed into the booths. Under these conditions, minimum breathing zone dust concentrations were achieved with booth face velocities less than 100 fpm.

4.4.2 Control of Toxicologically Active Dust

The use of the ventilation system design criteria for captor hoods and shaped enclosures presented above will provide satisfactory control of inert dust under most circumstances. However, the degree of control provided will not be sufficient to protect against exposure to toxicologically active particles generated by GBP operations. When active workpiece materials or abrasive tools are used, other approaches to dust control must be utilized. These approaches may consist of the use of enclosures or booths, or the addition of auxiliary ventilation hoods to supplement the performance of captor hoods or shaped collectors. With any of these approaches to active dust control, the effectiveness of the ventilation system must be evaluated by direct monitoring of breathing zone dust concentrations.

5. CONCLUSIONS

5.1 Conclusions

The results of this program demonstrate that it is possible to formulate criteria for the design and operation of ventilation systems used with GBP equipment by systematic analysis of the particle generation, transport, and capture processes associated with this equipment. These criteria, when verified by correlation with experimental ventilation system performance data, can be utilized as guidelines for obtaining effective control of dust generated by GBP equipment. In addition to this general conclusion, the following specific conclusions have evolved from the results of this program:

a. GBP equipment can be classified according to ventilation system design requirements so that a reasonable number of separate design criteria can provide for the ventilation requirements of most types of equipment. In this program, nine classes were found to be sufficient to include most types of abrasive machines used for the processing of metals.

b. GBP operations can be classified on the basis of toxicological activity of the workpiece and abrasive materials utilized. Such a classification is necessary because most conventional ventilation systems are effective only for the control of inert dust. Consequently, ventilation system design criteria must indicate the classes of GBP operations (or materials) for which each type of ventilation system is effective.

c. The ventilation system performance measurement procedures developed in this program can be used for rapid and accurate evaluation of dust concentrations resulting from GBP operations. The procedures provide continuous, real-time measurements of breathing zone dust concentrations which can be converted to NIOSH-equivalent concentrations.

d. The particle motion analysis conducted in this program has indicated that the transport of particles around GBP equipment is more complex than generally realized. An awareness of the various particle flow paths which exist is necessary for the effective development and use of ventilation equipment.

e. The breathing zone dust concentration models developed in this program have proven to be effective for correlating ventilation system performance data from GBP equipment. The models relate ventilation performance to readily-identified characteristics of the equipment, and thus provide a quantitative basis for ventilation system design criteria.

f. The ventilation system design criteria resulting from the program, if followed, will provide maximum control of airborne dust with a minimum ventilation rate requirement. In general, the ventilation rates specified by the proposed criteria do not differ substantially from the rates recommended by the Industrial Ventilation Manual.

g. Captor hoods and shaped collectors designed and operated according to the proposed criteria will maintain dust concentrations below the threshold limit values for total and respirable inert dust. Auxiliary ventilation hoods combined with conventional hoods, or booths or enclosures are necessary for the control of toxicologically active dust.

5.2 Recommendations

Further investigation of ventilation system performance is recommended in the following areas:

a. Additional testing of conventional ventilation systems is recommended to further verify the design criteria for these systems.

b. Systematic evaluation of auxiliary ventilation systems is recommended so that detailed criteria can be formulated for the design and operation of these systems.

c. Evaluation of ventilation systems used in abrasive processing of non-metals is recommended.

Until further investigations can be undertaken, the ventilation system design criteria resulting from this program should be adopted as recommended practice. However, provision should be made to modify these criteria as additional ventilation system performance data are obtained.

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Appendix A: GBP Equipment Classification

1. Introduction

1.1 Purpose

A classification of GBP equipment has been prepared to provide a basis for planning other tasks in the program. This classification was used in the selection of different types of equipment to be investigated in the test program, and also was used to identify different equipment and ventilation system configurations for which ventilation analyses are required.

1.2 Scope

The classification is concerned primarily with equipment used for buffing, polishing, and dry grinding of metals. Wet grinding processes are not considered to be a source of airborne particulate material. However, in some instances, equipment designed for wet grinding is used dry, and these applications are included in the classification. Equipment designed specifically for processing non-metals is not included in the classification. This preliminary classification is based only on equipment design, and no consideration has been given to the nature of the workpiece material or the method of operation of the equipment.

1.3 Problem Description

Preparation of this classification of equipment has been conducted in two steps. The first step involved identification of types of equipment, and the second step involved classification of the equipment types according to their characteristics which affect ventilation requirements.

In the first step, we are concerned with the terminology of the metal finishing industry. Equipment is identified by the nomenclature utilized by the equipment manufacturers and operators, and categorized essentially according to the operations performed with the equipment. This identification process is both the starting and end points of the analysis. It is by means of the terminology used in this step that the results of this analysis must be communicated to the metal finishing industry. That is, both the initial identification of equipment and the final designation of ventilation system designs must be formulated in terms of equipment types and applications.

In the second step, we have classified GBP equipment according to those characteristics which create the need for ventilation. This step serves only to facilitate the analysis. Equipment types are combined into classes such that each class is concerned with a particular dust generation configuration and can be approached by one common ventilation system design method. This step combined equipment types which are not normally considered to be in the same class. Thus, this step must be unscrambled before the results can be related to the real world of GBP equipment.

2. Grinding Equipment

2.1 Equipment Identification

For purposes of this classification, grinding equipment is considered to include only machines which utilize grinding wheels. Abrasive belt machines are included under polishing equipment. As mentioned above, this identification does not include machines used exclusively for wet grinding or for grinding of non-metals.

Types of grinding equipment included in the classification are listed in Table I. This table is based primarily on information supplied by the Grinding Wheel Division of Norton Company. However, additional information on equipment types has been obtained from equipment manufacturers. The table contains twelve categories of equipment which are identified primarily by the nature of the operations for which they are designed.

TABLE I

Dry Grinding Equipment

Identification by Design and Application

A. Abrasive Cutoff

1. Chop Stroke
2. Traveling Head
3. Orbital (Wheel around work)
4. Traveling Table
5. Bench Stand
6. Portable
   a. Hand-held
   b. Swing Frame

B. Floorstand Grinders

1. Peripheral Grind
2. Side Grind

C. Pedestal and Bench Stand Grinders

D. Tool Grinding and Cutting

1. Hand-held Tools
2. Fixtured Tools
   a. Tool and Cutter Grinders
   b. Tool Post Grinders
   c. Surface Grinders

E. Portable Grinding (Except Cutoff)

1. Right-Angle Grinders
2. Straight Grinders
3. Mounted Wheels, Cones, Plugs, Pot Balls, and Points

F. Profile Grinder - Fixed Wheel

Table I, Continued

G. Hand-Held Swing Frame Snaggers

1. Fixed
2. Traveling

H. Mechanized Steel Conditioning Equipment

1. Slab Grinders — Both Fixed and Traveling Head
2. Billet and Round Grinders — Both Fixed and Traveling Head

I. Disc Grinders

1. Tub Grinders
2. Vertical Spindle - Fixed and Movable Head
3. Horizontal Spindle, Single End
4. Double end, inboard and outboard mount, horizontal or vertical spindle

J. Cylindrical and Centerless Grinders (when used dry)

1. Fixed
2. Traveling

K. Surface Grinders

1. Reciprocating Table, Horizontal or Vertical Spindle
2. Rotary Table, Horizontal or Vertical Spindle

L. Railroad Track Grinder

1. Car Grinder
2. Semi-portable, Flexible Shaft

2.2 Equipment Classification

The preliminary classification of grinding equipment is listed in Table II. The various equipment types have been combined into six classes such that the approach to ventilation system design can be similar for all items within each class. Factors considered in classifying grinding equipment were the direction of the grinding action and the resultant flow of particulate material or "swarf", and the configuration of the guard required for the grinding wheel. The wheel guard is required to protect personnel from wheel failure and has a considerable influence on the trajectories of the particulates generated by the wheel.

The first five equipment classes are reasonably well defined and form a preliminary basis for further investigations of ventilation requirements for grinding equipment. The sixth class, however, includes an assortment of equipment types which require further consideration. Ultimately, each of the equipment types in class 6 will be assigned to one of the previous classes, or will be assigned to a separete class of its own. It is possible, however, that there will remain certain types of equipment which are either highly variable in design or quite specialized such that carrying these equipment types through the analysis will not be practical.

3. Polishing and Buffing Equipment

3.1 Equipment Identification

For purposes of this program, polishing equipment is defined to include all tools employing coated abrasive materials. These materials are commonly used in the forms of belts, discs, or multiple elements in a brush-like assembly. Buffing equipment is defined to include tools utilizing loose abrasive materials in conjunction with a soft wheel. The abrasive material may be applied to the wheel as a suspension in a liquid or grease carrier, or as a loose powder.

TABLE II

Dry Grinding Equipment

Classification by Ventilation System Design Requirements

1. Pedestal-type Grinders

   a. Fixed-head machines for grinding small workpieces. Grinding done on periphery of wheel.

   b. Category includes bench, pedestal, floorstand, cylindrical, and some tool grinders.

   c. Direction of grinding and swarf flow is fixed.

   d. Wheel guard openings can be small so that wheel guard can be designed to collect swarf flow directly.

2. Abrasive Cutoff Tools (not including portable or traveling-head tools)

   a. Fixed or movable-head machines using thin wheels which penetrate deeply into workpiece. Grinding action occurs primarily on periphery of wheel.

   b. Category includes machines with fixed heads or with heads which move through small travel, such as chop-stroke types.

   c. Grinding and swarf flow directions are fixed or vary through moderate angles.

   d. Wheel guards require large openings to accommodate workpiece so that guard does not usually intercept swarf stream.

3. Surface-type Grinders

   a. Machines using periphery of wheel to grind flat stock or workpieces of large diameter.

   b. Category includes surface grinders, except disc type, roll grinders, snaggers, slab, and billet grinders.

Table II, Continued

c. Grinding direction and swarf flow direction are usually fixed.

d. Wheel guard openings must be moderate so that wheel can be applied to flat workpiece surface. Thus, guard does not normally intercept swarf flow.

4. Disc Grinders

a. Machines using side of grinding wheel to grind flat surfaces on work pieces. Grinding head may be fixed or may have moderate movement parallel to spindle.

b. Category includes single and double spindle machines with workpieces moved past grinding wheel or wheels. Tub grinders are a special type included in this category.

c. Directions of grinding and swarf flow vary throughout complete grinding plane.

d. Wheel guards generally must be open to accommodate workpieces so that swarf flow can be only partially intercepted by guard.

5. Portable Grinders and Cutoff Machines

a. Hand-held machines with grinding, disc, or cutoff wheels.

b. Category includes all portable grinding machines, including flexible-shaft grinders.

c. Swarf flow variable and dependent upon tool position and method of operation.

d. Guard openings wide to allow grinding of flat surfaces. Swarf stream not intercepted by guard.

6. Other Grinding Machines

a. Special-purpose machines with unique ventilation requirements.

Table II, Continued

b. Category includes the following sub-categories:

(1) Internal grinders
(2) Plunge grinders
(3) Tool grinders not included in Category 1 above.
(4) Traveling cutoff machines
(5) Traveling head surface-type grinders

c. Grinding direction and swarf flow direction variable, and grinding position varies with traveling machines.

d. Guards usually require large openings, and, in some cases, wheels are unguarded.

3.2 Equipment Classification

The preliminary classifications of polishing and buffing equipment are shown in Table III and IV. The classes are somewhat analagous to the classes of grinding equipment in Table II. Classification has been based primarily on the configuration of the equipment and the flow directions of the particulate materials generated by the abrasive tools. The number of classes of equipment is less than with grinding equipment because the types of operations performed with polishing and buffing equipment are fewer.

4. Combined Classification of GBP Equipment

The previous analyses of equipment configurations have been conducted separately for grinding, polishing, and buffing equipment, and have resulted in fourteen separate equipment classes. Because of similarities between various classes of equipment in the different categories, it is possible to reduce the number of classes further. It also is necessary to eliminate as far as possible the "other grinding machine" class. With these objectives in mind, a final equipment classification has been prepared and is listed in Table V. This final classification has been used in the program as the basis for defining ventilation requirements.

TABLE III

Preliminary Classification of Polishing (Coated Abrasive) Equipment

I. Wheel and Drum Type Polishers

  A. This class of equipment includes machines employing abrasive wheels or drums consisting of coated abrasives attached to the periphery of a drum or attached to a hub to form a brush-like assembly (Flap wheel).

  B. These machines are used to polish small parts or flat surfaces and the polishing action is limited to a small portion of the wheel periphery. Thus, swarf flow direction is generally fixed.

II. Disc Type Polishers

  A. This class of equipment utilizes coated abrasive discs bonded to the side of a wheel.

  B. Disc polishers are used to finish flat surfaces and a large fraction of the polishing disc may be utilized. Thus, swarf flow occurs in all directions in the polishing plane.

III. Belt Polishers

  A. This class of equipment includes the common belt polisher (or grinder or sander) with a short belt suspended between two drums.

  B. Belt polishers are used to finish flat surfaces on small or elongated parts, and the swarf flow direction is fixed in the direction of belt motion.

IV. Portable Polishers

  A. This class of equipment includes portable tools employing wheels, discs, or belts constructed of coated abrasives.

  B. Direction of swarf flow with portable tools is variable and dependent on the manner in which the tool is employed.

Table III, Continued

V. Complex Polishing Machines

A. This class of equipment includes machines employing long belts with complex travel paths, and machines employing multiple polishing heads.

B. These machines are characterized by large, complex configurations or multiple sources of swarf generation.

TABLE IV

Preliminary Classification of Buffing (Loose Abrasive) Equipment

I. Pedestal Type Buffers

A. This class of equipment includes buffing lathes with a single wheel used for offhand buffing of small parts.

B. Buffing action results in particulate generation at a fixed location on the wheel periphery and swarf flow direction is relatively fixed.

II. Portable Buffers

A. This class of equipment includes portable tools with buffing wheels.

B. The buffing action and particulate flow direction are highly variable and dependent upon the manner of use of the tool.

III. Multiple Buffer Machines

A. This class of equipment includes assemblies of two or more buffing heads for performing sequential buffing operations in an automated manner. The movement of parts may be linear or circular through the buffing head assembly.

B. This type of equipment may involve many buffing heads located in close proximity and with different directions of buffing action. Thus, the flow of particulate materials occurs in many directions, and the flow directions will vary with different workpiece configurations.

TABLE V

Combined Classification of GBP Equipment

	Equipment Classes based on Ventilation System Design	Equipment Types included in Classes
1.	Surface-Type Grinders	Surface Grinders Roll Grinders Snaggers Slab and Billet Grinders
2.	Pedestal-Type Grinders	Pedestal Grinders Bench Grinders Floorstand Grinders Tool Grinders
3.	Abrasive Cutting-Off Machines	Abrasive Cutting-Off Machines
4.	Internal Grinders	Internal Grinders
5.	Disc Grinders and Polishers	Single Spindle Disc Grinders Double Spindle Disc Grinders Disc Polishers
6.	Pedestal-Type Polishers and Buffers	Wheel and Drum Polishers Backstand Idler Polishers Buffing Lathes
7.	Belt Grinders and Polishers	Belt Grinders and Polishers (using flat belt surface)
8.	Portable GBP Machines	Portable Grinders Portable Polishers Portable Buffers
9.	Complex Machines	Multiple-Belt Polishers Multiple-Head Buffers

Appendix B: GBP Operations and Ventilation Requirements

1. Introduction

1.1 Purpose

This program is concerned primarily with the design and performance of ventilation systems for grinding, buffing, and polishing (GBP) operations with ventilation system performance measured in terms of the concentrations of particulate material existing around the GBPequipment. A companion problem is the determination of the particulate concentrations which can be tolerated around this equipment to provide criteria for setting ventilation system performance requirements. In this appendix, the types of particulate materials encountered in GBP operations are reviewed, and allowable concentrations of these materials are defined on the basis of current air quality regulations.

1.2 Scope

This analysis of ventilation requirements has been limited to operations involving dry grinding, buffing, and polishing of metals and metal products. The ventilation requirements which have been defined are based upon the particulate materials associated with these operations.

2. Particulate Materials

2.1 Sources

In analyzing the concentrations of particulate material around GBP equipment, all sources of such material must be considered. These sources can be classified broadly as consisting of background particulate concentrations and particulate materials generated by the equipment. The ventilation system design criteria to be developed in this program will be concerned primarily with the control of particulate material generated by the equipment. However, the ventilation requirements must allow for the existence of both classes of materials.

Equipment-generated particulate materials can be further classified into three categories: workpiece materials, abrasive materials, and abrasive support materials. Workpiece materials consist of particulates removed from the workpiece during the metalprocessing operation. Abrasive materials are defined here to include only the particles which accomplish the cutting of the workpiece. Abrasive support materials are other materials in the tool which are worn away in the cutting action, including binders, belts, and buff materials.

The relative amounts of the three categories of equipment-generated particulates in the total particulate concentrations around GBP operations vary with the type of equipment and the nature of the operation. Data on the distributions of these materials are limited, but estimates have been made for different operations and are listed in Table I. It is observed that the workpiece material makes up the largest fraction of the equipment-generated particulates in grinding and coated-abrasive operations. Whereas, with buffing operations, the workpiece material is estimated to be present only as a minor fraction of the total particulate which consists mostly of abrasive material and support materials such as abrasive carrier (grease or glue) and buff material.

2.2 Characteristics

The most common workpiece materials in grinding and coated-abrasive operations are iron and various grades of steel. These materials are regarded as physiologically inert so that ventilation requirements can be based on allowable concentrations of inert dust. Other metals processed in GBP operations, which are regarded as physiologically active, are listed in Table II along with the threshold limit values of particle concentrations for these materials. The TLV is the maximum concentration to which a worker may be exposed as an average over an 8-hour workday. Quartz is also listed in the table, even though it is a non-metal, because it is encountered in the workpiece in the grinding of sand castings in foundry operations. The materials are listed in the table in increasing order of physiological activity, or in decreasing order of TLV.

TABLE I

Sources of Equipment-Generated Materials from GBP Operations

Operation	Sources (Percent of Total) Workpiece	Abrasive	Support	Data Source
Heavy Grinding	80	16	4	1
Light Grinding	95	4	1	1
Coated-Abrasive Operations	98	2	0	2
Buffing	20	40	40	Estimated

Data Sources:

1. R.S. Hahn and R.P. Lindsay, "Principles of Grinding", Machinery, July-Nov., 1971.

2. L.P. Tarasov, "Abrasive Belt Grinding Does Heavy Metal Removal", Machinery, March 1969.

TABLE II

Materials Processed in GBP Operations and Their Threshold Limit Values

Material	Threshold Limit Value (mg/m^3)	TLV* Ratio
Inert Dust (Includes iron, steels, and most other industrial metals)	15 (Total)	-
	5 (Respirable fraction)	-
Copper	1	0.1
Chromium	1	0.1
Nickel	1	0.1
Quartz (as inclusion in sand castings)	0.3 (Total)	0.03
	0.1 (Respirable)	0.01
Lead	0.2	0.02
Cobalt	0.1	0.01
Silver	0.01	0.001
Beryllium	0.002	0.0002

*Ratio of TLV to 60% of TLV for total inert dust.

Little data have been found on the particle size distributions of work-piece particles from GBP operations. It is likely that the average and maximum particle sizes increase with the coarseness of the abrasive material and the cutting rate of the abrasive tool. However, it also is likely that fine particles, including those in the respirable range of 10 micrometers diameter and below, are generated in all GBP operations. Preliminary results of the testing in the IKOR laboratory indicate that the respirable fraction of particles from grinding operations constitutes a significant fraction of the total airborne particle concentration.

Abrasive and abrasive support particles also include both inert and active materials. The most commonly used abrasive materials -- aluminum oxide and silicon carbide -- are considered to be inert, although some silica-based materials are still in limited use, including natural sandstone in grinding wheels, quartz (flint) in coated abrasives, and amorphous silica (tripoli) in buffing compounds. Similarly, most abrasive support materials, including grinding wheel bonding materials and buffing compound liquids and greases, also are regarded as inert. Exceptions include lead, reportedly used as an additive in some grinding wheels, and cotton particles resulting from the wear of cotton buffs. These materials are listed in Table III with their respective threshold limit values in increasing order of physiological activity.

3. Ventilation Requirements

It is clear from the foregoing discussion that most particulate materials generated by GBP operations are physiologically inert. Therefore, it is logical that the design of ventilation systems for GBP equipment be based upon the control of inert dust. Operations involving the generation of active particles will require special ventilation equipment or procedures in order to avoid health hazards to the equipment operators. This approach to ventilation system design will require the least expenditure by industry for ventilation equipment since most operations can be served by the minimum requirement of inert dust control. Additional expense for ventilation equip-

TABLE III

Abrasive Materials and Abrasive Support Materials

and Their Threshold Limit Values

Material	Threshold Limit Value (mg/m^3)	TLV Ratio (1)
Inert Dust (Includes all abrasives other than quartz, grinding wheel binders, and buffing liquids and greases)	15 (Total) 5 (Respirable)	- -
Cotton dust (2)	1	0.1
Amorphous silica (3)	0.8	0.08
Quartz (3)	0.3 (Total) 0.1 (Respirable)	0.03 0.01
Lead	0.2	0.02

Notes:

(1) Ratio of TLV to 60% of TLV for total inert dust.

(2) TLV listed is for raw cotton

(3) TLV values are based on 100% silica content.

ment will be incurred only in the small fraction of operations which involve active materials. The alternate approach to ventilation system design, which would involve ventilation system performance sufficient for the control of active materials for all GBP equipment, would be considerably more expensive and would require high performance ventilation systems in many installations where they are not required.

The ventilation performance required for operations involving the various materials listed in Tables II and III is indicated by the TLV ratio for each material. The TLV ratio is the ratio of the TLV for the active material divided by 60 percent of the TLV for total inert dust (TID). The 60-percent TID-TLV, which is approximately 10 mg/m^3, is the minimum ventilation requirement for the control of total inert dust generated by the equipment. The 60-percent criterion provides for the addition of background dust levels up to 5 mg/m^3 without the TID-TLV being exceeded. The TLV ratio, then, indicates the increase in ventilation performance necessary to control active particulate materials generated by GBP equipment.

On the basis of the TLV ratios, the materials listed in Tables II and III have been divided into three categories of ventilation requirements as shown in Table IV. Category I includes only inert materials, and the ventilation system design criteria to be developed in this program will be directed primarily at the control of these materials. Thus, the term "standard ventilation system" will refer to a system which conforms to the criteria resulting from this program and which is suitable for the control of inert, or Category I, particulate materials.

Category II includes materials whose TLV-Ratios are in the range of 0.1 to 1.0. These materials can be processed with GBP equipment with standard ventilation systems under either of the following circumstances:

a. The fraction of the Category II material in the workpiece is less than 10 percent.

b. An auxiliary ventilation hood is used with a standard captor hood or shaped collector or a booth or enclosure is used.

Table IV

Classification of GBP Operations

Operations Class	TLV* Ratio	Operations Included	Ventilation Requirements
I	1.0	All operations with inert workpiece, abrasive, and abrasive support materials.	Standard ventilation systems.
II	0.1 to 1.0	Grinding, buffing or polishing of copper, chromium, or nickel	(1) Auxiliary ventilation system combined with standard system, or (2) Totally enclosed ventilation system.
III	Less than 0.1	(1) Grinding, buffing, or polishing lead, cobalt silver, or beryllium (2) Grinding sand castings (3) Grinding with wheels containing lead or silica (4) Buffing with silica abrasive	(1) Totally enclosed ventilation system, and (2) Respiratory apparatus for personnel within enclosure.

*Ratio of threshold limit value of dust generated by operation to 2/3 the TLV for total inert dust or 10 mg/m^3.

In either case, the effectiveness of the ventilation system should be monitored periodically when active materials are processed.

Category III contains materials for which adequate control is not likely to be possible with standard ventilation systems. GBP operations involving these materilas will require total enclosures for effective control of particulates, and personal protective equipment for personnel who are required to operate within the enclosures.

4. Conclusion

We conclude that the approach suggested here to defining ventilation requirements for GBP operations will be practical and will result in effective ventilation systems with minimum expenditures for equipment. The ventilation requirements are based on various categories of materials involved in GBP operations.

Appendix C: Ventilation System Performance Measurement

1. Approach

The purpose of the measurement procedure was to measure the particulate concentrations in the breathing zones of the operators of grinding, buffing and polishing (GBP) equipment. These measurements were to be made for various ventilation system configurations and flow rates. In this way, the particulate concentration levels near the GBP equipment would change so as to reflect the changes in the ventilation flow rates and thus allow criteria to be chosen for the effective ventilation of the various types of GBP equipment. Both the concentration of total particulate (all particles which the sampling systems could catch) and the respirable particulate (particles below about $5 \mu m$ in diameter) were to be measured.

It was anticipated early in the program that in most cases the concentration levels would be low (on the order of 1 - 5 mg/m^3 for respirable particulate) and that a typical personal sampler normally used by NIOSH would not be able to obtain a weighable sample in a reasonable length of time. It was therefore decided to use the IKOR Model 206 Air Quality Monitor (AQM) to make the measurements for the changing ventilation conditions and to use the NIOSH personal sampler as a calibration standard for the IKOR monitor. The IKOR AQM is highly sensitive to mass flow and can obtain particulate concentrations in a much shorter period of time.

2. Instrumentation

2.1 The IKOR Model 206 Air Quality Monitor

The operation of the IKOR continuous particulate monitor system is based on the "triboelectric effect" or electron transfer as a result of particles suspended in a gas stream continuously impinging on a bullet-shaped sensor within (but electrically isolated from) the sample line. This electron or charge transfer phenomena was succinctly noted by L. Cheng, S. K. Tung and L. S. Soo[16] as follows, "When two bodies with surfaces of different work functions are brought into contact, the equilibrium state requires that their Fermi levels coincide with the transfer of electrons from the surface having a lower work function to the one with a higher work function. This gives rise to a contact potential difference. When this contact is suddenly broken, the body having a lower work function becomes positively charged while the one with a higher work function becomes negatively charged. In this way, dust particles become charged by wall impact and the method of their formation. By the same token, a metal probe subjected to collision by a dust cloud can give an electric current as a signal due to redistribution of charges during impact which is proportional to the mass flow of dust particles, their materials and that of the probe." This can be related to the double layer theory, if it is assumed that "the surface of a particle is surrounded by a layer of condensed air in which an electric double layer is formed by polar adsorption of the ions in the air. When the particles impinge on the surface of a compact body, the ions of loosely bounded upper layer are detached from the double layer by inertial forces and reach the molecular attraction range of the body surface. This causes a separation of the charge in which a compact body, e.g., the electrode, becomes charged by the ions separated from the double layer of the dust particle. The dust particles, however, entrain the charges of the more strongly bonded lower level of the double layer".

IKOR has made advances in high sensitivity solid state circuitry design to provide ultra-high amplification of a signal equal in magnitude to the current generated by charge transfer, and produce an output voltage precisely related to particulate mass flow.

In operation of the IKOR AQM, the magnitude of the electrical charge transferred between the particles in the sample stream and the sensor element is dependent upon two factors: the triboelectric transfer process described above, and the probability of collision between the particles and the sensor element. Each of these factors is related in a different way to particle size or mass and, consequently, the overall charge transfer process is a complex function of particle size or mass. Calibration of the IKOR AQM response in terms of particle mass concentration can be accomplished by comparison of the electronic sensor amplitude to the particle mass concentration determined by gravimetric analysis, and a filter assembly is incorporated in the AQM sampling train for this purpose. Once calibrated, the IKOR AQM can be used to monitor particulate mass concentration by means of electronic sensing alone over an unlimited range of particle concentration and a moderate range of particle size. However, if a large change in particle size or a change in particle composition is encountered, the monitor must be recalibrated for the new condition.

Processing of data obtained with the IKOR monitor is a simple procedure. The first data processing step involves determination of a calibration factor by relating the sample mass collected on the filter to the integrated sensor mass flow. These quantities generally are related by the following expression:

$$m = BI \qquad (1)$$

where m = sample mass determined gravimetrically

I = integrated sensor mass flow

B = calibration factor at constant sampling velocity

The integrated sensor mass flow (I) actually consists of three factors as follows:

$$I = \frac{M_i K}{S_s} \qquad (2)$$

where M_i = integrator scale reading

K = integrator time constant

S_s = sensor sensitivity setting

These latter factors correspond to instrument adjustments which provide for wide ranges of operating conditions.

After the calibration factor (B) is determined, it can be used to interpret the sensor mass flow reading as follows:

$$\dot{m} = B \frac{\dot{M}_s}{S_s} \quad (3)$$

where $\dot{M}_s$ = sensor mass flow reading

$\dot{m}$ = instantaneous particulate mass flow rate

The calibration factor is found to vary in magnitude with the composition of the particulate material being monitored, and for a given material the factor may also vary with sampling velocity. If a sufficient number of calibration tests are conducted, the sampling velocity dependence can be expressed separately as follows:

$$\dot{m} = \frac{A}{U^n} \cdot \frac{\dot{M}_s}{S_s} \quad (4)$$

where A = calibration factor independent of sampling velocity

U = sampling velocity

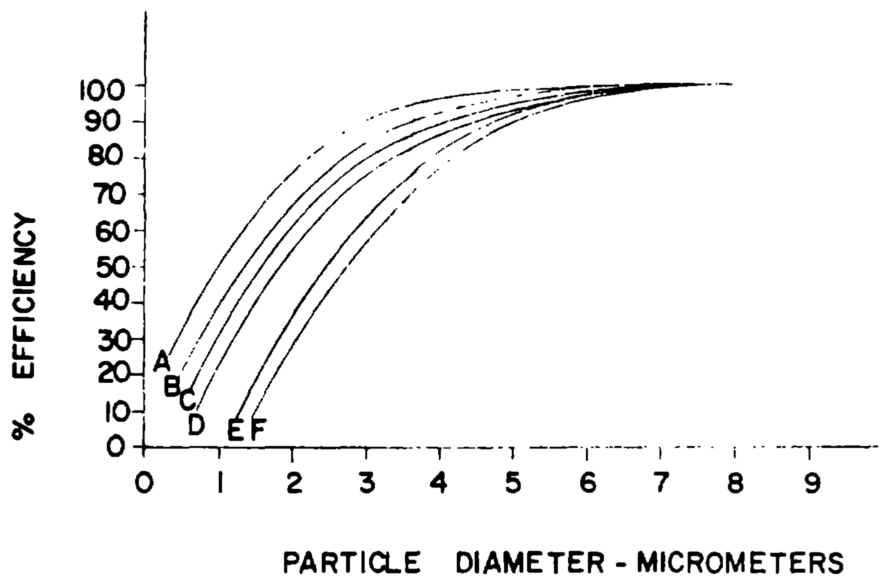
n = velocity sensitivity index

The velocity sensitivity index can be determined during monitor calibration and is found to vary from 0 to 2 for different particulate materials. However, when sampling is conducted at a constant velocity, which was the case in this program, the velocity sensitivity does not need to be considered, and equation 3 can be used for processing data obtained with the AQM.

In operation, the IKOR AQM was used with an Aerotec Industries size 1 1/2 cyclone when measurements for respirable particulate were made. For total particulate measurement, the cyclone was removed from the sampling line. This particular cyclone was chosen because it could be operated at 0.495 m^3/min (17.5 cfm) and still exhibit its rated collection efficiency characteristics (see figure C-1). The flow rate of .495 m^3/min. was chosen

Figure C-1

Particle Size Efficiency Curves
for Aerotec Cyclone



IRON		ALUMINUM OXIDE		QUARTZ	
SP GR = 7.86		SP GR = 4.0		SP GR = 2.65	
Curve	CFM	Curve	CFM	Curve	CFM
A	40	B	40	E	40
		C	30	F	30
		D	20		

in order to maximize the filter catch.

2.2 NIOSH Personal Sampler

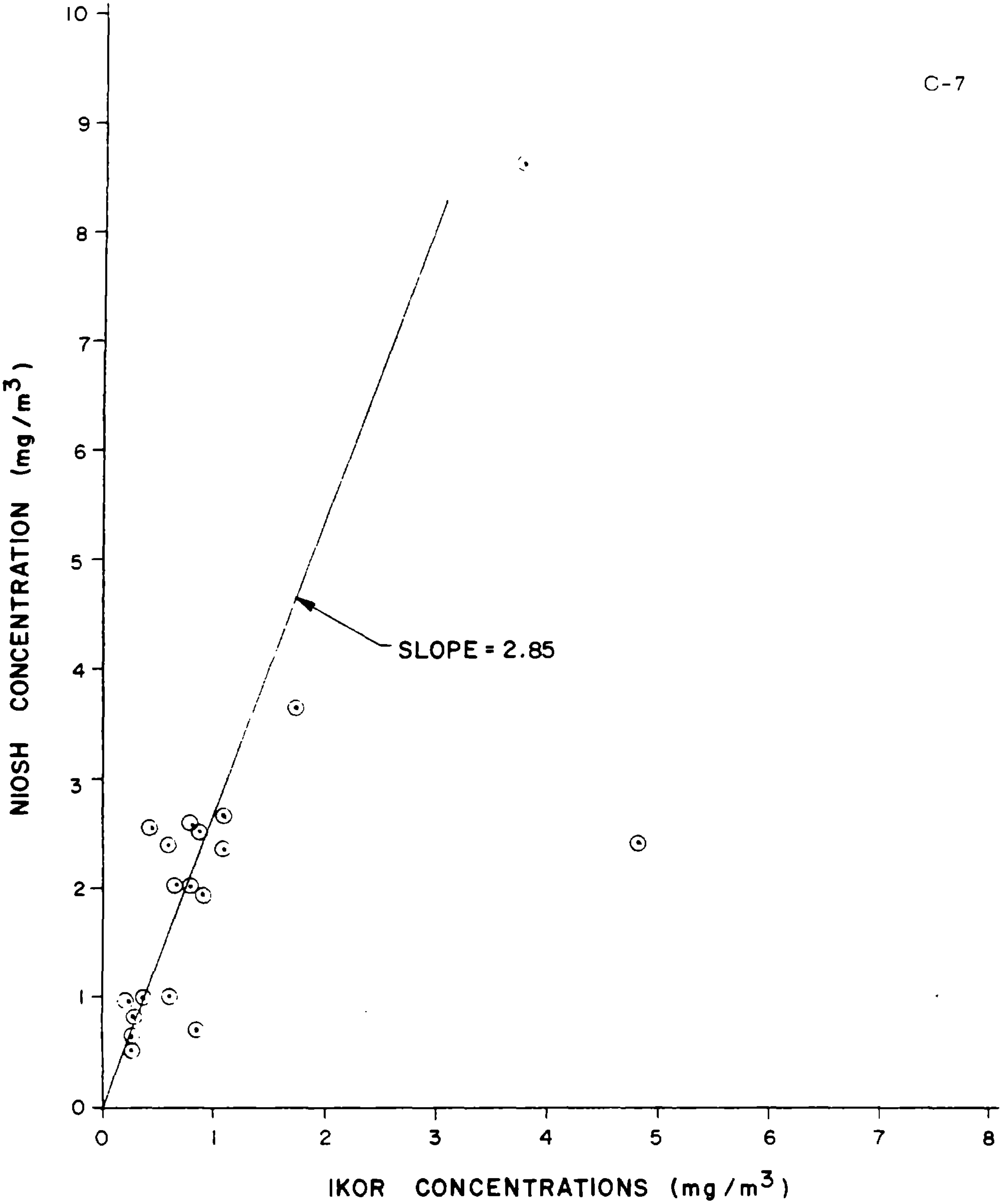
The NIOSH personal sampler is a pump-operated gravimetric filter in a plastic filter holder which is designed to be used at a 9 liter/min (0.3 cfm) flow rate. The filter used was a 37 mm diameter type AA filter with a mean pore size of 0.8 μm. When respirable particulates were being collected, a Bendix Model 9 cyclone supplied by NIOSH was used to separate out the larger particles.

2.3 Calibration

The IKOR Model 206 was calibrated by using the filter catch data collected simultaneously by the NIOSH personal sampler. This was done because the NIOSH filter method is the standard method of determining particulate concentration levels in occupational environments.

For respirable particulate the ratio of the NIOSH filter catch to the IKOR filter catch was determined to be 2.85 based on 19 simultaneous runs (see figure C-2). The factor of 2.85 was used to correct all the concentrations measured by the IKOR unit for respirable particulate. The respirable particulate results are thus expressed in terms of the NIOSH sampler measurement performance.

For total particulate, the ratio of the NIOSH filter catch to the IKOR filter catch was 0.80. This factor was used to correct the IKOR readings for total particulate. It was observed that the IKOR filter collected more larger particles than the NIOSH filter. This fact was presumably due to the greater cross sectional area of the IKOR probe inlet per unit of flow rate. (See figure C-3.)



IKOR AIR QUALITY MONITOR CALIBRATION: RESPIRABLE PARTICULATE

Figure C-2

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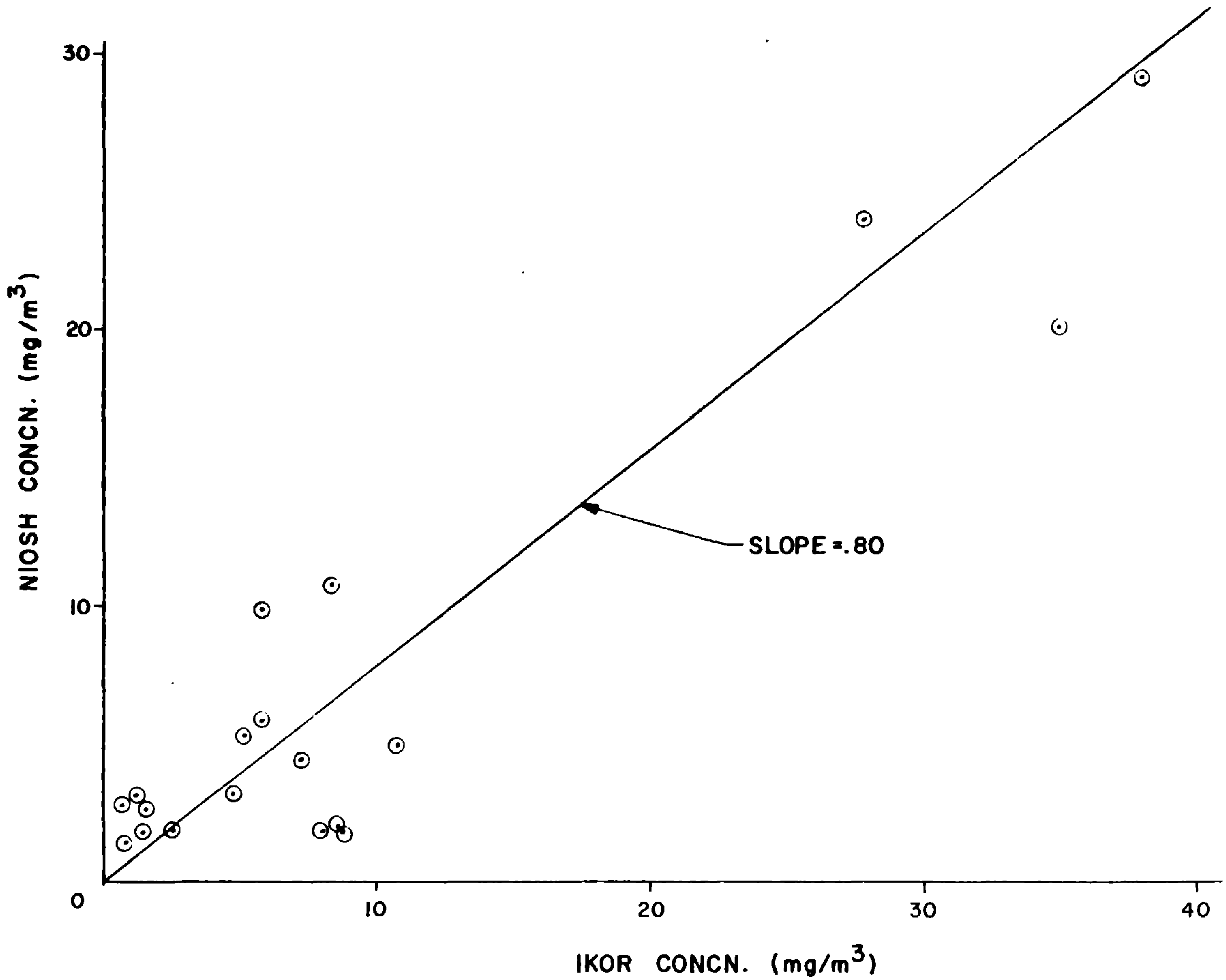


Figure C-3 **IKOR AIR QUALITY MONITOR CALIBRATION: TOTAL PARTICULATE**

2.4 Probe Inlet Position

Before the measurement program began, the optimum location of sampling probe inlets was determined. Three different positions were tried with the last one chosen as the final configuration:

(1) Position A - the IKOR and NIOSH probes were located in the breathing zone at the same height but were spaced about 1 foot apart. The correlation between IKOR and NIOSH filter catches was poor. It was felt that perhaps the units were actually sampling different concentrations due to their location.

(2) Position B - the IKOR and NIOSH probes were bundled together with the NIOSH inlet 4 1/2" lower than the IKOR inlet. The height difference was chosen because it was felt that in position A the IKOR unit was dominating the collection of particulate due to its large flow field. The correlation between NIOSH and IKOR was better than in position A but it was decided that a third position should be tested to see if the sampling probes could be operated even closer together.

(3) Position C - in this position the IKOR and NIOSH probes were bundled together with the NIOSH probe inlet about 1 1/2" below the IKOR inlet. The correlation was as good in this position as in B, and it was decided to use position C for the test program because it was felt that the probes were more likely to be sampling the same concentrations.

3. Procedure

The sampling procedure was as follows: a background reading was taken with the IKOR electronics so that test readings could be corrected as required. The IKOR and NIOSH filters were then inserted, the IKOR integrator set to zero and the test begun by starting grinding with the ventilation system at the full ventilation flow rate (actual ventilation velocity was measured by a pitot tube in the vent duct). The sampling time varied depending on the concentration present and whether the filter became loaded during the run. For illustration, let us pick 5 minutes as the sampling time for each part of each test. At the end of the 5 min. full ventilation test, the integrator reading was recorded and the ventilation would be changed to a lower flow rate. The integrator reading would then be recorded at the end of this 5 minute interval and a new ventilation flow rate chosen. Filters were changed as often as necessary. Usually the NIOSH filter, because of its lower flow rate, would not be clogged and would be used for an entire series of ventilation tests on a given grinding machine. First, the respirable particulate would be measured in the above manner, and then the filters would be changed and the total particulate would be measured. At the end of a day's run, the filters would be weighed on an analytical balance and the weight changes recorded. Data processing would then be performed as previously explained in order to determine the actual particulate concentrations at each ventilation flow rate setting. The concentrations according to the IKOR Monitor would then be adjusted by the NIOSH/IKOR calibration factors as mentioned in Section 2.3 of this Appendix.

4. Measurement Results

4.1 Concentration Build-Up Effect

Early in the measurement program, it was discovered that the concentration of particulate at the breathing zone of the operator of the grinding machine increased slowly with the time of grinding until it finally reached a steady state level (see figure C-4). It is theorized that this gradual build-up is due to the nature of the transport process which conveys the dust particles from the grinding machine to the operator's breathing zone. In a still air environment, this process is turbulent diffusion, and the process requires a finite time to reach a steady-state concentration distribution around the grinding machine. When grinding was stopped, the concentration

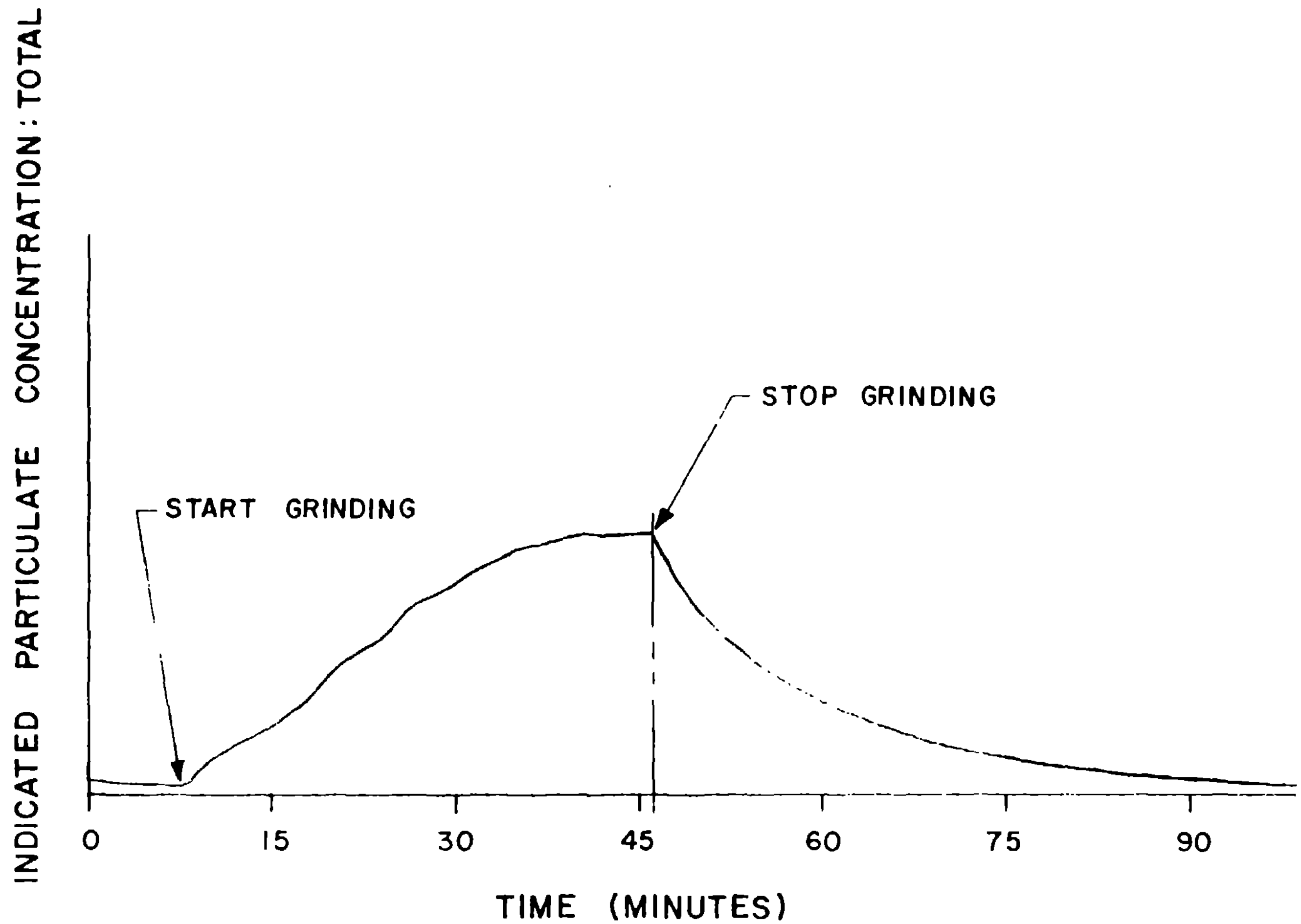


Figure C-4

DUST CONCENTRATION BUILD-UP AND DECAY CURVES was reduced to background levels by the vent system after a similar delay time - about 45 minutes.

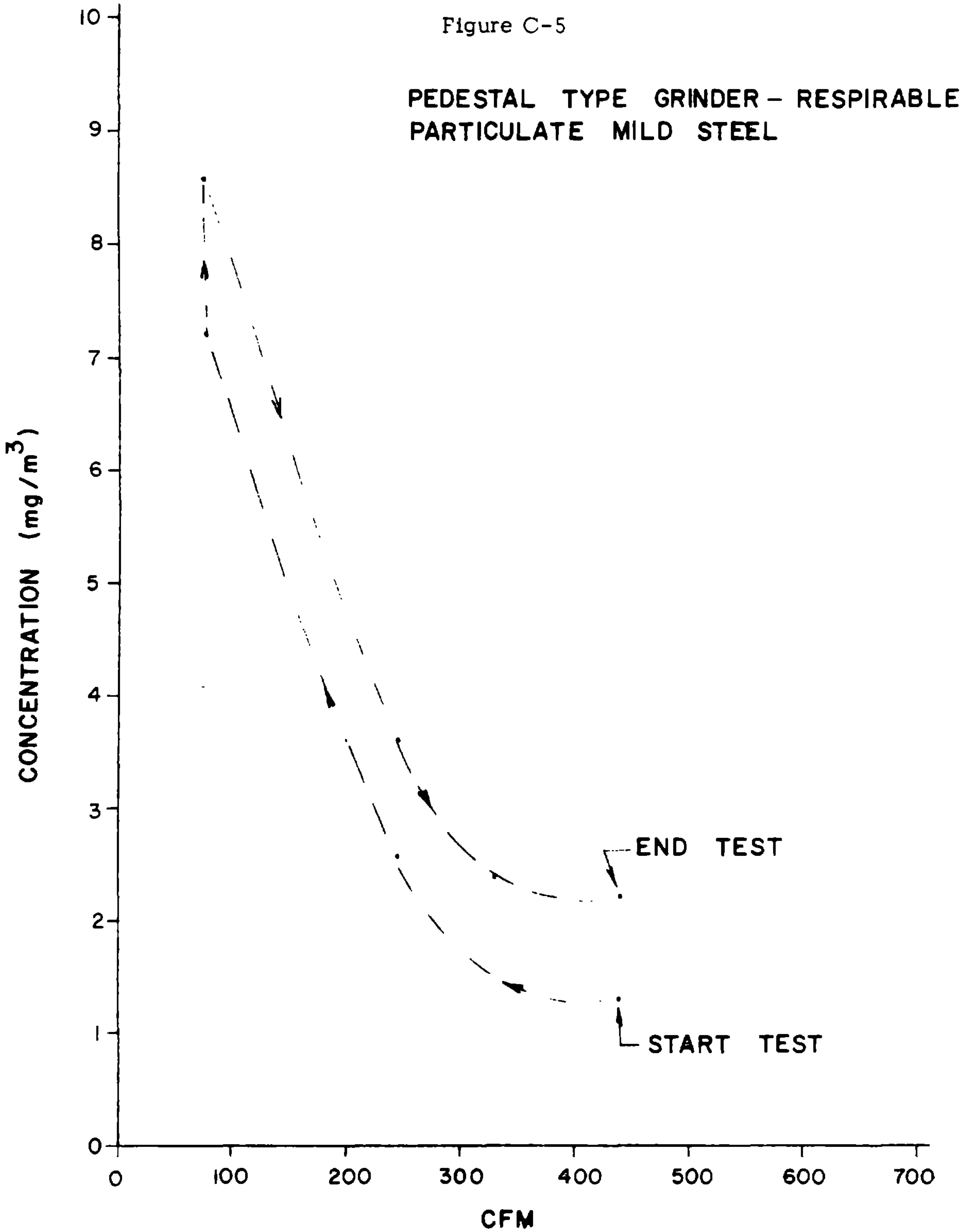
The significance of this result, of course, is that the concentration at any given time at the breathing zone is a function of the concentration due to any previous grinding and the concentration due to grinding at that ventilation flow rate. To therefore attempt to vary the vent flow rate and claim that the measured concentrations are characteristic of each of the chosen vent flow rates, we had to introduce a new measurement procedure.

4.2 The Hysteresis Effect

For an illustration of the modified measurement procedure, see figure C-5. This test was started at the full ventilation flow rate of about 450 cfm. The ventilation flow was then reduced and the breathing zone concentrations measured at 325 cfm, 225 cfm and 100 cfm in that order. While this test was in progress, the concentration build-up was underway. By the time the lowest ventilation point (100 cfm) had been reached, it was no longer possible to obtain the same concentration at the same flow rate as before. The concentration had increased from about 7.2 mg/m^3 to about 8.6 mg/m^3. The vent flow rate was then increased through the same steps as before and the concentrations measured at each step. It is evident from figure C-5 that the concentration at each vent flow rate point is higher coming down the curve than going up. This is somewhat analagous to a hysteresis effect.

The measurement procedure was thus to a complete a hysterisis loop test and to average the concentration at each vent point in order to develop a curve which was characteristic of that particular piece of GBP equipment.

Figure C-5



VENTILATION SYSTEM PERFORMANCE

5. Ventilation System Performance Data

The results of tests of ventilation system performance are presented in graphical form in Figures C-6 through C-22. In each figure, breathing zone concentrations of total and respirable dust are presented as functions of the ventilation system flow rate. Wherever possible, the ventilation rate required by current standards is noted as well as the ventilation rate specified by the criteria proposed in this report.

A number of tests were conducted with equipment which was not ventilated. Breathing zone dust concentrations measured with this equipment are included in Table C-1. The performance of auxiliary ventilation hoods used in conjunction with conventional hoods is presented in Figures C-23 through C-25.

In reviewing the test data for equipment for which both total and respirable dust concentrations were measured, it should be kept in mind that the two data sets were not obtained simultaneously. In some cases, changes in grinding conditions have produced what appear to be anomalous results, such as respirable dust concentrations exceeding total dust concentrations. These results are attributed to unavoidable variations in factors, such as abrasive tool surface condition, which affect the rate of particle generation.

GBP EQUIPMENT DESCRIPTION	BREATHING ZONE DUST CONCENTRATION (mg/m^3)	
	Total	Respirable
Belt Polisher		
1. Top of Belt rotating toward operator	23.7	2.95
2. Top of belt rotating away from operator	9.9	4.06
Buff Wheels		
1. Pleated Red Devil	.81	1.37
2. Flannel	8.4	1.19

TABLE C-1 Summary of Breathing Zone Dust Concentration Data for GBP Equipment with no Ventilation

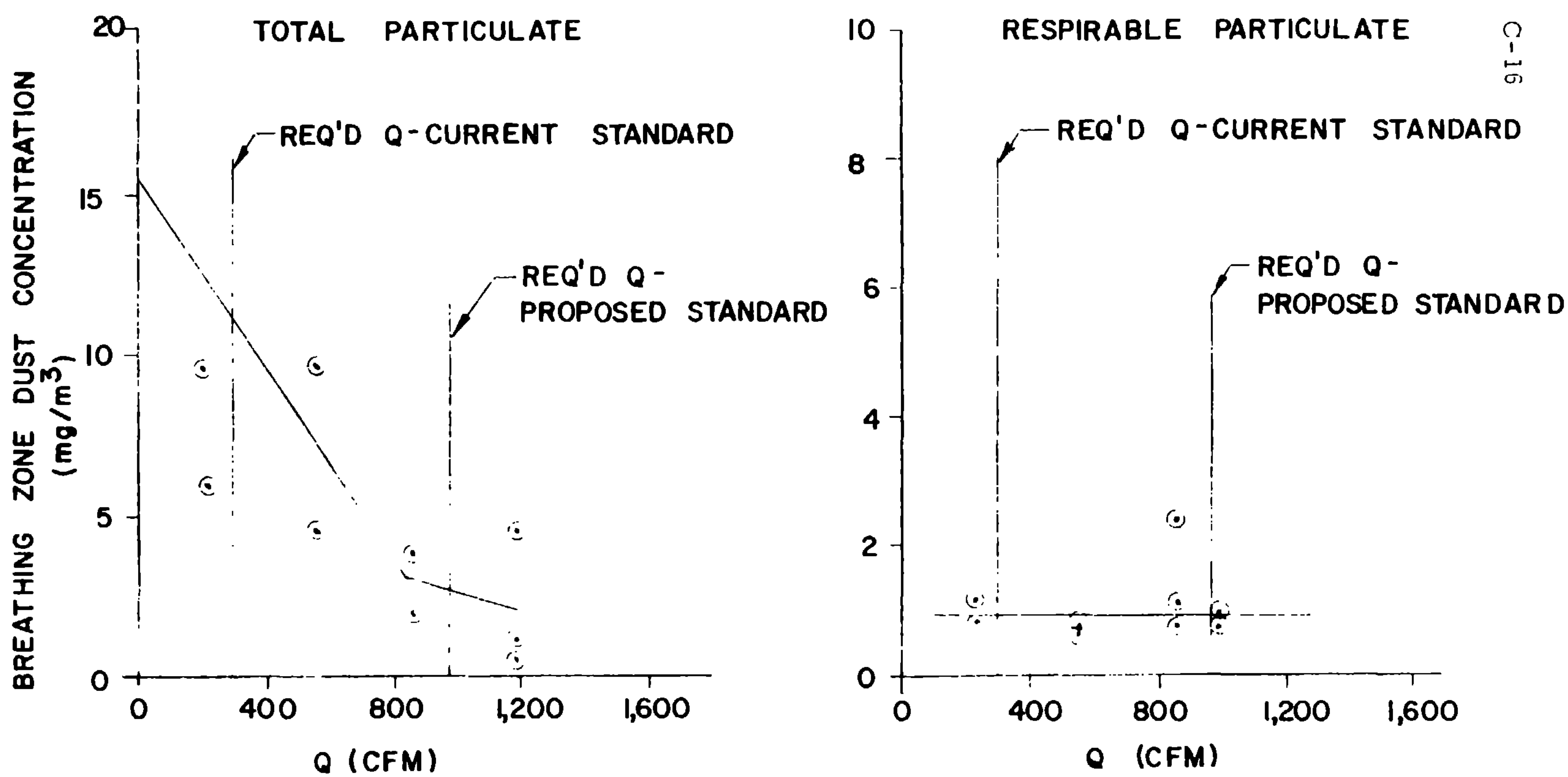


Figure C-6

Ventilation System Performance Data
6"-Rough Surface Grinder (5,900 RPM)
V_s = 9,260 SFM
Workpiece - Cast Steel

0213A20482

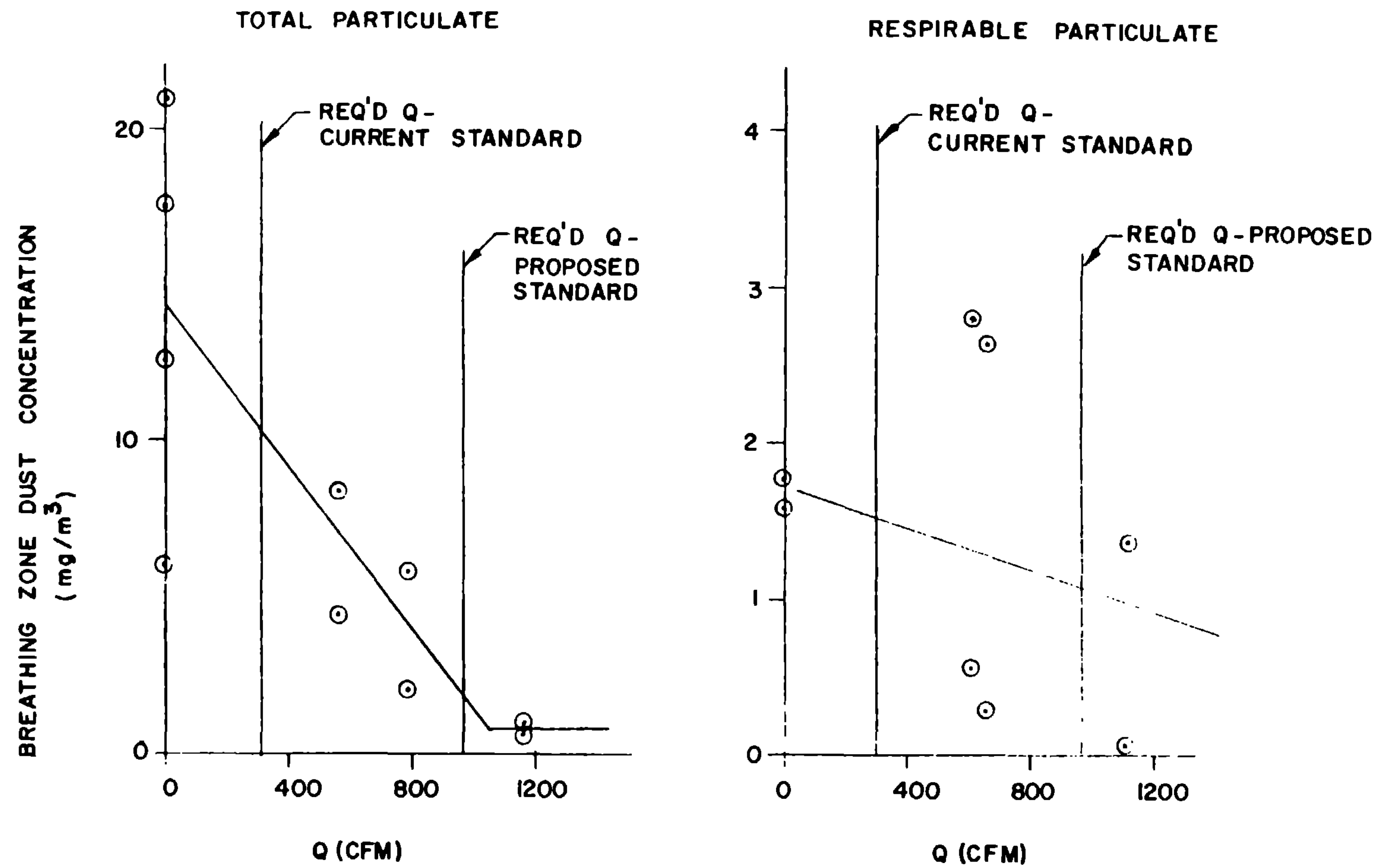


Figure C-7

Ventilation System Performance Data
6" Rough Surface Grinder (5,900 RPM)
V_s = 9,260 SFM
Workpiece - Cast Steel

0213A20498

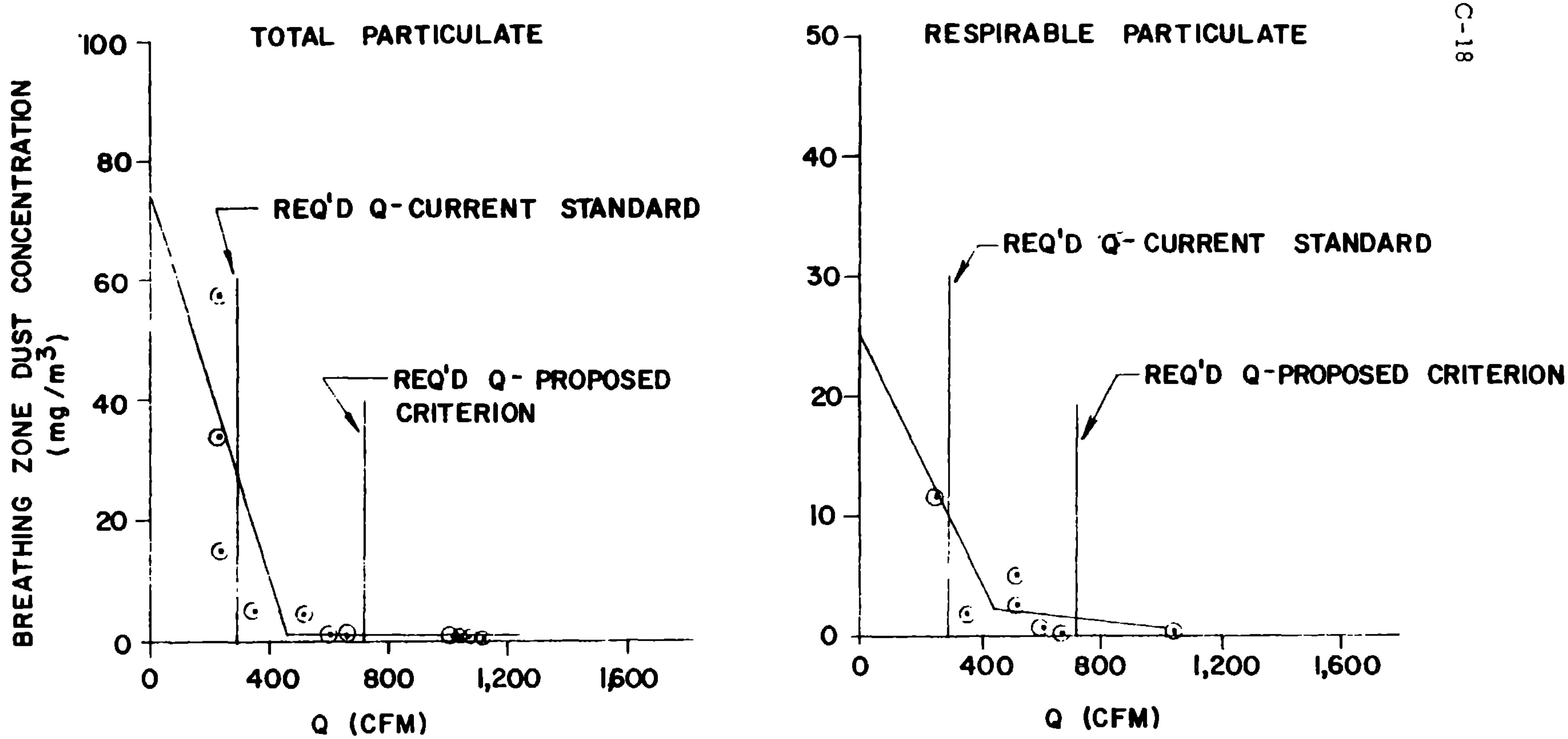


Figure C-8

Ventilation System Performance Data
7"-Rough Surface Grinder (5,200 RPM)
V_s = 9,530 SFM
Workpiece - Cast Steel

0213A20487

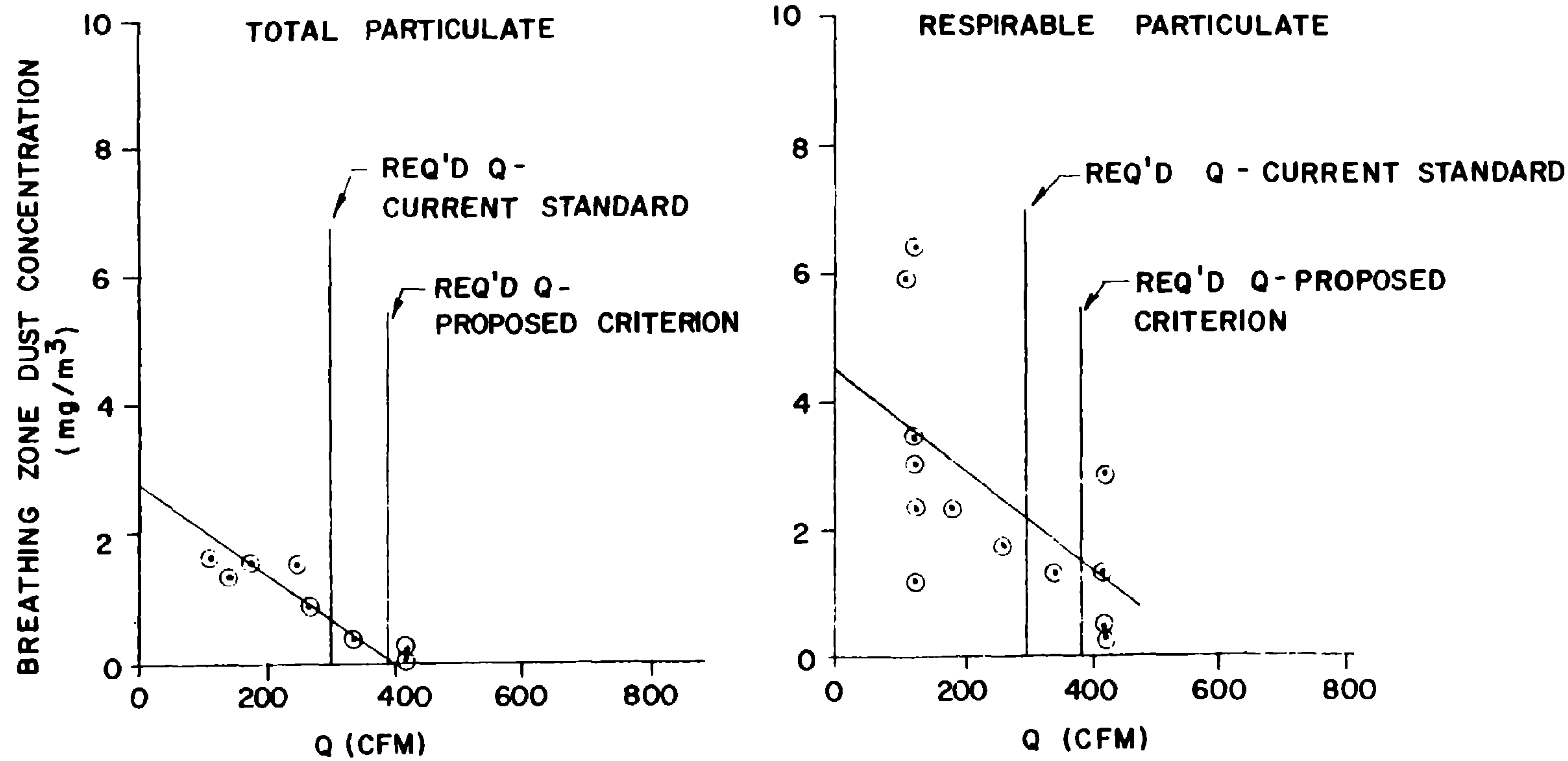


Figure C-9

Ventilation System Performance Data
7"-Precision Surface Grinder (3,200 RPM)
V_s = 5,860 SFM
Workpiece - 1045 Steel

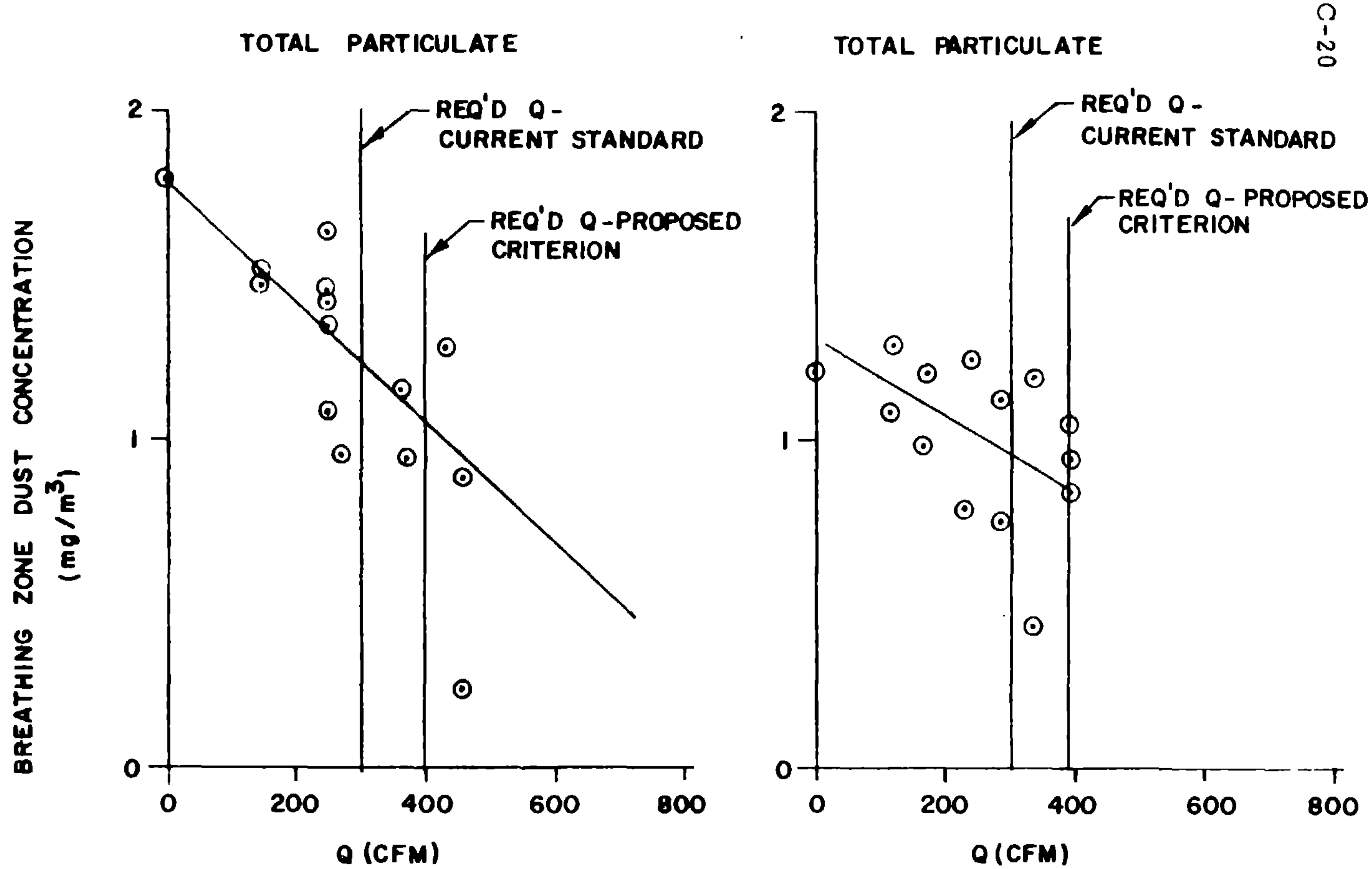


Figure C-10

Ventilation System Performance Data
7"-Precision Surface Grinder (3,200 RPM)
V_s = 5,860 SFM
Workpiece - 1045 Steel

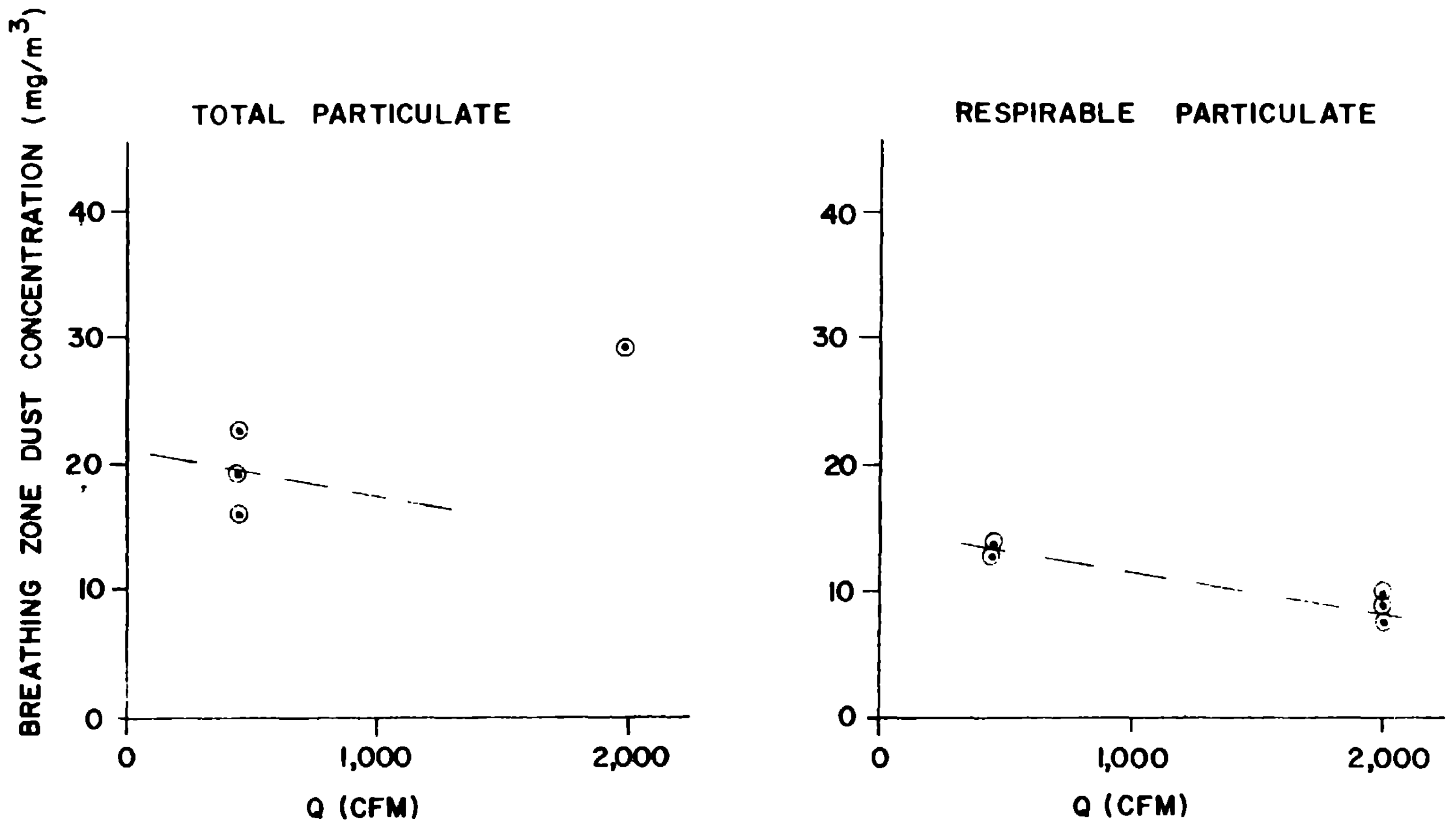


Figure C-11

Ventilation System Performance Data
16"-Swing Frame Grinder (2,100 RPM)
V_s = 8,790 SFM, Workpiece-E4140 Steel

Note: As a surface grinder the req'd Q = 8,250 CFM using the proposed criteria

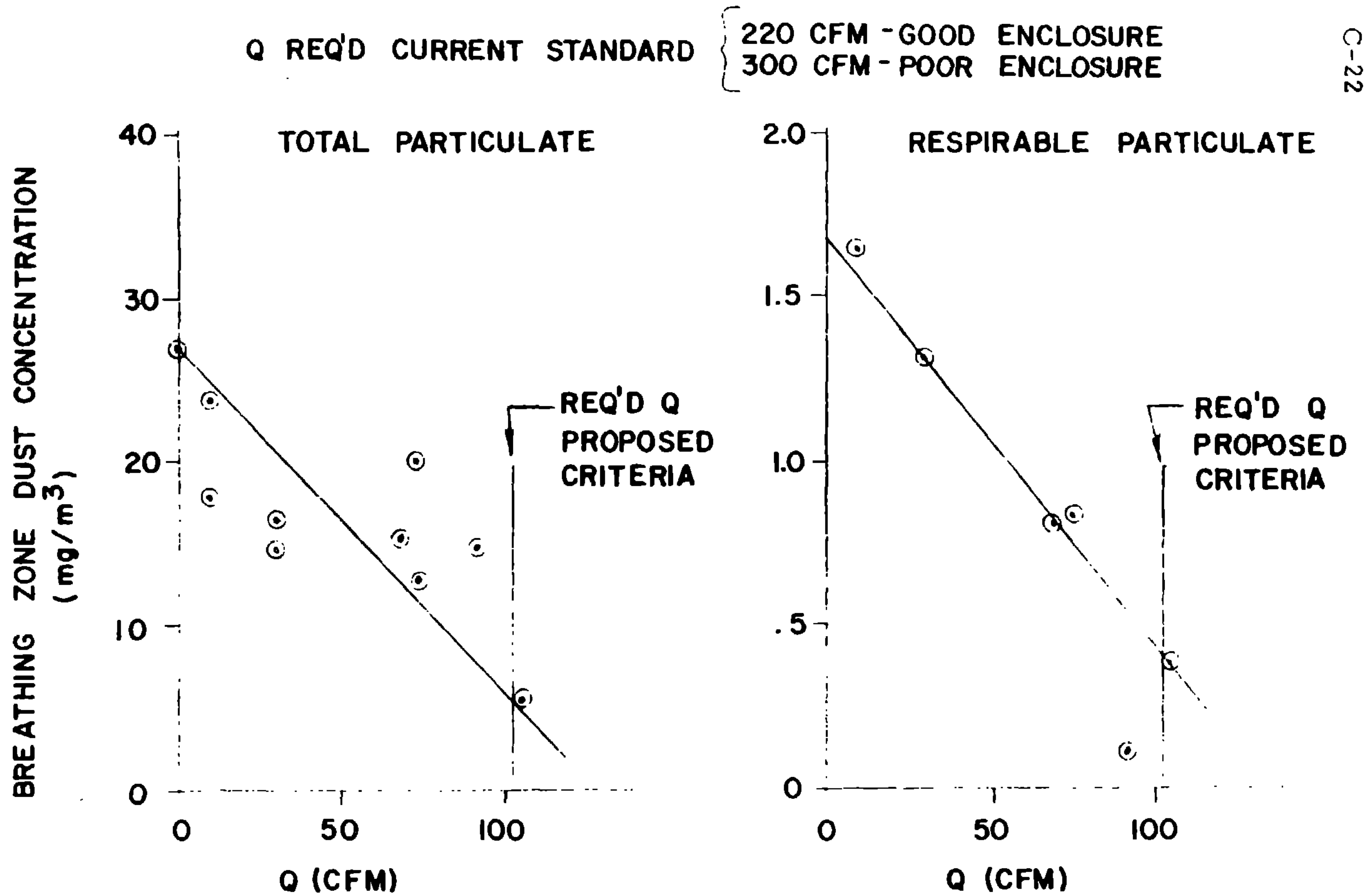


Figure C-12

Ventilation System Performance Data
10"-Pedestal Grinder (1,800 RPM)
V_s = 3,300 SFM for 7" Dia. Wheel
Workpiece - Mild Steel

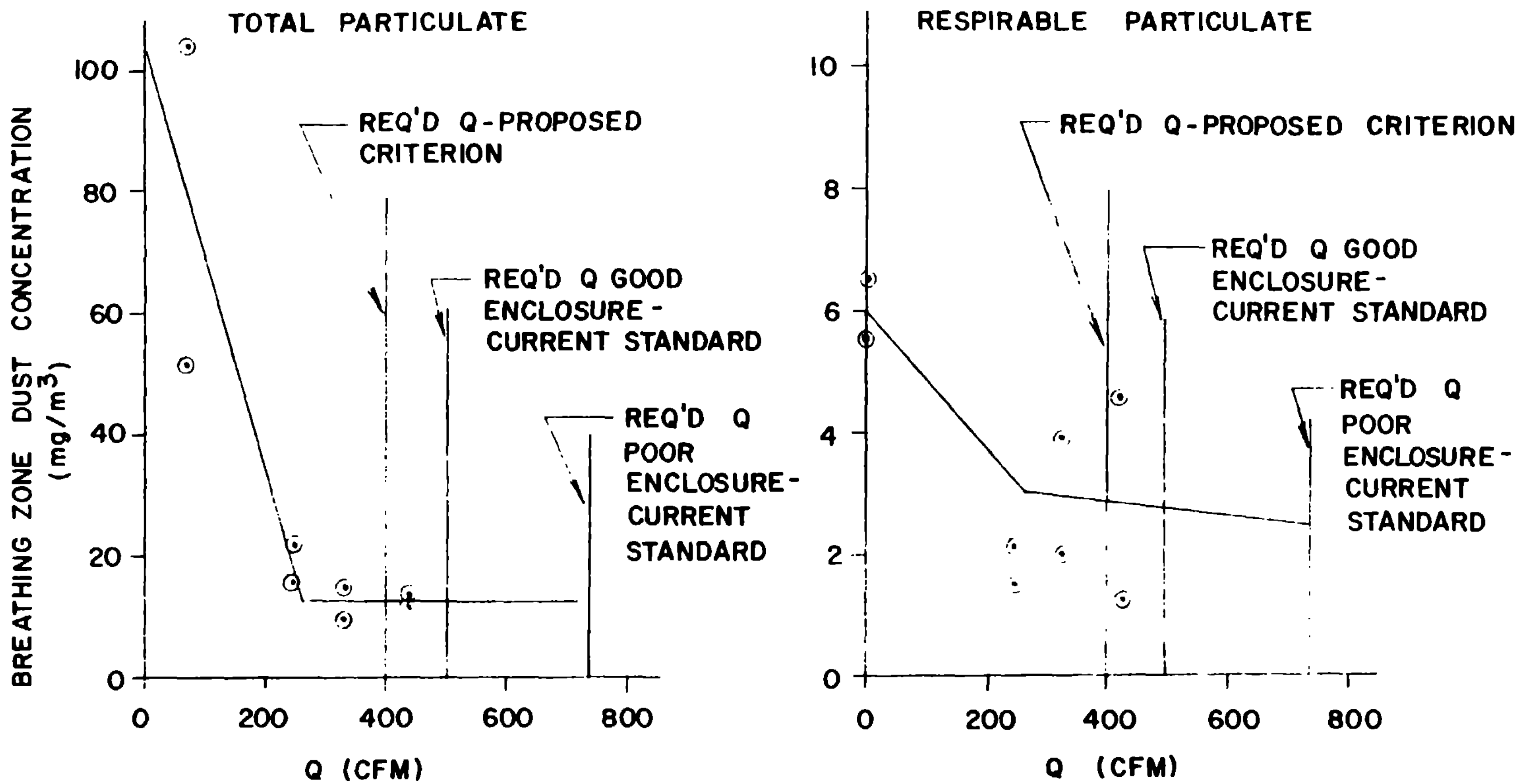


Figure C-13

Ventilation System Performance Data
12"-Bench Grinder (2,800 RPM)
V_s = 8,800 SFM
Workpiece - Cast Steel

0213A204 80

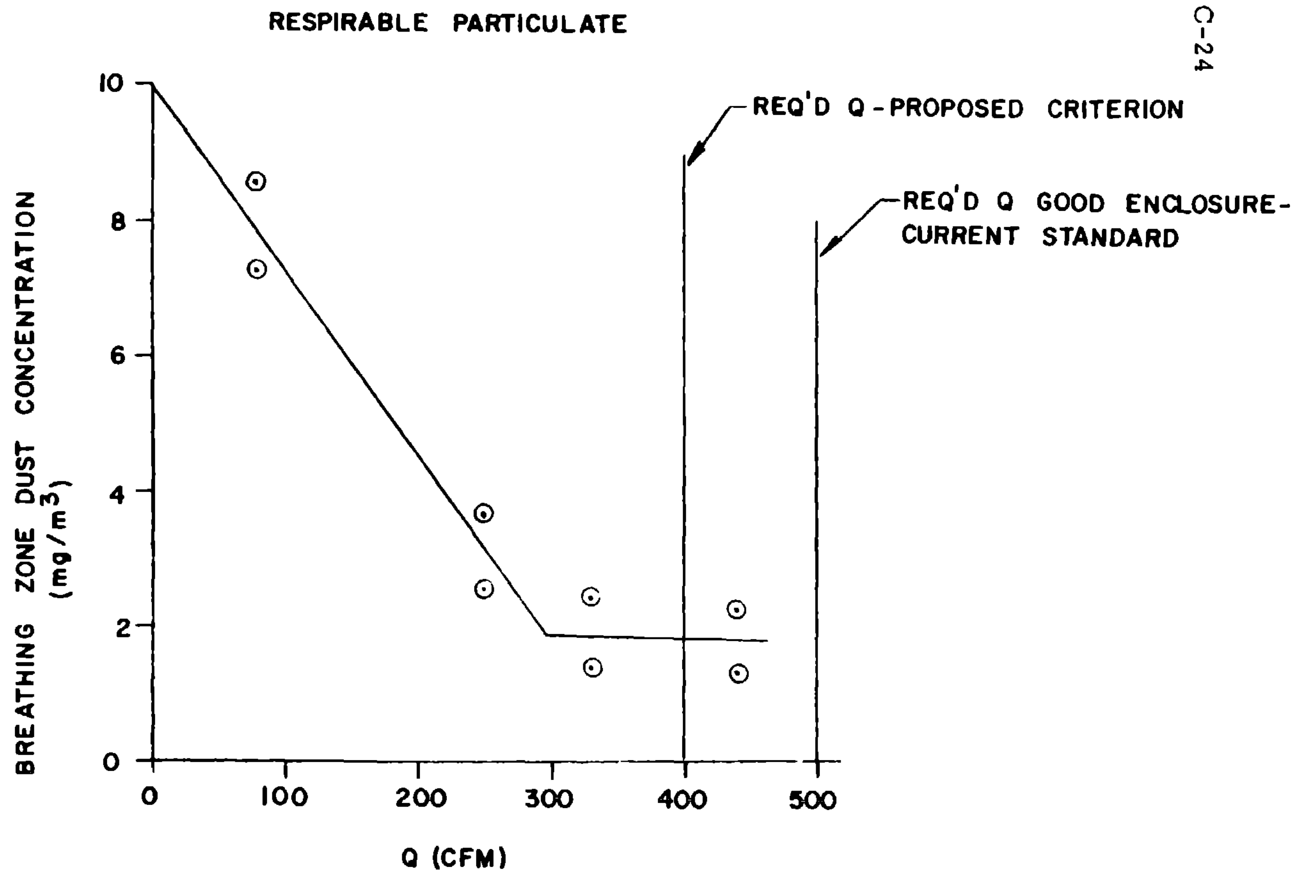


Figure C-14

Ventilation System Performance Data
12"-Bench Grinder (2,800 RPM)
V_s = 8,800 SFM
Workpiece - Mild Steel

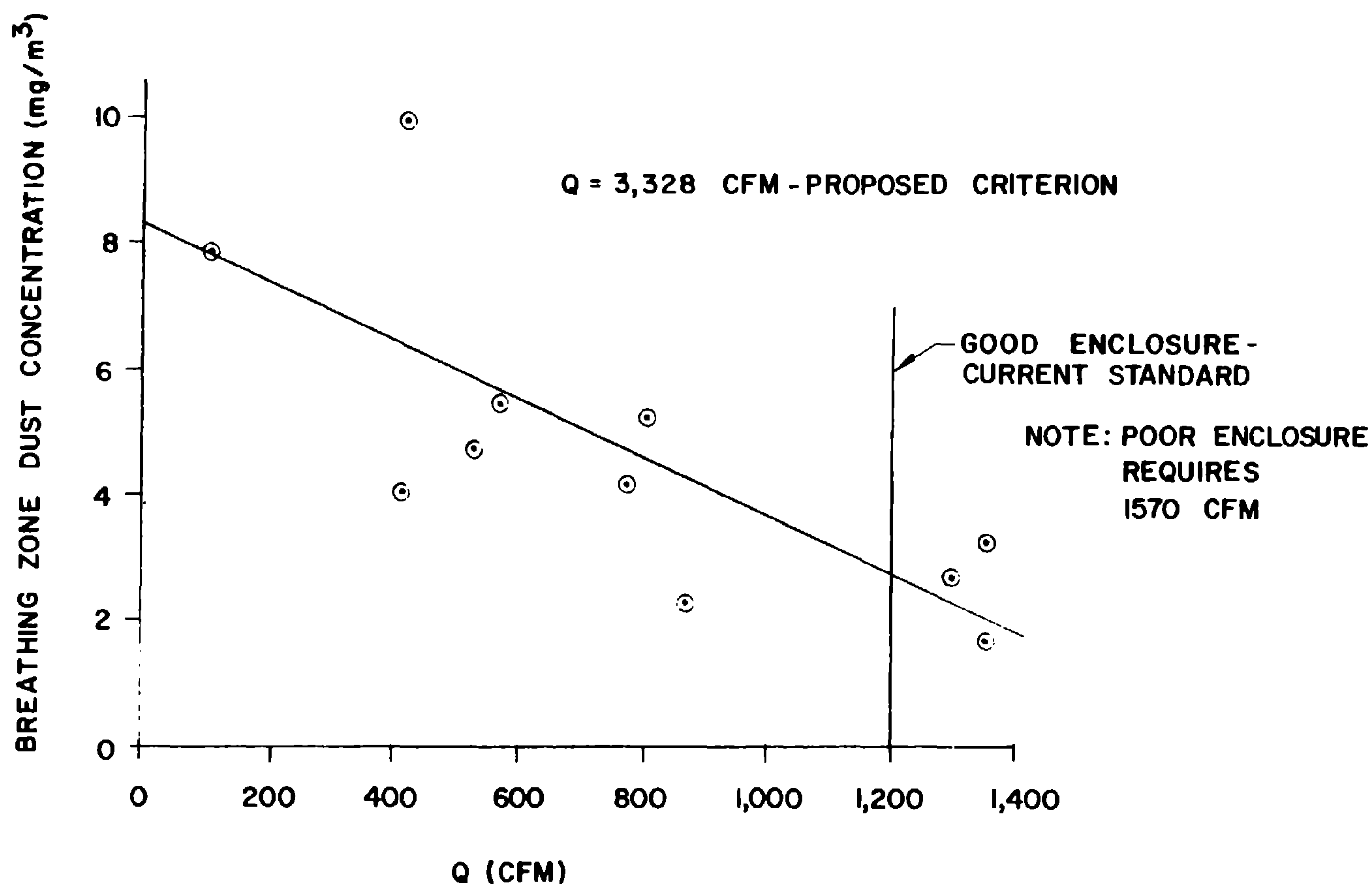


Figure C-15
Ventilation System Performance Data
30"-Floorstand Grinder (1,600 RPM)
V_s = 11,830 SFM w/28.25 Dia. Wheel
Workpiece - Iron Bar

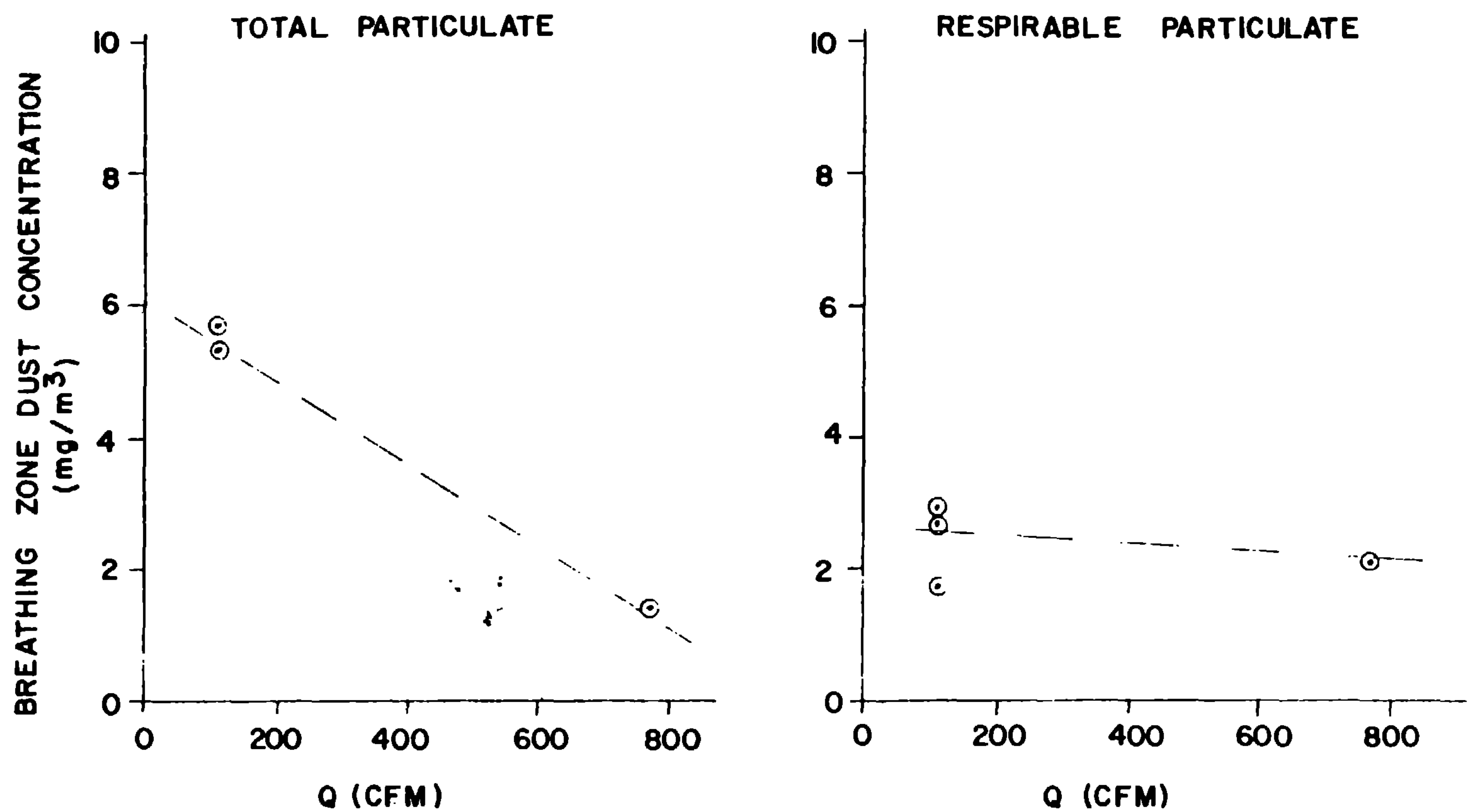


Figure C-16

Ventilation System Performance Data
20"-Cutoff Wheel (2,300 RPM)
V_s = 12,040 SFM
Workpiece - Steel
Q = 2570 CFM - Proposed Criterion

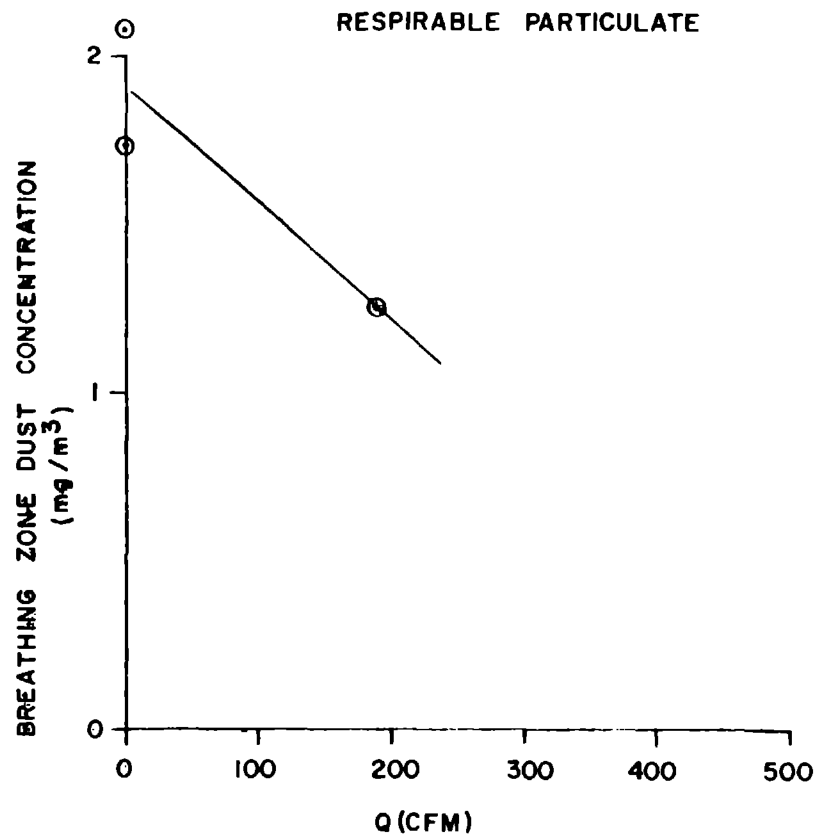


Figure C-17

Ventilation System Performance Data
10"-Cutoff Wheel (4,300 RPM)
V_s = 11,200
Workpiece - Steel

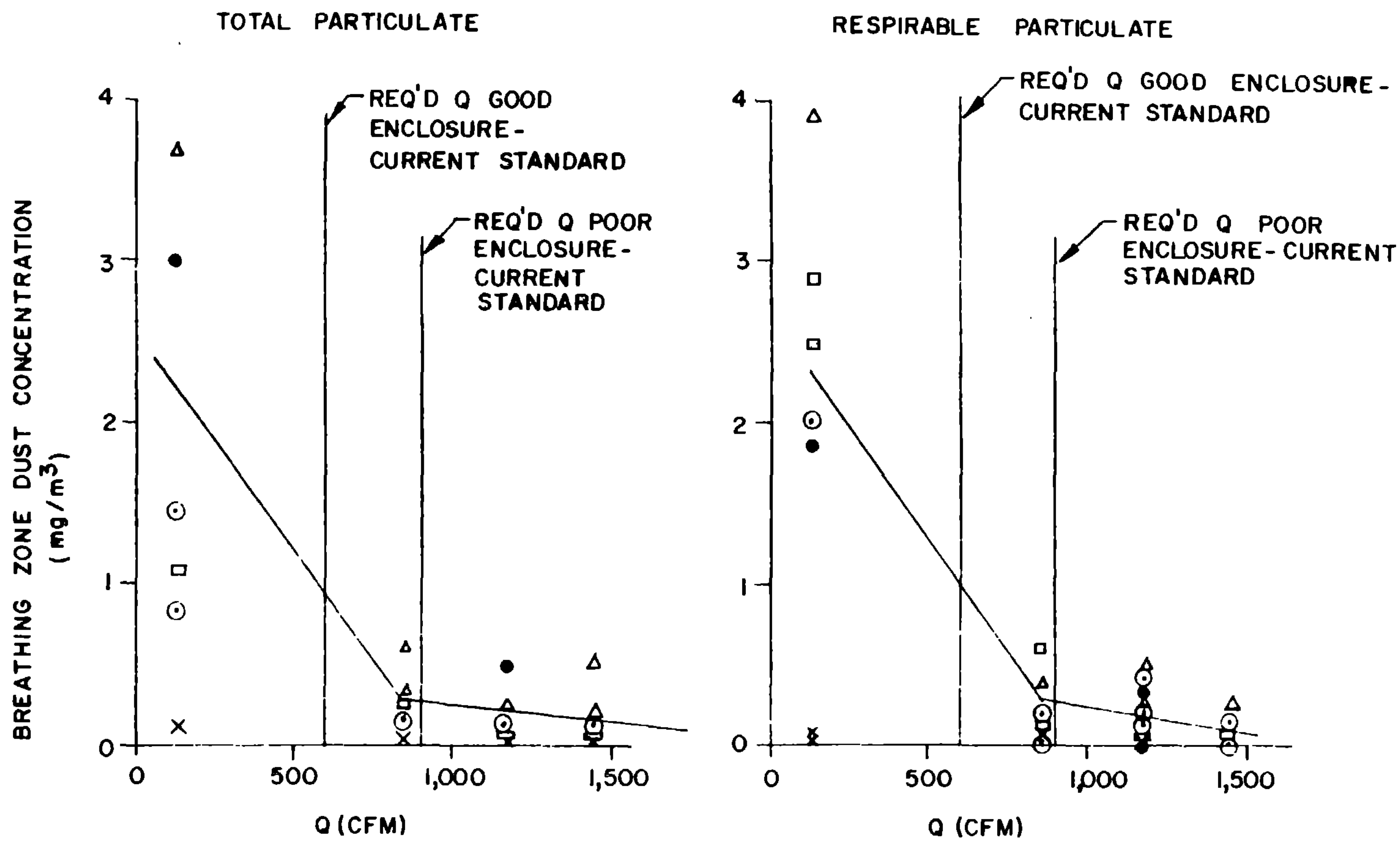


Figure C-18

Ventilation System Performance Data
Pedestal Type Polishers (1,800 RPM, V_s = 6,600 SFM)

- ⊙ 36 Grit W/1018 Steel
- □ 80 Grit W/1018 Steel
- ● 120 Grit W/1018 Steel
- △ 80 Grit W/6AL4V Titanium
- X 80 Grit W/Aluminum

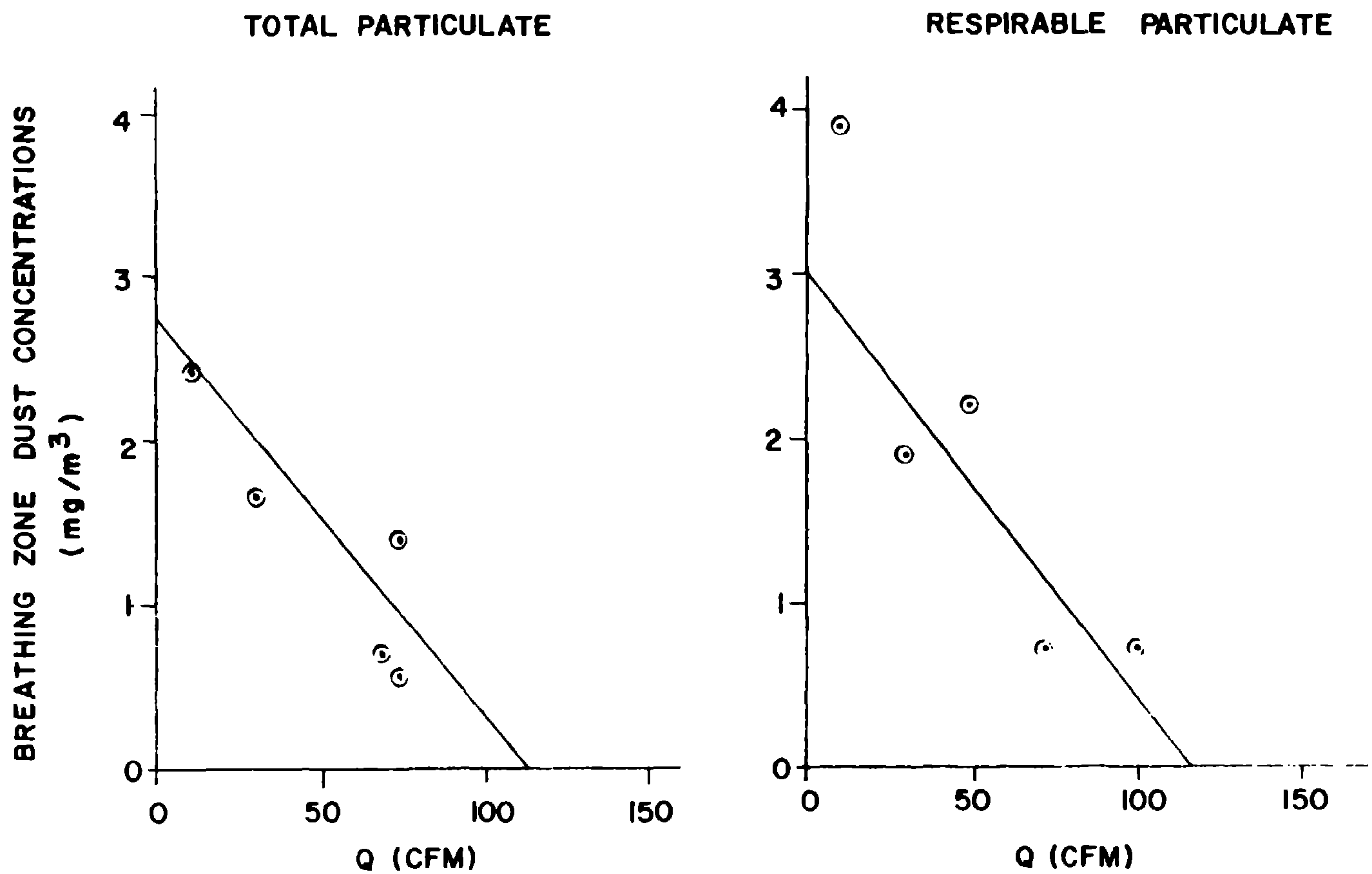


Figure C-19

Ventilation System Performance Data Belt Grinder
6" Belt Width
V_s = 3,170 SFM
Workpiece - Steel
Note: The req'd Q - 390 CFM - Current Standards

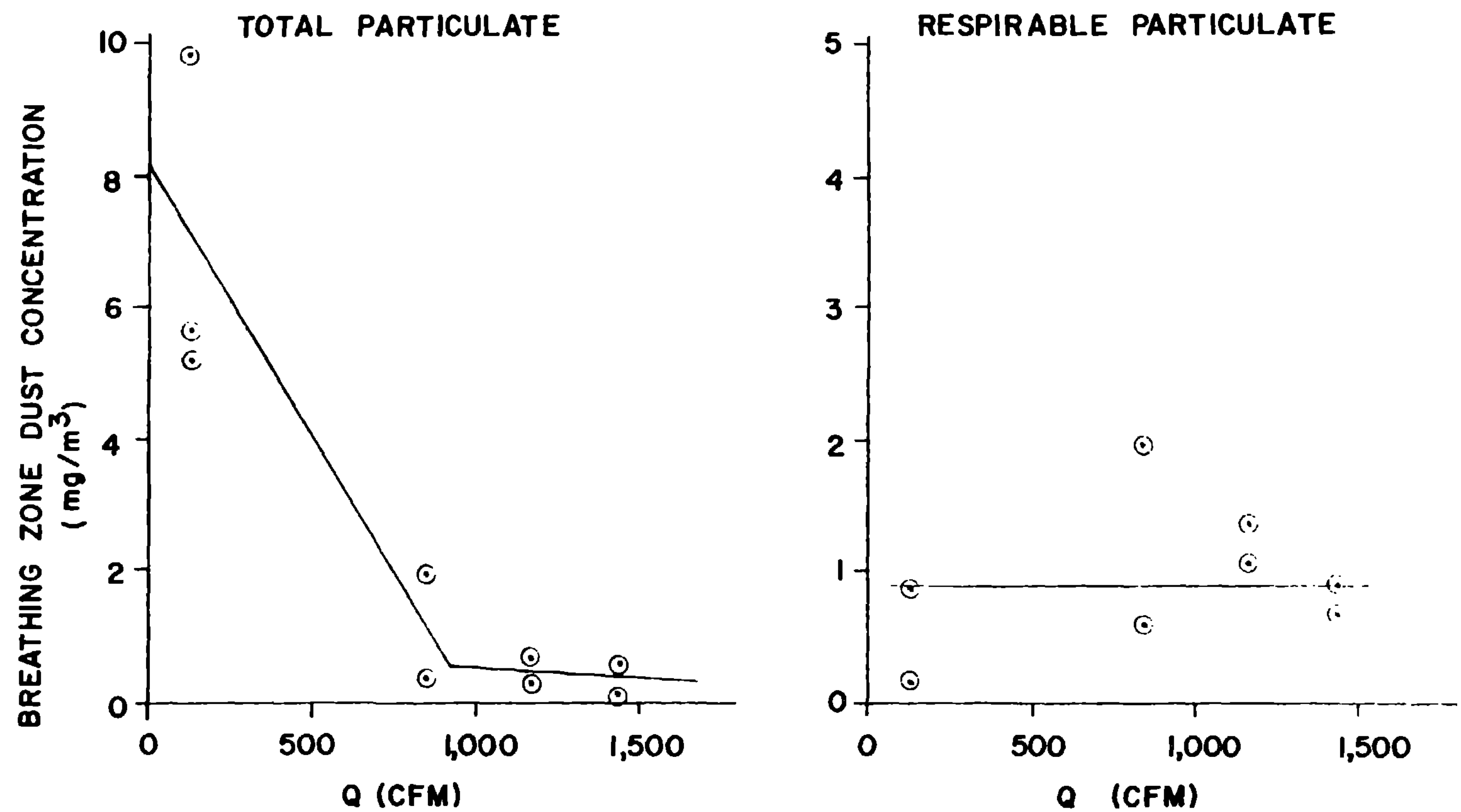


Figure C-20

Ventilation System Performance Data
16"-Flap Wheel (1,800 RPM)
V_s = 7,550 SFM
Workpiece - 1018 Steel

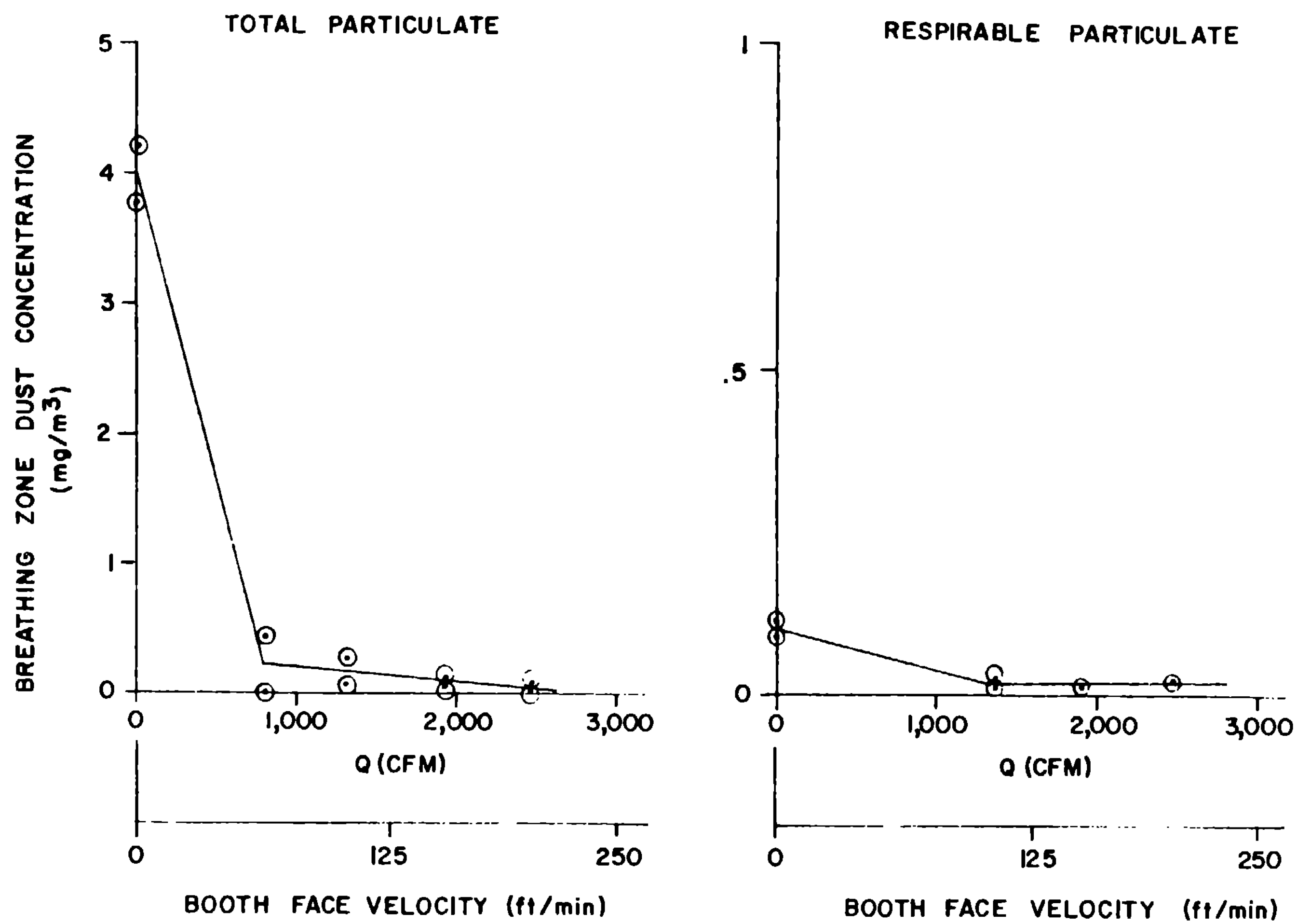


Figure C-21

Ventilation System Performance Data
9"-Portable Disc Grinder (5,000 RPM)
Workpiece - Low Carbcn Steel

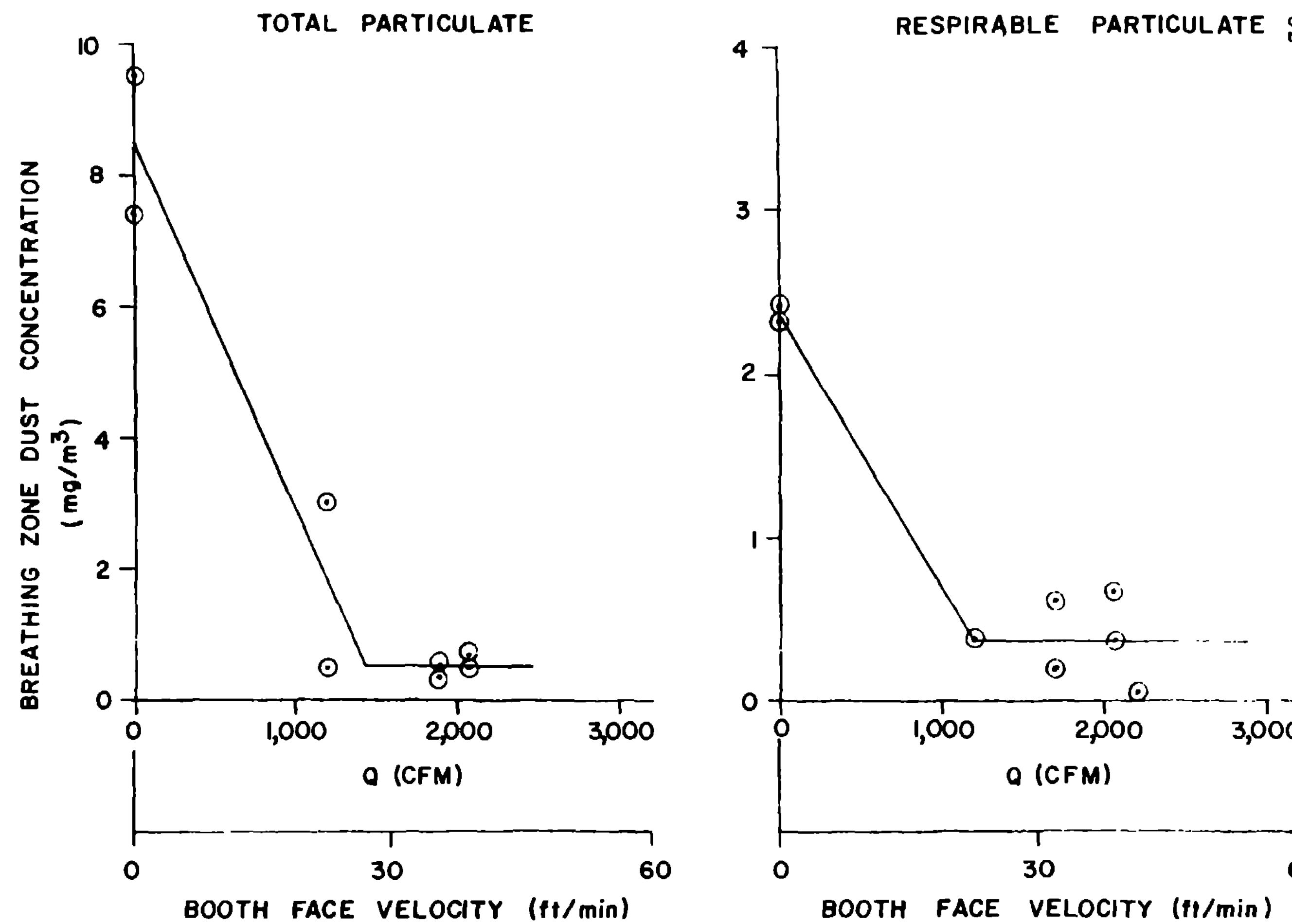


Figure C-22

Ventilation System Performance Data
Swing Frame Sander (3,500 RPM)
V_s = 5,500 SFM
Workpiece - Mild Steel

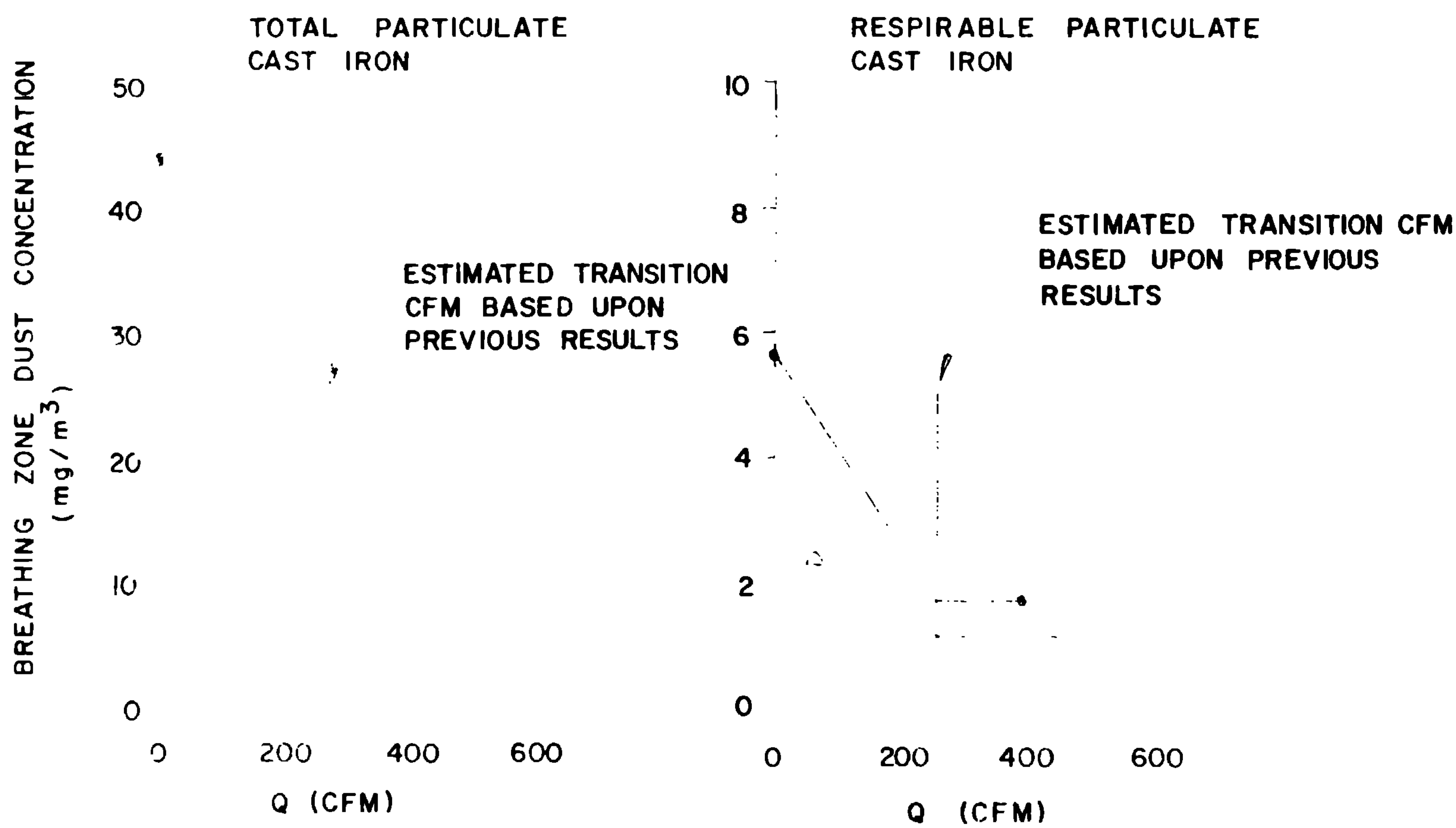


Figure C-23

Ventilation System Performance Data
12" Bench Grinder W/Auxiliary Captor Hood (2,800 RPM)

• - Auxiliary Captor Hood - Off
Δ - Auxiliary Captor Hood - On

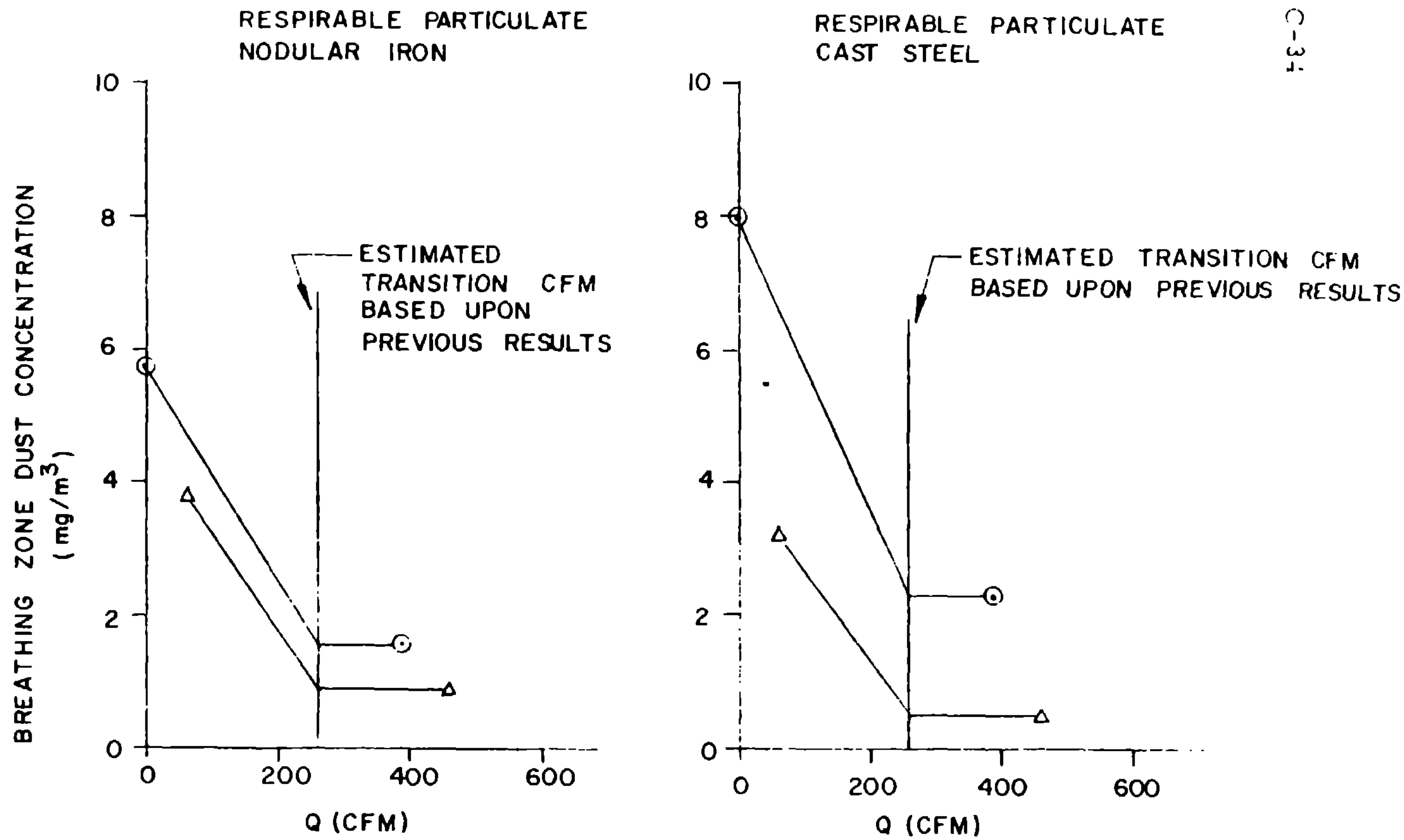


Figure C-24

Ventilation System Performance Data
12" Bench Grinder W/Auxiliary Captor Hood (2,800 RPM)

⊙ - Auxiliary Captor Hood - Off
△ - Auxiliary Captor Hood - On

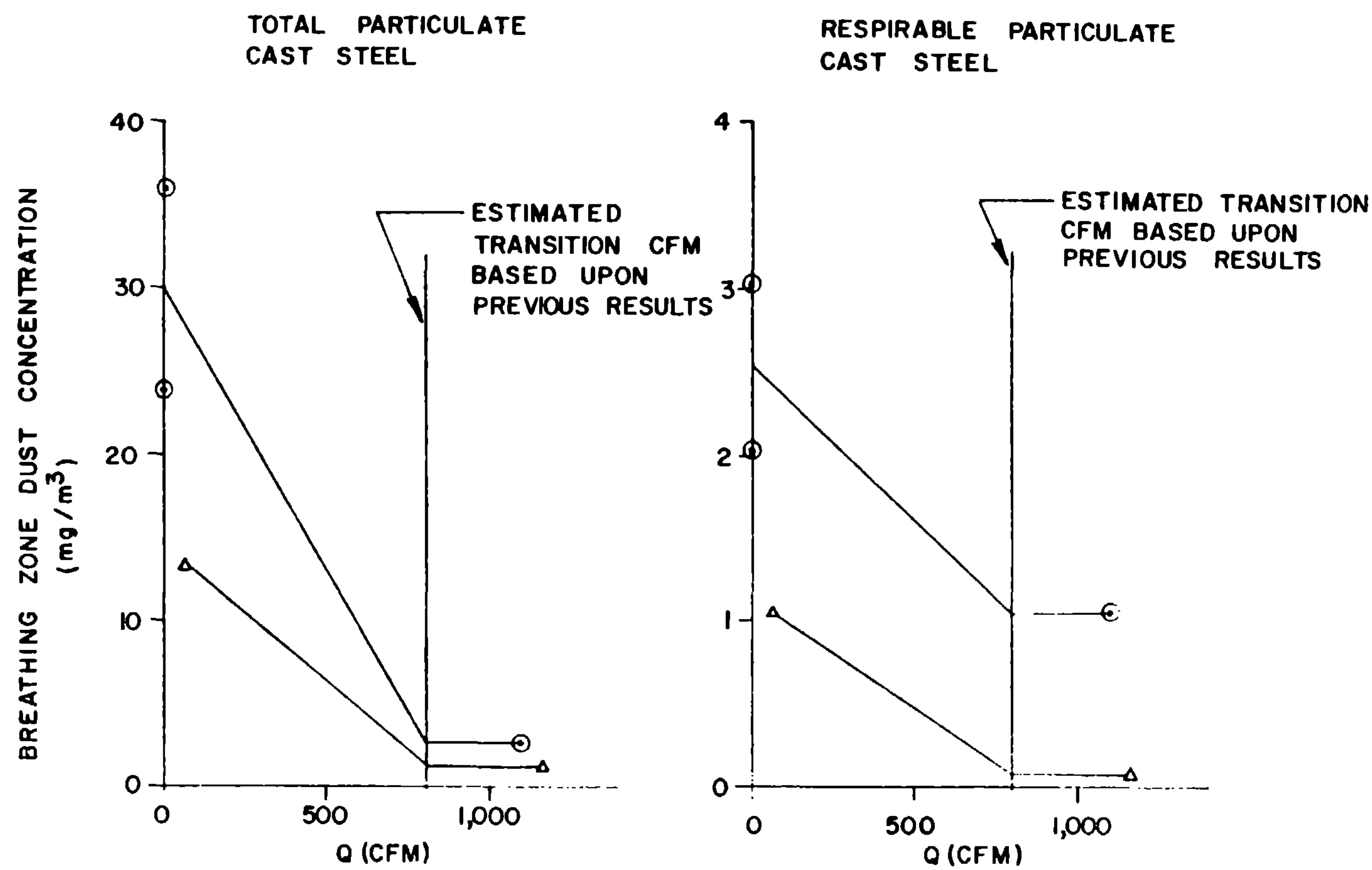


Figure C-25

Ventilation System Performance Data
6" Rough Surface Grinder W/Auxiliary Captor Hood (5,900 RPM)

⊙ - Auxiliary Captor Hood - Off
Δ - Auxiliary Captor Hood - On

Appendix D: Particle Motion Analysis Procedure

1. Equations of Motion

To develop the equations of motion for a single particle model, consider a particle in a gravitational field which has an initial velocity and encounters a flow field. For the analysis, polar coordinates will be used, thereby allowing the origin of the coordinate system to be conveniently placed at the center of a GBP wheel. By using polar coordinates, the forces acting upon the particle are reduced to radial and tangential components.

The motion of a particle can be thought of in terms of a translation and a rotation. Referring to figure D-1 and assuming a small $\Delta\theta$, the following expressions were derived.

$$v_{r_2} = v_{r_1} + \Delta\theta\, v_{\theta_1} + \frac{d v_{r_1}}{dt}\,\Delta t \qquad (1)$$

$$v_{\theta_2} = v_{\theta_1} - \Delta\theta\, v_{r_1} + \frac{d v_{\theta_1}}{dt}\,\Delta t \qquad (2)$$

$$r_2 = r_1 + v_{r_1}\,\Delta t \qquad (3)$$

$$\theta_2 = \theta_1 + \Delta\theta \qquad (4)$$

$$\Delta\theta = \frac{v_{\theta_1}\,\Delta t}{r_1 + v_{r_1}\,\Delta t} \qquad (5)$$

Note that

$$v_{\theta_n} = v_{F\theta_n} - v_{P\theta_n} \tag{6}$$

$$v_{r_n} = v_{FR_n} - v_{PR_n} \tag{7}$$

$$v_n = \left(v_{\theta_n}^2 + v_{r_n}^2 \right)^{1/2} \tag{8}$$

where

( )$_r$ = radial component

( )$_\theta$ = tangential component

( )$_p$ = particle

( )$_f$ = flow field

All that remains to be defined are the components of particle acceleration. Referring to the free-body diagram, shown in Figure D-2, summing the forces acting on the particle in the radial and tangential directions and rearranging terms, we obtain

$$\frac{dv_{r_1}}{dt} = -g\left(\frac{\rho - \rho_o}{\rho}\right)\sin\theta_1 + \frac{C_D \rho_o A v_1 v_r}{2m} \tag{9}$$

$$\frac{dv_{\theta_1}}{dt} = -g\left(\frac{\rho - \rho_o}{\rho}\right)\cos\theta_1 + \frac{C_D \rho_o A v_1 v_{\theta_1}}{2m} \tag{10}$$

where

g = gravitational force

ρ = particle density

ρ_o = fluid density

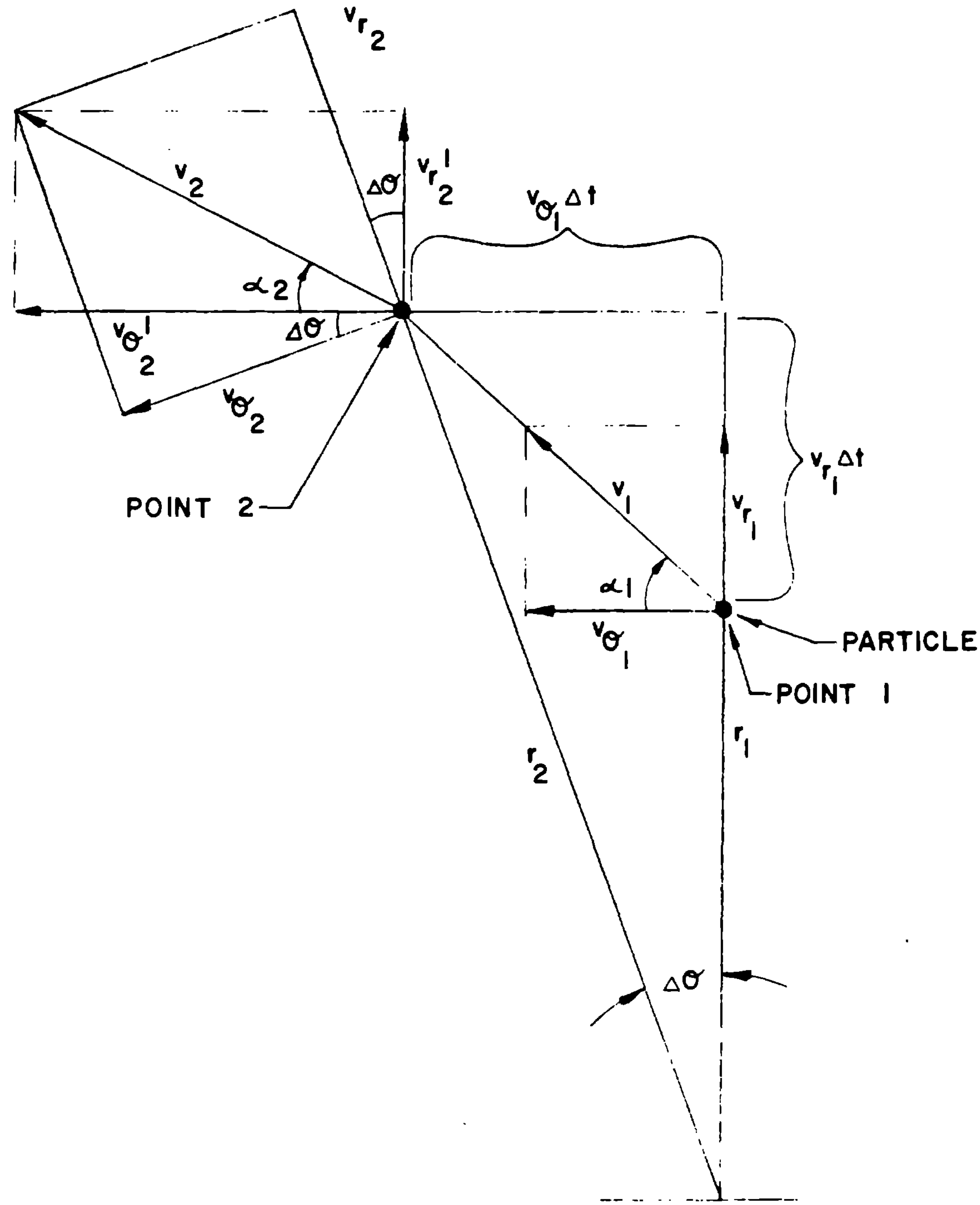


Figure D-1

Model of Particle Motion
Showing the Radial and Tangential Velocity Components

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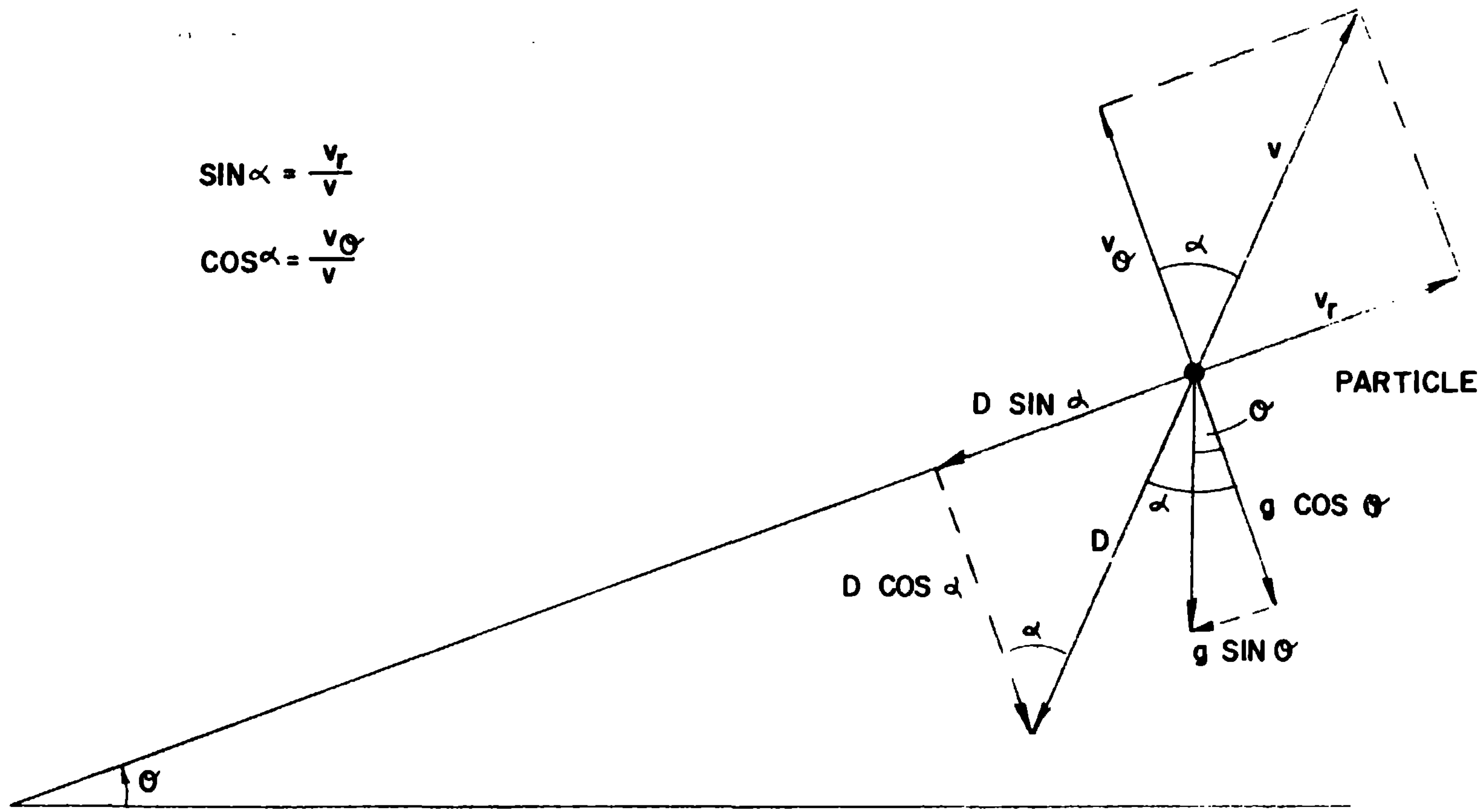


Figure D-2

Free-Body Diagram of the Forces
Acting Upon a Particle as it Moves Through Space

C_D = particle coefficient of drag

A = particle cross sectional area

m = particle mass

2. Single Particle Model

Trajectories for particles of various sizes and densities were calculated using a computer program written in Fortran IV computer language. The trajectory calculations utilized the equations of motion for a particle and the experiementally determined velocity profiles for Region I.

In the trajectory calculations the following assumptions were made. First, the radial velocity component of the flow field generated by the GBP equipment was assumed negligible in comparison with the tangential component in Region I. This assumption is based upon the observation that although the velocities are reduced with distance from the wheel, they retain approximately the tangential direction. Secondly, the particles are assumed to be spherical but not necessarily of unit density. Thus, previous experimental results relating the coefficient of drag (C_D) and the Reynolds number (Re) for spherical particles can be utilized (refs. 12,15). In particular, the equation

$$C_D = \left(.63 = \frac{4.8}{\sqrt{Re}}\right)^2 \qquad (11)$$

is a reasonable expression for spherical particles in laminar, intermediate and turbulent flow regimes. Some similar results for cylindrical and disk shaped particles are shown in Reference 15. It was determined that equation 11 is also reasonably valid for disk shaped particles where Re $\lesseqgtr$ 100. The same is not true for cylindrical particles. Lastly, it was assumed that the Saffman lift force which has been observed on spherical particles in a sheer flow is negligible (Refs. 17,18). The experimentally determined velocity profiles around spinning disks revealed that a steep velocity gradient exists indicating a strong shear flow region near the surface of GBP wheels. Particle motion in shear flow regions has been the subject of extensive research, since particles in this type of flow field exhibit a lateral migration. This migration of particles is attributed to a force acting on the particle which was named after the mathematician who first solved the extremely difficult equations governing this motion. Saffman solved the equations using some restrictive assumptions. The problem is so difficult that the governing equations without these assumptions have not been solved. As a result, numerous experimental schemes have been devised to study this migration. Unfortunately, the results are conflicting. Thus the effect is noted here but neglected since there is no practical means of including the Saffman lift force in the analysis procedure.

Appendix E: Breathing Zone Dust Concentration Analysis

1. General Model Form

Analytical models have been developed which relate the concentration of airborne particulate material in the GBP equipment operator's breathing zone to design and operating characteristics of the machine and its ventilation system. The formulation of these models has been based on the concepts of particle generation, transport, and capture developed in the particle motion analysis described in Section 4.1 and Appendix D. The general form of the breathing zone dust concentration models is the same for all classes of equipment, but certain ventilation parameters are defined differently for different equipment classes. The general model form is discussed first, followed by discussions of the application of the model to specific equipment classes.

The concentration of dust particles in the breathing zone of the equipment operator is considered to consist of three elements as follows:

$$C = P + S + B \tag{1}$$

where C = Total dust concentration

P = Total dust concentration from primary generation mechanism

S = Total dust generation from secondary generation mechanism

B = Background concentration of total dust

An analogous relationship can be defined for the breathing zone concentration of respirable dust as follows:

$$C_r = P_r + S_r + B_r \tag{2}$$

The background concentration B is assumed to be constant for any given situation and unaffected by the operation of the equipment.

The primary dust concentration P is represented by a model of the following form:

$$P = \begin{bmatrix}\text{Rate of primary}\\ \text{particle generation}\end{bmatrix} \times \begin{bmatrix}\text{Fraction of pri-}\\ \text{mary particles}\\ \text{escaping}\end{bmatrix} \times \begin{bmatrix}\text{Distribution}\\ \text{of primary}\\ \text{particles in}\\ \text{space}\end{bmatrix} \tag{3}$$

The rate of particle generation for a given workpiece material can be represented as follows:

$$\dot{m}_{p,g} = c_1 V_s F_n \tag{4}$$

where $\dot{m}_{p,g}$ = Rate of generation of primary particles

c_1 = Proportionality constant

V_s = Grinding wheel (or belt) surface velocity

F_n = Normal force of workpiece against grinding surface

Equation 4 is based upon relationships for metal removal rate developed by Hahn and Lindsay (Ref 19).

The fraction of primary particles escaping from the ventilation system is represented as follows:

$$f_{p,e} = 1 - c_2 \tilde{Q} \tag{5}$$

where $f_{p,e}$ = fraction of primary particles escaping

c_2 = constant

$\tilde{Q}$ = ventilation performance parameter

This particle escape model was formulated heuristically on the assumption that the fraction of particles escaping varies in an inverse, linear manner with a parameter describing the capture performance of the ventilation system. The ventilation performance parameter $\tilde{Q}$ is defined in the form of a ratio of air velocity induced by the ventilation system to particle velocity. In this form, the value of the parameter is zero when the ventilation rate is zero, and the parameter increases monotonically with ventilation rate. The specific formulation of the parameter for different types of equipment is discussed later.

The spatial distribution of primary particles is represented as follows:

$$P = (c_3 \dot{m}_{p,e}/r) \exp[-c_4 U (r - x)] \quad (6)$$

where $\dot{m}_{p,e}$ = mass flow rate of escaping primary particles

c_3, c_4 = constants

U = background air velocity

r = radial distance from particle source

x = downwind distance from particle source (U-direction)

Equation 6 is a general solution to the diffusion equation for a point source in a three-dimensional, uniform flow field (Ref 20). Its use to model particle distribution is based on the assumption that the principal transport mechanisms conveying particles from the source are turbulent diffusion and convective transport. In a still air environment, equation 6 would reduce to the simple form:

$$P = c_3 \dot{m}_{p,e}/r \quad (7)$$

Combining equations 3 through 6 results in an overall equation for the primary dust concentration:

$$P = (c_5 V_s F_n /r) (1 - c_2 \tilde{Q}_p) \exp[-c_4 U (r - x)] \quad (8)$$

Under still air conditions and for constant grinding conditions, equation 8 can be simplified to the following form:

$$P = P_o (1 - c_2 \tilde{Q}_p) \quad (9)$$

where P_o = concentration of primary dust at a fixed point in space with zero ventilation rate

An analogous equation can be formulated for the concentration of secondary dust particles:

$$S = S_o (1 - c_6 \tilde{Q}_s) \quad (10)$$

Substituting equations 9 and 10 into equation 1, the general model forms are obtained for breathing zone concentrations of total respirable dust:

$$c = c_o - c_p Q_p - c_s Q_s \tag{11}$$

$$c_r = c_{o,r} - c_{p,r} Q_p - c_{s,r} Q_s \tag{12}$$

This model form is shown graphically in Figure E-1 which shows the functional relationship between dust concentration and ventilation rate as predicted by the model. The resulting relationship is a two-segment curve which is similar to the experimental data curves of ventilation system performance presented in Appendix C.

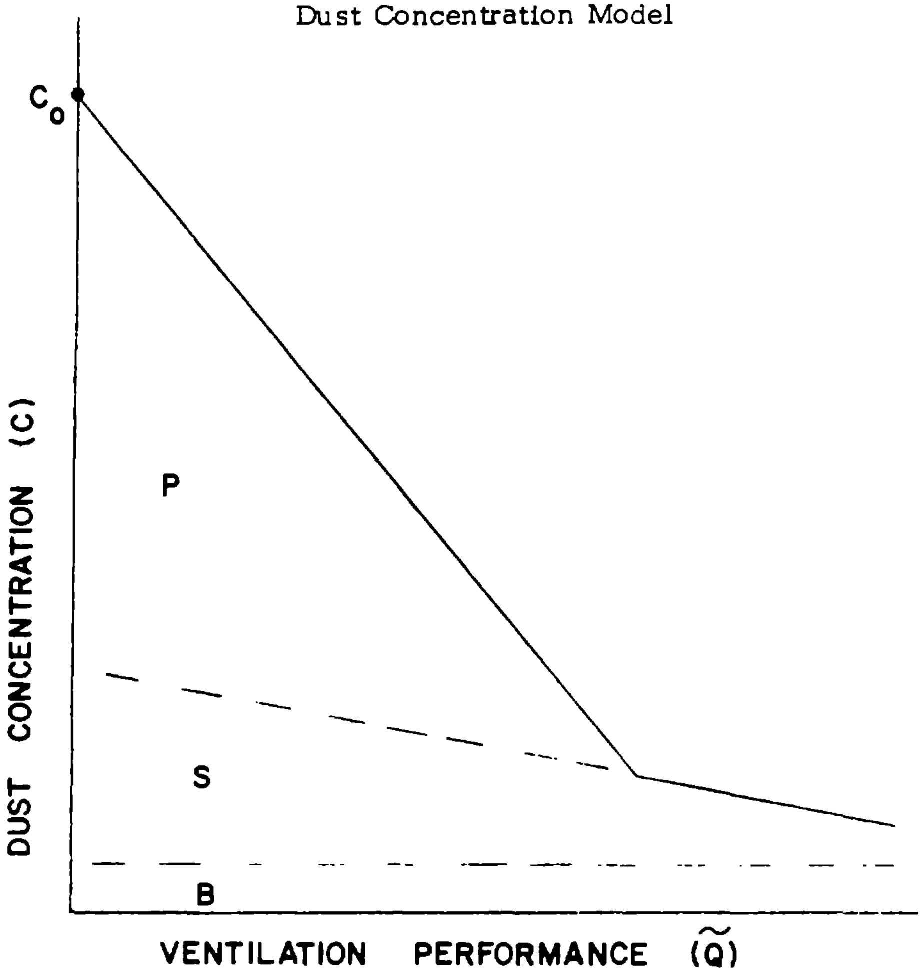
The general model forms presented in equations 11 and 12 would be useful in correlating data from ventilation systems involving both conventional and auxiliary ventilation hoods where the two hoods are designed to capture primary and secondary particles respectively. However, for correlation of data from equipment with simple, conventional ventilation hoods, these general forms are unnecessarily complex and a simpler form is preferable.

2. Simplified Model Form

To derive a simplified version of the general model form, a qualitative analysis was conducted of the relative importance of the primary and secondary particle generation mechanisms. Since larger particles generally have a greater influence on airborne particle mass concentration than smaller particles, it is reasonable to conclude that primary particles are of greater importance in dust control than secondary particles. This conclusion is supported by the results of ventilation system performance measurements presented in Appendix C. These results indicate that, in general, a high degree of control of breathing zone dust concentration can be achieved with conventional ventilation hoods designed for control of primary particles. Consequently, the logical approach to deriving a simple model form is to neglect the secondary particle generation and capture mechanism.

Figure E-1

General Form of Breathing Zone
Dust Concentration Model



$C = P + S + B$
where P = primary dust
S = secondary dust
B = background dust

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Using this approach, the models expressed in equations 11 and 12 can be simplified and rearranged to produce the following forms:

$$\frac{c}{c_o} = 1 - \frac{\tilde{Q}}{\tilde{Q}_o} \tag{13}$$

$$\frac{c_r}{c_{o,r}} = 1 - \frac{\tilde{Q}}{\tilde{Q}_{o,r}} \tag{14}$$

The term $\tilde{Q}_o$ in the simplified model forms is called the "ventilation index" and this term represents the value of the ventilation parameter $\tilde{Q}$ necessary to achieve a zero level breathing zone dust concentration. Actually, a zero concentration is rarely achieved since a conventional ventilation hood will not remove the background dust level and will not be effective in capturing secondary particles. However, the ventilation index indicates the condition where maximum effectiveness of a conventional ventilation hood is achieved. Consequently, it is a significant parameter and is useful in defining ventilation system design criteria.

3. Ventilation Performance Parameters

3.1 Captor Hoods

The ventilation performance parameter $\tilde{Q}$ is expressed as a ratio of the velocity induced by the ventilation system to the velocity of the particles to be captured. These velocities are evaluated at the location where particle capture is assumed to occur. In the case of a simple captor hood, the hood-induced velocity field is known and can be expressed by the traditional ventilation formula (Ref 1):

$$V = \frac{Q}{10x^2 + A} \tag{15}$$

Using this formula, and assuming that the particle capture location is close to the abrasive tool surface, the ventilation parameter has been defined as follows:

$$\tilde{Q} = \frac{Q}{V_s\,(10x_p^2 + A)} \tag{16}$$

where Q = ventilation rate

X_p = distance from center of hood face to nearest point on abrasive tool surface

A = hood face area

V_s = abrasive tool surface velocity

This form of the ventilation parameter is used with the breathing zone dust concentration models when applied to surface-type grinders or polishing and buffing wheels with simple captor hoods.

3.2 Shaped Collectors

With a shaped collector, the velocity profile induced by the collector and the particle capture location are not known. Consequently, the ventilation parameter can be expressed only in a functional form which must be verified empirically. This approach is satisfactory for equipment classes using shaped collectors with standardized designs. Collector designs are reasonably standardized for three equipment classes: (1) pedestal-type grinders, (2) pedestal-type polishers and buffers, and (3) belt grinders. The ventilation parameter formulations which have been proposed for use with these equipment classes are listed below:

Equipment Class	Ventilation Parameter*
Pedestal-Type Grinders	$\tilde{Q} = \frac{Q}{V_s D^2}$
Pedestal-Type Polishers and Buffers	$\tilde{Q} = \frac{Q}{V_s D^2}$
Belt Grinders	$Q = \frac{Q}{V_s WL}$

The ventilation parameter for pedestal-type grinders has been verified to a limited extent. However, the parameters proposed for the other equipment classes have not been verified.

*Terminology: D = wheel or drum diameter
W = belt width
L = distance between belt roller centers

Appendix F: Ventilation System Design Guides

1. Proposed Design Guide Modifications

Modified design guides presented in figures in this appendix, are proposed for the following six classes of GBP equipment:

Equipment Type	Figure
Surface grinder with captor hood	F-1
Pedestal-Type grinder	F-2
Pedestal-type buffing or polishing machine with shaped collector	F-3
Backstand Idler polishing machine with shaped collector	F-4
Soft wheel buffing lathe with shaped collector	F-5
Belt grinder or polisher with shaped collector	F-7

The proposed design guides are based upon the ventilation system design and operating criteria presented in Section 4 of this report.

In addition to the modified guides, new guides are proposed in Figures F-6 and F-8 for buffing and polishing wheels with captor hoods and for abrasive cutting-off machines with captor hoods. Since captor hoods are used frequently for dust control with these types of equipment, guides to good design and operating practice should be provided.

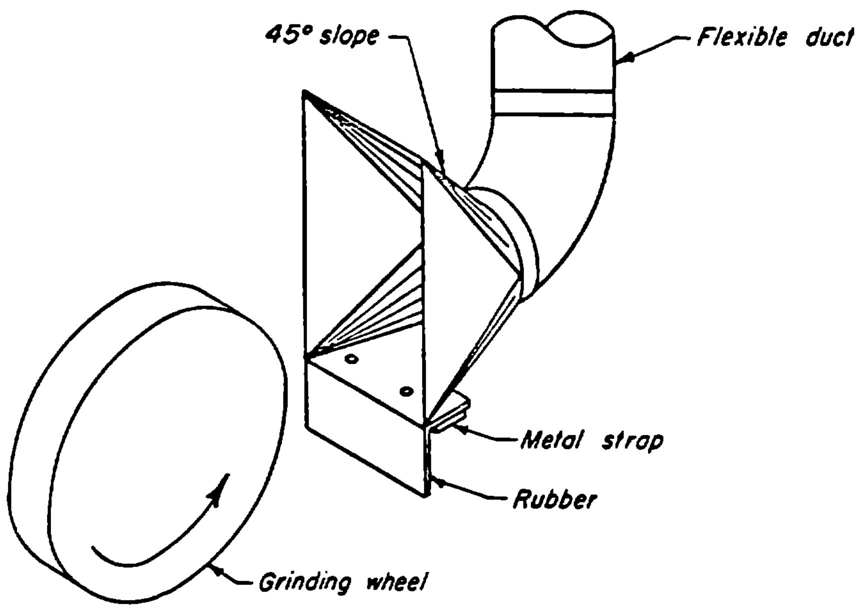
2. Design Guides to be Retained without Modification

Certain design guides currently contained in the Industrial Ventilation Manual pertain to the use of booths or enclosures with GBP equipment. It is suggested that these guides be retained without modification. These guides are as follows:

VS-401	Abrasive Cut-off saw ventilation
VS-404	Circular automatic buffing
VS-405	Straight line automatic buffing
VS-408	Horizontal double-spindle disc grinder
VS-409	Horizontal single-spindle disc grinder
VS-410	Vertical spindle disc grinder
VS-412	Portable hand grinding
VS-413	Portable chipping and grinding table
VS-414	Swing grinder
VS-801	Extractor head for cone wheels and mounted points
VS-802	Hood for cup type surface grinders and wire brushes
VS-804	Extractor head for small radial grinders
VS-805	Extractor head for disc sander
VS-806	Extractor tool for vibratory sander

3. Design Guides for Control of Toxicologically Active Dust

It is proposed that a classification of GBP operations be adopted which is based on the toxicological activity of the particulate materials generated by the operation. The three-class system defined in Appendix B would serve this purpose, or a simpler two-class system (inert and non-inert) might be sufficient. Each ventilation system design guide should be designated according to the classes of operations for which it is effective, and, if possible, different levels of ventilation rates should be specified for different classes of operations.



$Q = 0.0003\ V_s\ (10x^2 + A)$

where Q = ventilation rate (cfm)

V_s = wheel surface speed (fpm)

X = hood-wheel distance (in)*

A = hood face area (in^2)

Entry loss = 0.25 VP

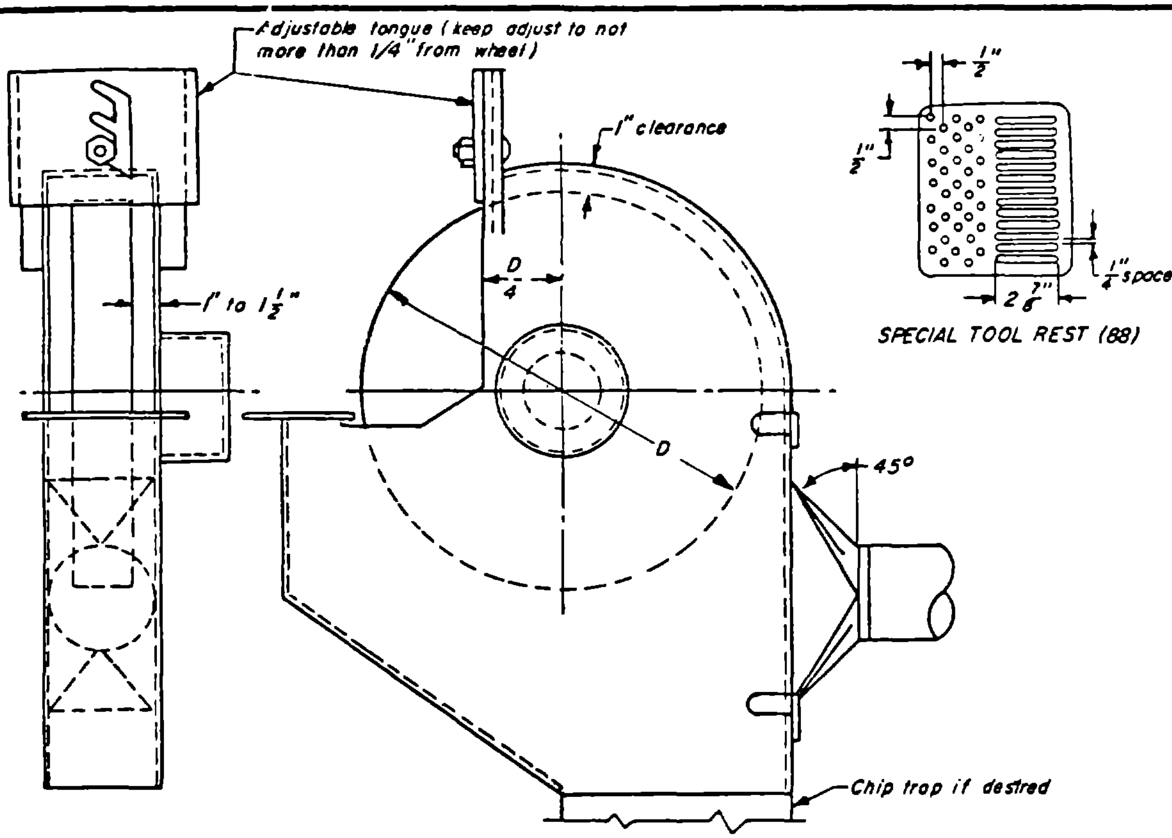
Duct velocity = 3500 fpm minimum

*X measured from center of hood face to nearest point on wheel surface

SURFACE GRINDER
WITH CAPTOR HOOD

DATE

Figure F-1



$$Q = 0.0003\, V_s\, D^2$$

where Q = ventilation rate (cfm)

V_s = wheel surface speed (fpm)

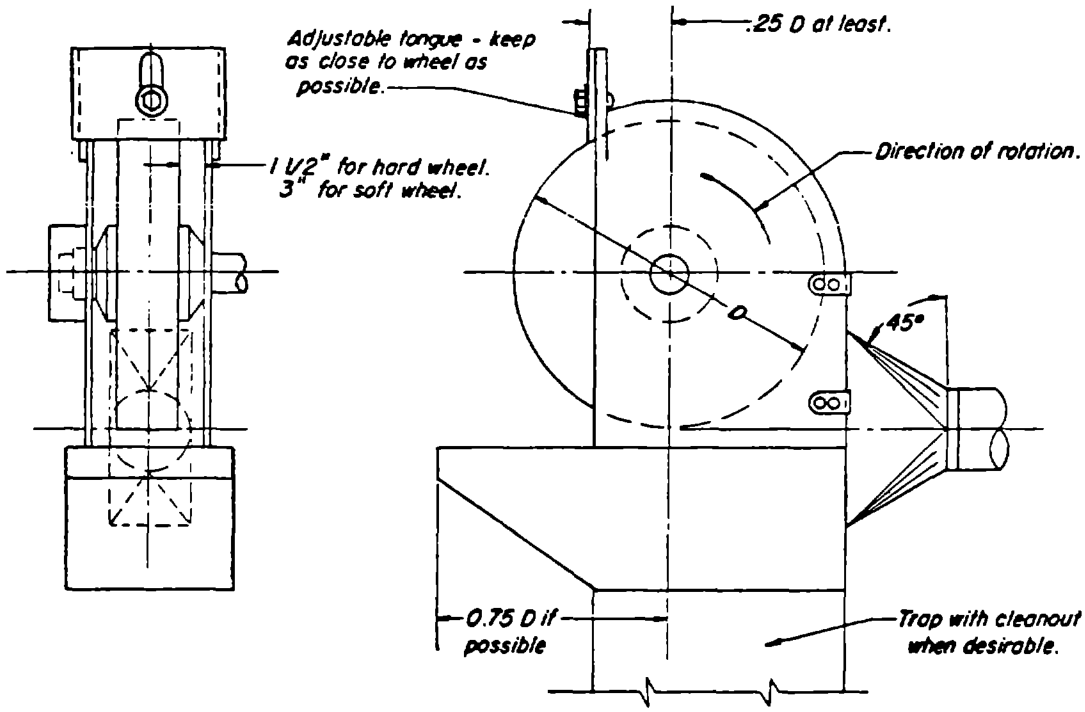
D = maximum wheel diameter (in)

Minimum duct velocity = 4500 fpm in branch
3500 fpm in main
Entry loss = 0.65 VP for straight takeoff
0.40 VP for tapered takeoff

PEDESTAL-TYPE GRINDER

DATE

Figure F-2



Minimum duct velocity: 4500 fpm branch.
3500 fpm main.

Entry loss: 0.65 VP for straight take-off.
0.40 VP for tapered take-off.

$$Q = 0.0003\, V_s\, D^2$$

where Q = ventilation rate (cfm)

V_s = wheel surface speed (fpm)

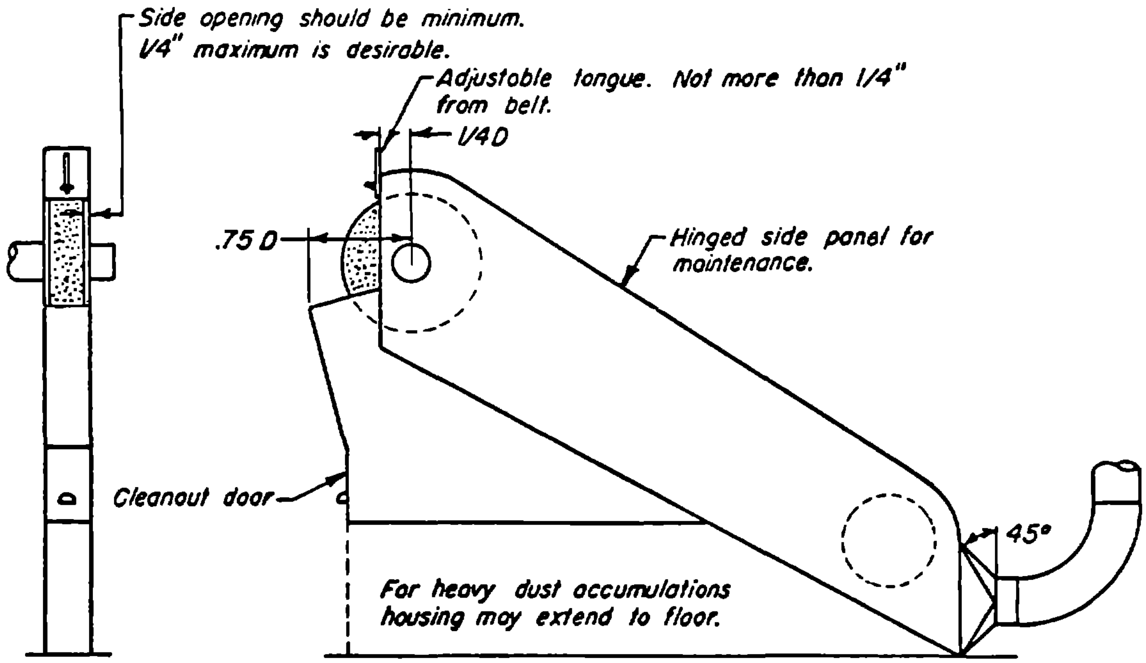
D = maximum wheel diameter (in)

In cases of extra wide wheels, increase Q by factor equal to $\frac{4W}{D}$. (W = wheel width)

PEDESTAL-TYPE
BUFFING OR POLISHING MACHINE
WITH SHAPED COLLECTOR

DATE

Figure F-3



$$Q = 0.0003\ V_s\ D^2$$

where Q = ventilation rate (cfm)

V_s = belt surface speed (fpm)

D = contact wheel diameter (in)

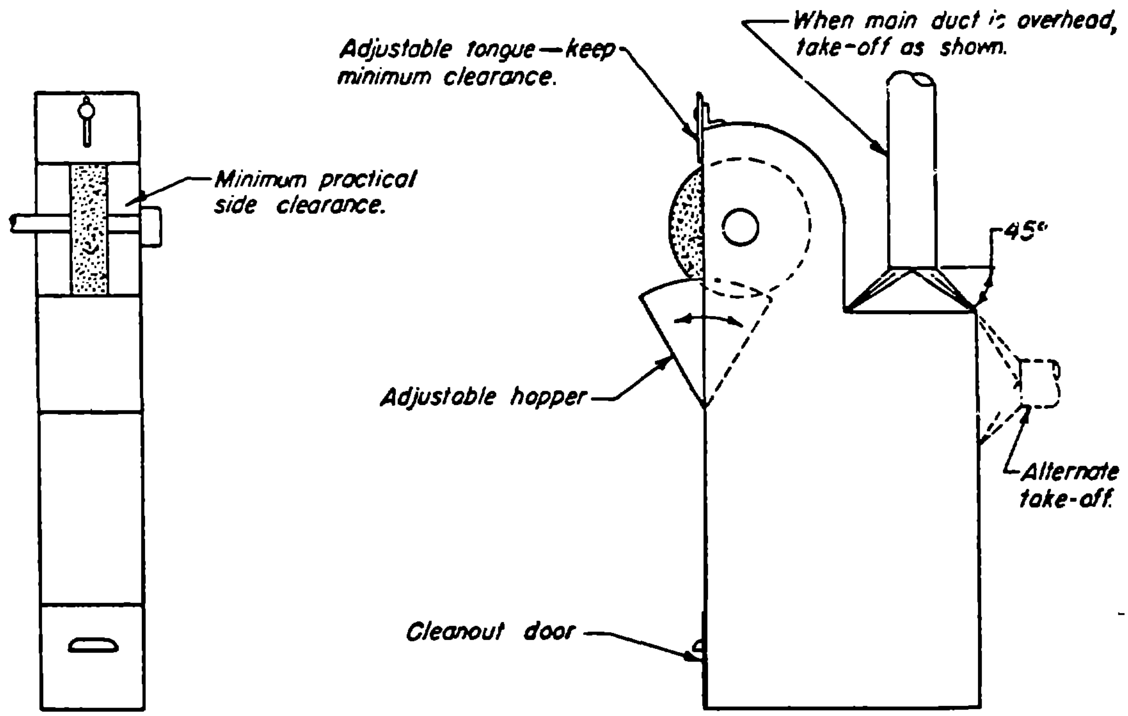
Entry loss = 0.40 VP
Duct velocity = 3500 fpm mimimum

Note:
For titanium and magnesium eliminate hopper and use 5000 fpm through hood cross section.

BACKSTAND IDLER POLISHING MACHINE
WITH SHAPED COLLECTOR

DATE

Figure F-4



$$Q = 0.0003\, V_s\, D^2$$

where Q = ventilation rate (cfm)

V_s = wheel surface speed (fpm)

D = maximum wheel diameter (in)

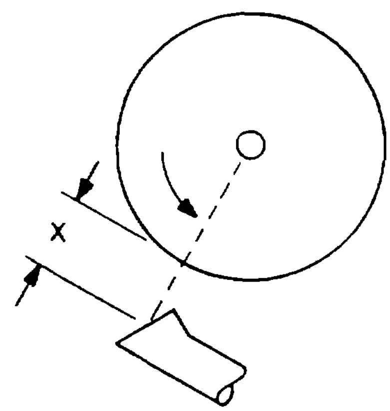
Duct velocity = 4500 fpm minimum

Entry loss = 0.40 VP

In cases of extra wide wheels increase Q by factor equal to $\frac{4W}{D}$. (W = wheel width)

SOFT WHEEL BUFFING LATHE WITH SHAPED COLLECTOR

DATE



$$Q = 0.0003\ V_S\,(10X^2 + A)$$

WHERE Q = VENTILATION RATE (CFM)

V_S = WHEEL SURFACE SPEED (FPM)

X = HOOD - WHEEL DISTANCE (IN)

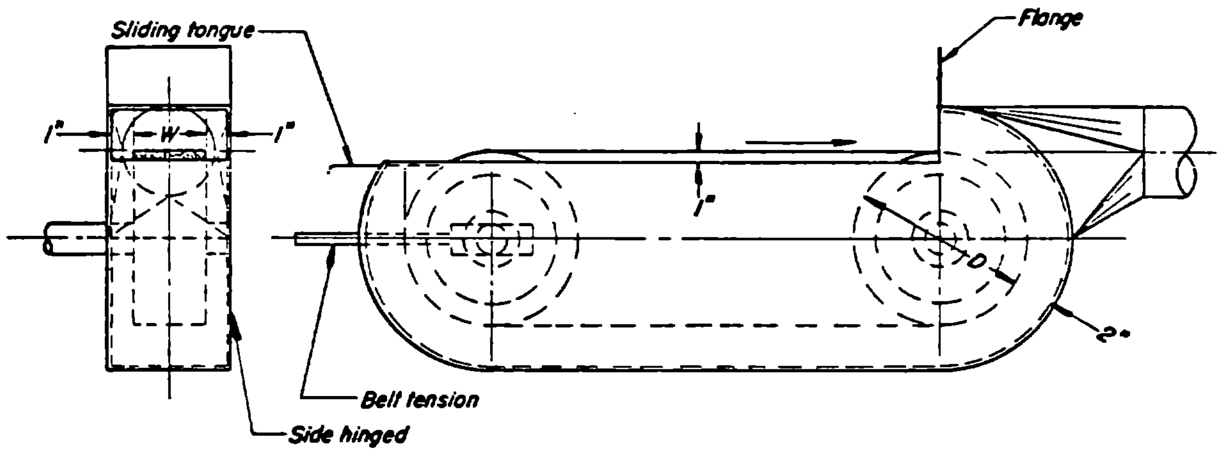
A = HOOD FACE AREA (IN^2)

ENTRY LOSS = 0.25 VP

DUCT VELOCITY = 3500 FPM MINIMUM

BUFFING AND POLISHING WHEELS
WITH CAPTOR HOODS

Figure F-6



$$Q = 0.00035\ V_s\ W\ L$$

where Q = ventilation rate (cfm)

V_s = belt surface speed (fpm)

L = roller spacing (in)

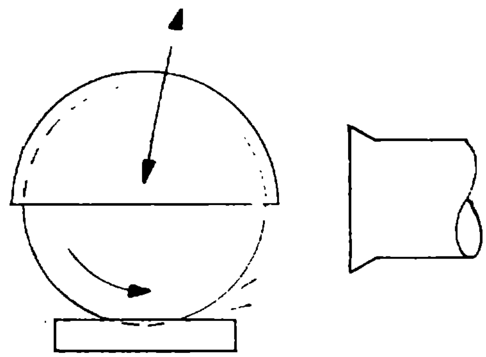
W = belt width (in)

Minimum duct velocity = 4500 fpm branch, 3500 fpm main.
Entry loss = 0.65 velocity pressure for straight take-off.
0.45 velocity pressure for tapered take-off.

BELT GRINDER OR POLISHER
WITH SHAPED COLLECTOR

DATE

Figure F-7



$$Q = 0.0003\, V_s\, (10 X^2 + A)$$

where Q = ventilation rate (CFM)

V_s = wheel surface speed (FPM)

X = hood-wheel distance (in)

A = hood face area (in^2)

Entry loss = 0.25 VP

Duct velocity = 3500 FPM minimum

Notes:

1. X measured from center of hood face to nearest point on wheel surface.
2. Hood face area must be sufficient to be effective at all positions of wheel.

Abrasive Cutting-Off Machine with Captor Hood	
Date	

Figure F-8

Appendix G: Literature Review and Bibliography

1. Introduction

1.1 Purpose

A review has been conducted of information on various aspects of the design of ventilation systems for grinding, buffing, and polishing (GBP) operations. The purpose of this appendix is to identify the information sources which have been utilized, and to describe the nature of the information which has been reviewed in terms of its depth and completeness.

1.2 Scope

Information has been compiled in three principal subject areas related to ventilation system design: Equipment, operations, and ventilation or dust control.

1.2.1 Equipment

Information compiled on GBP equipment includes configurations of machines and characteristics of abrasive tools. Machine configuration is of interest because of its effect on the flow of air and particulate materials, and the constraints imposed by the machine configuration on the ventilation hood design. Abrasive tools, which include grinding wheels, coated abrasives, and buffing compounds, are of interest primarily because a portion of the dust generated by abrasive operations consists of abrasive material.

1.2.2 Operations

Information compiled on GBP operations includes the nature of the workpiece materials, and abrasive tool speeds and material cutting rates. The workpiece material is important because it determines to a large degree the nature of the dust particles formed in GBP operations. Tool speeds and cutting rates affect the initial trajectories of dust particles and the rates of particle generation.

1.2.3 Ventilation

Information compiled on ventilation of GBP operations includes data on dust levels generated and the effectiveness of ventilation systems designed according to current practice. Information also has been gathered on new approaches to ventilation system design.

2. Data

2.1 Sources

Sources of information utilized in the review have included books, journal articles, manufacturers' literature, and discussions with manufacturers. Books on GBP equipment and operations have been found through searches of card catalogues at the M.I.T. and Harvard University Medical School libraries, and through communications with manufacturers. Journal articles have been found primarily through a search of recent years of the Engineering Index. Volumes included were years 1967 through 1972, and the subject headings searched were Abrasives, Buffing, Dust, Grinding, Grinding Machines, Grinding Wheels, Industrial Hygiene, Industrial Plants - Dust Control, Metal Cutting-Abrasive, Metal Finishing, Polishing, and Ventilation. Other pertinent journal articles have been located by searching specific journals including "Machinery", "Filtration and Separation", and "Staub - Reinhaltung der Luft" in English.

Information has been solicited from manufacturers by mail requests sent to approximately 200 manufacturers of abrasive materials and GBP equipment. These manufacturers were located through Thomas Register. These requests were for product literature only, and the addressees provided a large collection of descriptive material which has been very useful in indicating the types of machinery being produced and the characteristics of abrasive materials and tools. However, a number of manufacturers volunteered additional information through letters and personal contacts. These contacts have been very helpful in obtaining information on current practices in equipment utilization and dust control.

2.2 Bibliography

A bibliography of books and journal articles on subjects relevant to this program has been prepared and is included at the end of this appendix. Entries in the bibliography are classified as follows:

GBP Equipment and Operations

Abrasives
Grinding Equipment and Operations
Polishing and Buffing Equipment and Operations

Ventilation and Dust Control

The bibliography on equipment and operations is by no means exhaustive. The technical literature includes numerous articles on grinding equipment and its applications. The articles included in the bibliography are representative of the literature on these subjects and can be used as starting points if a more extensive bibliography is required. Each of the articles cited is of recent publication and contains references to earlier publications.

The bibliography on ventilation contains books and articles of recent vintage which pertain directly or indirectly to GBP operations. This listing is not extensive and contains a large fraction of European entries.

3. Discussion

3.1 Equipment

3.1.1 Machines

The types of GBP equipment being manufactured today are fully described in the technical literature. These equipment descriptions have been utilized in this program to classify GBP equipment according to its ventilation requirements and the classification is described in Appendix A.

3.1.2 Abrasives and Abrasive Tools

Abrasive materials used with GBP equipment are well defined in the technical literature, and the characteristics of these materials used in different types of grinding wheels, coated abrasive products, and buffing compounds are published by the manufacturers of these products. Less detailed information is available on the binders and additive materials used in the formulation of grinding wheels, adhesives, and buffing fluids. The nature of these materials usually is specified, but specific compositions often are proprietary and are not published by the manufacturers.

3.2 Operations

3.2.1 Workpiece Materials

No references have been found to date which indicate the materials to which GBP operations are applicable, or which indicate any variations in applicability of different machines to different materials. The implication of this lack of information on materials applicability is that any machine can be used to process any material.

To fill this information void, Norton Company personnel were asked to formulate a list of materials most commonly processed with the different types of grinding equipment. The list prepared by Norton company is presented in Table I.

3.2.2 Tool Speeds and Cutting Rates

Several references have been found which describe tool speeds and material cutting rates involved in grinding and polishing operations. These references provide useful information on rates of particle formation resulting from abrasion of the workpiece materials and wear of the abrasive tools. No information has been found on material removal rates in buffing operations. However, some information is available on the rates at which the abrasive compounds used in buffing operations are injected.

3.3 Ventilation

Information collected on ventilation of GBP operations provides a qualitative description of the principles of the control of dust generated by these operations. However, very little information of a quantitative nature has been published on the performance characteristics of ventilation systems or relationships between ventilation system design and the degree of dust control achieved. Thus, information required for the formulation of ventilation system design criteria does not appear to be available in the technical literature. This information, to a large degree, had to be derived by analysis of ventilation system performance.

TABLE I

Workpiece Materials - Dry Grinding Operations

A. Abrasive Cutoff

1. Metallics

a. Ferrous Metals - General

(1) Steels
(2) Irons

b. Heat Resisting Alloys

(1) Iron, Nickel, or Cobalt Base

c. Refractory Metals and Alloys

(1) Columbium, Tantalum, Molybdenum, Tungsten

d. Nonferrous Metals

(1) Aluminum and Alloys
(2) Beryllium
(3) Copper and Alloys
(4) Magnesium and Alloys
(5) Nickel and Alloys
(6) Titanium and Alloys
(7) Zinc and Alloys

2. Nonmetallics

Asbestos	Gypsum Board	Stone (Marble, Limestone, Slate)
Brake Lining	Porcelain	Refractory Furnace Liners
Brick	Rubber	
Carbon	Ceramic Tile	
Concrete	Wallboard	
Fiberboard	Plastics	

B. Floorstand, Pedestal and Bench Stand Grinders

1. Metallics - primarily irons and steels, but also includes aluminim alloys and copper alloys.

C. Tool Grinding and Cutting

1. High speed steels

2. Cemented carbides and oxides

   a. containing various amounts Co, WC, TiC, TaC, and mixtures of Al_2O_3 and TiO

3. Cast cobalt - chromium-tunsten alloys

4. Alumina-based ceramics

D. Portable Grinding (ex. cut-off) and Hand-Held Swing Frame Snaggers

1. Primarily castings and forgings of iron, steel, brass, bronze, aluminum, magnesium, and titanium.

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Appendix H: Purpose and Scope of Work; Contract No. HSM 99-72-126

1. Purpose of Contract and Background

Toxic materials are generated whenever grinding, buffing, or polishing takes place. The quantity of these materials, and the problems associated with capturing them at their source, depend upon the base material, the width, diameter, and rotative speed of the wheel, and the pressure exerted.

Design criteria for engineering controls now available in the Industrial Ventilation Manual and The American Standard for Ventilation Control of Grinding, Polishing and Buffing Operations (Z43.1-1966), and similar sources are at least five years old. The criteria were based largely on past industrial practive rather than research.

Since presently available criteria were developed there has been a continual increase in the surface speeds and wheel widths used. A recent survey has indicated that present criteria, when applied to modern industrial practice, do not assure adequate protection for the workmen.

This contract is for the development of criteria for the design of ventilation systems capable of capturing and removing particulate matter generated by grinding, buffing and polishing equipment currently used in industry.

2. Scope of Work

Under this contract criteria shall be developed for the design of ventilation systems for the control of air contaminants resulting from grinding, buffing and polishing operations. Systems designed in accordance with these criteria shall be capable of controlling the contaminant concentration in the breathing zone of the operator to a level of not greater than 60 percent of the threshold limit value (TLV) as given by the American Conference of Governmental Industrial Hygienists (ACGIH).

Data for the development of the required design criteria shall be obtained from:

a. A broad program of field inspections of various industries to observe the different types of grinding, buffing and polishing operations being carried on, the types of equipment in use today, the base metals being processed, and the range of surface speeds and wheel widths being used.

b. A thorough review of the technical literature, both domestic and foreign.

c. Information obtained from manufacturers of grinding, buffing, and polishing equipment.

d. Information obtained from the users and/or operators of grinding, buffing and polishing equipment.

e. Research conducted by the contractor either in his own facility or in selected industrial plants.

f. Any other sources available.

The sampling method to be used to determine the effectiveness of the various systems shall meet with the approval of the Engineering Branch of DLCD.

The following types of ventilation systems are to be included in the study:

a. Various types of local exhaust hoods, including the development of the British Cast Iron Research Association.[1]

b. Booth type hoods.

c. Low volume - high velocity systems.

d. Others.

The suitability of a given type of system or procedure for use in production facilities shall be demonstrated by laboratory and/or field tests. If data from recently performed and properly documented tests are available to the offerer, they may be acceptable.

This study shall cover the full range of surface speeds found in industry, with a top speed of not less than 20,000 sfm, and shall include the full range of wheel widths now in use. On the basis of these two variables and any other pertinent parameters, grinding, buffing, and polishing equipment shall be divided into several classifications, each of which will require different ventilation criteria. There shall be as many classifications as may be required to adequately satisfy the requirements.

At the completion of the project, the contractor shall furnish to the Engineering Branch, DLCD, a complete description of each of the above described classifications, together with complete criteria and details of the ventilation system required for each. These shall include:

a. A schematic drawing of the local exhaust hood similar to the VS drawings in Section 5 of the Industrial Ventilation Manual.
b. Required air quanity given in terms of wheel size or other suitable parameter.
c. Recommended hood face or slot velocities.
d. Branch and main duct velocities.
e. Entry loss expressed in terms of the velocity pressure in the branch duct.

Complete test data to justify the recommended design criteria shall also be submitted.

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