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EFFECT OF FILTRATION PARAMETERS ON DUST CLEANING FABRICS

Industrial Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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EFFECT OF FILTRATION PARAMETERS ON DUST CLEANING FABRICS

by

Jan R. Kościanowski and Lidia Kościanowska

Institute of Industry of Cement Building Materials
45-641 Opole
Oświecimska Str. 21 POLAND

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EPA Project Officer: James H. Turner

Industrial Environmental Research Laboratory
Office of Energy, Minerals, and Industry
Research Triangle Park, NC 27711

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SECTION I

CONCLUSIONS

The test measurements on filtration fabrics and mathematical analysis of the results led to the following initial conclusions:

- Depending on the conditions of the experiments, dust filtration processes can be classified as one of three types:
  - Type I - the initial phase, starting with unused fabric and terminating when the pressure drop reaches a predetermined level;
  - Type II - the middle phase, terminated when the residual dust load in the fabric remains constant after each cleaning cycle; and
  - Type III - the last phase, characterized by the fabric being fully filled with dust and having a stabilized value of pressure drop and residual dust load immediately after cleaning.
- Although laboratory testing of Filtration Type I is not comparable to industrial-scale testing, it does provide data about filtration mechanisms which are important to further theoretical exploration.
- Excessive filtration velocity can destroy the dust cake structure through creation of ducts/canals, lowering the dust removal efficiency.
- Further research is required to determine the effects of electrostatic properties on dust filtration processes.

More specific conclusions on each aspect of this work are included in the individual sections.

SECTION II

RECOMMENDATIONS

Further research is necessary under the program. It should emphasize the physical aspects of dust filtration processes and provide a statistical presentation of empirical data.

SECTION III

INTRODUCTION

INVESTIGATION OF DUST FILTRATION PROCESSES

Fabric filters are widely used in industrial dust removal systems, the types varying by production processes. In the cement, lime, and gypsum industry, they have been used in both cool and hot gas filtration processes, working at temperatures below and above 140° C, respectively.

Fabric filters have the following advantages for use in production processes:

- High efficiency of dust collection;
- High fractional efficiency for fine dust particles;
- Low sensitivity to physical and chemical changes in the dust;
- Collection of dry matter of the same size distribution as in the inlet gas;
- Simple design, capable of operation without special training;
- Reliability of operation;
- Possibility of multichamber construction for flexibility in meeting size requirements.

These advantages of fabric filters outweigh their disadvantages:

- Sensitivity to the humidity of gases, especially when the dew-point is exceeded;
- High filtration resistance;
- High operating costs because of periodic filtration bag replacement.

Though known for many years, the dust filtration process for the removal of dust particles from a gas stream has not been fully studied. In this, it differs from the air filtration process which has a theoretical base. An increasing amount of research into dust filtration problems is being

conducted in the macroscopic range, but only a few studies are concerned with the microscopic or molecular range. Though the results of such research represent only a part of the needed information, they are important to the further study of filtration processes.

Analysis of the published data on the dust filtration process leads to the following conclusions:

- The dust filtration process is more complicated than that of air filtration; the use of empirical data for theoretical research into the former is therefore more difficult.
- Empirical data indicate closely defined relationships between dusts and fabrics which can be generalized.
- Available dust cake theory, though giving general information on changes in hydraulic resistance, does not consider parameters of the dust cake structure.
- Application of classic theory of filtration to dust filtration conditions is not justified because of quite different process parameters.
- At present we have no theoretical explanation of several peculiarities of the dust filtration process; this leads to inconsistencies between empirical expositions and fact, especially for certain combinations of dust and fabrics.

Consequently, the selection of types of dust and of fabric for particular filtration parameters requires laboratory-scale, pilot-scale, and sometimes industrial-scale experimentation. The most important requirements relate to the cleanliness of emitted industrial gases. The need for further research on the dust filtration process is related to the fact that it seems to be the most economic method for control of sources of large amounts of air pollution.

The well-known electrostatic precipitators probably will never achieve as high an economic effectiveness as that of dust filtration processes (particularly for fine particle collection) because of the specificity

of the electrostatic method of dust collection. This method is limited by many factors; in some cases, its use requires prior treatment of gases in a cooling tower, or an increase in the area of the collecting electrodes. Although the application of prior gas cooling occurs in some fabric filtration installations (because of the temperature limitations of the filtration materials), research on new filtration materials will eliminate this requirement, an achievement not possible for electrostatic precipitators.

Wet scrubbing has been limited by some technological factors (e.g., conditions in the cement and food industries), but it generally seems to be the best solution from an investment, as well as an operating, point of view.

There is increasing concern in the legislatures of many countries as to dust emission (and particularly its physical and chemical properties, fractional composition, etc.). The factors outlined above will be important to the determination, in the near future, of what kind of filtration devices are to be used. In this situation, continuing research into the dust filtration process will become indispensable.

Accordingly, future research on the filtration processes should have two purposes:

- Dissemination of data on dry dust filtration by the use of filtration fabrics;
- Determination of future objectives of research programs.

PROBLEMS IN DUST FILTRATION

The general qualitative parameters characterizing dust filtration fabrics in industrial units are:

- Mean dust removal efficiency;
- Filtration resistance as a function of the dust layer;
- Filtration velocity.

These parameters are not concerned with any classification as to quality of the structure of fabrics, but only to the types and kinds of fabric and of the gas and dust media in which the filtration process is tested.

The only quantitative parameter which characterizes the structure of fabrics resulting from their manufacture (except the technical conditions of production) is permeability, which defines the magnitude of gas flow through the fabric, measured at a given static pressure (0.5 inch of water for U.S. standards and 20 mm of water for Polish standards).

It is evident that permeability is not an adequate structural parameter for describing either clean or dusty gas flow. For that reason, it is necessary to establish quantitative definitions of parameters for fabric structure. Research experience and methodology for air filtration are not applicable to dust filtration fabrics.

The present inadequate knowledge of the dust filtration process and the lack of quantitative and qualitative definitions make it difficult at present to design appropriate structures for filtration fabrics (e.g., those of known performance characteristics under defined operating conditions).

Accordingly, the determination of optimal structural designs must be done by testing fabrics for:

- Thermal resistance;
- Dynamic resistance;
- Mechanical strength;
- Water absorption, capacity, etc.

The most useful results would be obtained from large-scale industrial test measurements under all conditions of filtration and regeneration. However, this is not an economical method, and it probably will be reserved for special dust removal problems.

The primary dust filtration research need at present is for the quantification of structural parameters so as to permit meaningful testing and classification of filtration fabric structures.

A secondary need is to examine the electrostatic properties of dust and fabrics as a means of increasing dust collection efficiency. This requires an understanding of the basic electrodynamic processes.

From the macroscopic/economic point of view, the useful solutions emerge from consideration of the entire complex of physical and chemical processes of dust filtration.

RESEARCH OBJECTIVES

The basic objectives of the program financed by the EPA and conducted by the Institute of Cement Building Materials in Opole were established as:

- A viable description of the effects of structural parameters on pressure drops, using gas flow through clean filtration fabrics.
- A viable description of the effects of structural parameters of the fabric and of the dust cake on pressure drops during the filtration process.
- A viable description of the dependence between dust collection efficiencies and the variables of the dust filtration process.
- Testing, by mathematical modeling, of those fabric structures with the best filtration properties.

Total program research will include the following:

- Laboratory testing, including that of dust and fabrics;
- Large-scale testing;
- Auxiliary studies;
- Application of mathematical methods including modeling.

GENERAL PROGRAM

Laboratory Testing

Laboratory testing was accomplished on four kinds of filtration fabrics and two types of dust, measured under the following conditions:

- Dust concentrations in the air at inlet of the test chamber:
  10 g/m^3 ± 10%.
- Dust loadings of filtration area of:
  100 g/m^2
  400 g/m^2
  700 g/m^2
  with $\Delta P < 250$ mm of water.
- Gas loadings of the filtration area of:
  60 m^3/m^2/hour
  80 m^3/m^2/hour
  120 m^3/m^2/hour.
- Humidity of dispersion medium (not adjustable):
  RH = 40% ± 10.
- Temperature of dispersion medium: 20° to 30° C.
- Dispersion medium: atmospheric air.
- Pressure: atmospheric pressure.

Large-Scale Testing

Large-scale tests were scheduled using filtration bags with an operating length of 3000 mm and the same dusts used in laboratory testing. Test conditions were:

- Dust concentration in the air at the inlet of the test chamber:
  10 g/m^3 ± 10%.
- Dust loading of filtration area of:
  500 g/m^2
  700 g/m^2
  with $\Delta P < 250$ mm of water.
- Gas loadings of the filtration area of:
  60 m^3/m^2/hour
  80 m^3/m^2/hour.

- Humidity of dispersion medium (not adjustable):
  RH 40% ± 10.
- Temperature of dispersion medium: 20° to 30° C.
- Dispersion medium: atmospheric air.
- Pressure: atmospheric pressure.

Definition of Structural Parameters for Fabric

Research for the definition of structural parameters for fabric included the following methods:

- Analytical,
- Measurement,
- Experimental.

Measurements and analyses concerned and included:

- The geometry of the spatial structures of fabrics,
- The technological parameters and production variables of fabrics and fabric structures,
- The technological parameters and production variables of threads and filaments,
- Microscopic tests, etc.

The parameters defined by analyses and measurements under atmospheric air flows were evaluated experimentally. Study was of four types of filtration fabrics, all manufactured in Poland and each differing as to raw material, filament diameter, weave, etc. A literature search was included in this program.

Definition of Structural Parameters for Dust Layers

Industrial polydispersed dust layers used in the testing program were characterized by particular physical and chemical properties. The research program for dust layers will be conducted in the same manner as that for fabrics, using the following methods:

- Analytical,
- Measurement,
- Experimental.

Testing of Electrostatic Properties of Dusts and Fabrics

Determination of the electrostatic value of dusts and fabrics was accomplished using the same materials for both laboratory and large-scale testing.

Testing included:

- Electrification of dusts by the Kunkel-Hansen method,
- Determination of the influence of the gas medium on dust electrification,
- Determination of the specific resistance of dust layers,
- Determination of the kinetics of the fabric electrification process during both clean and dusty air flows,
- Determination of the specific resistance of fabrics (superficial and through the fabric), and
- Determination of the other electrostatic effects during the dust filtration process.

DETAILED PROGRAM FOR FIRST PHASE

Laboratory Tests

- Completion of the entire testing program and compilation and preliminary analysis of the results.
- Completion of auxiliary tests on fabrics for definition of basic technological and production parameters, and
- Completion of auxiliary tests on dusts for determination of physical and chemical properties.

Definition of Structural Parameters for Fabrics

- Selection of test fabrics and definition of their primary and derivative parameters, both technological and production related,
- Determination of the hydraulic characteristics of test fabrics during clean air flow with maximum filtration velocities, and
- Compilation and preliminary analysis of the results.

Definition of the Structural Parameters of Dust Layers

- Determination of the normal range of dust pulverization, and
- Compilation and preliminary analysis of the results.

Definition of Characteristic Properties of Dusts and Fabrics

- Definition of electrification, by the Kunkel-Hansen method, of cement and coal dusts;
- Determination of the specific resistance of dust layers;
- Definition of the resistivity, both superficial and through the fabric, for the following filtration fabrics:
  ET-30
  ET-4
  F-tor 5
  PT-15;
- Summary and preliminary analysis of the results.

FABRIC AND DUST SELECTION

Four types of filtration fabric, differing as to spatial structure, were selected for use in the major part of the testing under Project No. 5-553-3. These selected fabrics are produced from the following raw materials:

- Polyester (staple fiber):
  Fabric ET-30 (EWA-1540)
  Fabric ET-4
- Polyester (continuous filament)
  Fabric F-tor 5

- Polyamide (continuous filament)
  Fabric PT-15.

Technical characteristics of these fabrics are shown in Table 1.

The following were selected as test dusts:

- Cement dust,
- Coal dust.

These industrial dusts were selected because of their chemical composition and their uniform particle size. Samples for testing were taken from appropriate points in the production processing line.

The selection of dust samples is dependent on various physical and chemical properties. Instead of testing material as sampled, testing under this project, in accordance with suggestions from Dr. James H. Turner, EPA Project Officer, was of only those dust samples containing no more than 10 percent by weight of particles with diameters greater than 20 μm. For laboratory testing, this separation was done by use of the ALPINE separator. For the large-scale tests, the dusts will be preseparated and prepared by subcontractors. The characteristics of the test dusts before and after separation are shown in Table 2 and Figures A-1 and A-2.

Table 1. FABRIC PARAMETERS

PARAMETER	UNIT	FABRICS							
		ET-4		ET-30		F-tor 5		PT-15	
		PS*	Measured	PS*	Measured	PS*	Measured	PS*	Measured
1	2	3	4	5	6	7	8	9	10
Width of fabric	cm	as required	36	140±4	135	140±4	140	85±1	85
Kind of yarn: warp fill		50TexZ x 2S 180Tex Z	45,21Tex x 2 178,25 Tex	21TexZ x 2S 21TexZ x 2S	22,15Tex x 2 21,99Tex x 2	Td 125/2 Td 250/1	Td 136,37 Td 253,52	Td 210/1 Td 210/1	Td 228,43 Td 233,77
Thread count in 10 cm: warp fill		180±5 126±5	180 126	477±10 276±6	488 274	540±12 376±12	528 360	564±12 360±11	545 363
Fabric weight	g / m^2	450±31	428.1	365±25	361.6	271±13	307.5	272±14	247
Thickness (pressure 100g/cm^2)	mm	-	0.92	-	0.74	-	0.50	-	0.39
Tensile strength, less than: warp fill	KG/5cm width KG/5cm width	220 260	240 310	250 130	323 182	346 276	310 225	300 200	336 233
Elongation during tension, no more than: warp fill	% %	70 50	51 35	6 50	60 48	20 30	37 15	60 40	43 28
Permeability	m^3/m^2 min at 20 mm H_2O	18-24	20.73	12-18	7.54	-	14.6	-	3.65
Weave	-	1/3 Z	1/3 Z	2/1 Z	2/1 Z	2/2 Z	2/2 Z	3/3	3/3
Finishing	-	steaming	steaming	thermal stabiliza-tion, washing	thermal stabiliza-tion, washing	crude	crude	stabilized	stabilized

*Polish standards

Table 2. PARTICLE SIZE DISTRIBUTION OF TEST DUSTS

a. Before separation

Range of Particle size in μm	Percent by weight	
	Cement dust	Coal dust
< 5	12 - 18	9.5
5 - 10	12 - 20	15.0
10 - 20	13 - 22	25.5
20 - 30	11 - 14	16.0
30 - 60	27 - 22	19.5
> 60	25 - 4	14.5

b. After separation

Range of Particle size in μm	Percent by weight	
	Cement dust	Coal dust
< 5	26 - 33	26.0
5 - 10	25 - 37	42.0
10 - 20	44 - 27	30.2
> 60	5 - 3	1.8

SECTION IV

LABORATORY TESTING OF FILTRATION

EQUIPMENT AND PROCEDURES

Laboratory testing of selected filtration fabrics was conducted on a stand (illustrated in Figure 1) specially designed by the I.P.W.M.B. and adapted for the testing of flat fabric specimens under ambient air conditions.

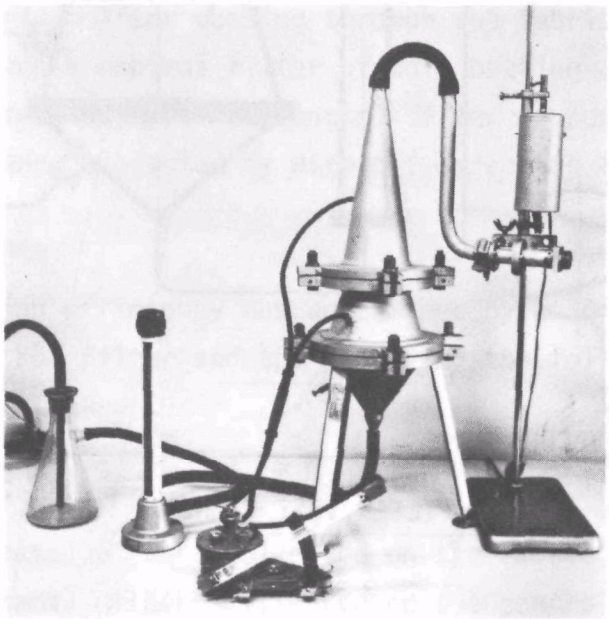


Figure 1. Illustration of laboratory stand.

This stand includes the following (see Figure 2):

- Testing chamber,
- Rotameter for measuring flow intensity,
- Needle valve to control flow intensity,
- Vibrato-injecting dust feeder,
- Micromanometer to measure pressure drop, and
- Vacuum pump.

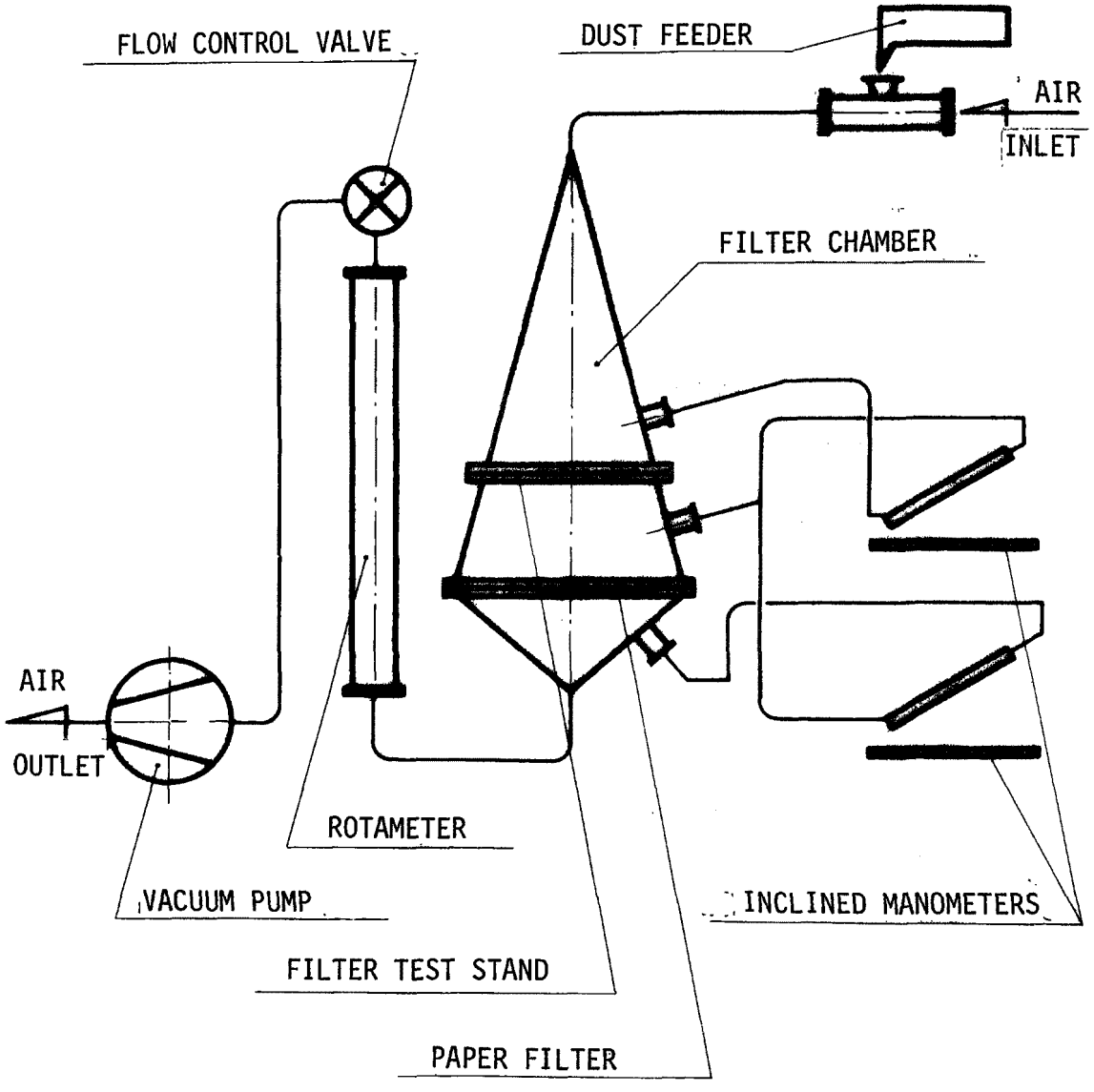


Figure 2. Diagram of the Laboratory Test Stand.

The testing chamber, which is the main part of the stand, is equipped with:

- Diffuser at the inlet end,
- Fabric specimen table, and
- Control filter table at the outlet end.

A round fabric specimen of 100 cm^2 test area was positioned in the middle of the table, supported by wire net screening (4.0 cm along one side).

In testing, dusty air flows through the fabric from the top downward, with the inlet diffuser providing a uniform flow throughout the entire test area of the fabric. After passing through the fabric specimen, the air then passes through a control filter of soft batting and paper (a disc with a 200-cm^2 test area). The control filter is positioned on the table at the outlet end, supported by wire net screening (1 cm along one side).

Average dust collection efficiency was determined by weighing the fabric specimen and the control filter and then applying the following equation:

$$\eta = \frac{G_z}{G_c} = \frac{G_c - G_o}{G_c} = \frac{G_z}{G_z + G_o} \times 100 \ (\%)$$

where G_z = weight (grams) of dust collected on the fabric,
G_o = weight (grams) of dust collected on the control filter,
G_c = weight (grams) of dust fed into the testing chamber.

During the test run, measurements were recorded for 72 hours of the temperature and humidity of the ambient air.

With this stand, the following data can be obtained:

- Mean filtration efficiency,
- Hydraulic characteristics of filtration materials during clean air flow,
- Increases in hydraulic resistance during dusty air flow, and
- Saturation degree of filtration materials.

Though specially designed for the laboratory testing of woven filtration fabrics, this stand can also be used for laboratory testing of other filtration materials (e.g., felt).

RESULTS AND DISCUSSION

The results of the laboratory tests conducted under this project are shown in Figures A-3 through A-34. A table presenting these results will be included in the final report. Because studies are continuing of structural parameter definitions of filtration fabrics and dust layers, Section IV of this interim report addresses the results displayed in Table 1 only partially or without conclusions.

Permeability is generally agreed to be one of the more important indices for characterizing a pure structure. The results of testing of permeability are contained in Table 3.

Table 3. PERMEABILITY OF FILTRATION FABRICS (In m^3/m^2/minute)

ET-4	ET-30	F-tor 5	PT-15
20.70	7.54	14.60	3.65

Table 4 shows the effect of differences in fabric and in dust on filtration resistance as measured by final pressure drop readings for the types of fabrics and dust layers tested.

The filtration resistance of fabric (as measured by pressure drop) seems to have no functional correlation to its permeability. The permeability of fabric F-tor 5 is twice that of fabric ET-30, but its filtration resistance reaches an approximately equal level. These fabrics have other similarities, such as the number of threads per 10 cm, the thickness of the yarn, and a weave using two threads as weft and warp in the plait (as contrasted to the skew weave of fabrics ET-4 and PT-15 which uses only

Table 4. FILTRATION RESISTANCE (in mm H_2O) FOR SEPARATED DUSTS (Dust concentration of C = 10 g/m^3 and L_o = 300 g/m^2)

Gas loading of filtration area $m^3/m^2/hr$	Kind of dust	Kind of fabric			
		ET-4	ET-30	F-tor 5	PT-15
60	Cement	20	35	33	47
	Coal	29	40	40	72
80	Cement	35	52	55	70
	Coal	48	65	72	88
120	Cement	68	103	128	178
	Coal	93	140	160	208

one yarn). But fabrics F-tor 5 and ET-30 differ as to type of fiber and finish, ET-30 being of staple fiber and F-tor 5 of continuous filament.

The conclusion is that fabrics of continuous filament have a faster build-up of dust and a slightly higher filtration resistance than do those of staple fiber.

As to the effect of type of dust on filtration resistance (for size distribution of MMD-7.5 μm), Table 4 shows that the latter is higher for coal dust than for cement dust for all fabrics tested. This finding probably reflects the following:

- A correspondence between construction and shape of dust particles and the differing forms of dust cake structure,
- Differences in the penetration processes of dust particles inside fabric filter structures, and
- Different effects of electrostatic forces.

Because they are of interest, the results, obtained by similar research performed by I.P.W.M.B. on unseparated dusts and dust concentration C = 30 g/m^3, are shown in Table 5 (and are plotted in Figures A-35 through A-58).

Table 5. FILTRATION RESISTANCE (in mm H_2O) FOR UNSEPARATED DUSTS (Dust concentration of C = 30 g/m^3 and L = 300 g/m^2)

Gas loading of filtration area $m^3/m^2/hr$	Kind of dust	Kind of fabric			
		ET-4	ET-30	F-tor 5	PT-15
60	Cement	12	20	20	26
	Coal	13	17	--	20
80	Cement	25	42	40	56
	Coal	22	29	--	--
120	Cement	45	84	78	100
	Coal	36	66	--	79

In the case of unseparated dusts with particles of similar size (Table 2, MMD = ca. 20 μm), an increased effect of the kind of fabric on filtration resistance was noted. Higher filtration resistance occurred in cement dusts. Filtration efficiency, following gas loading, is charted by type of fabric and of dust in Figures A-19 through A-34. For comparison with similar effects for unseparated dusts, the results of the I.P.W.M.B. tests are shown in Figures A-47 through A-58.

Considering the effects on filtration efficiency of types of dust and of fabrics in any given filtration situation, it was noted that:

- For all combinations of dusts and fabrics, with dust loads of 400 g/m^2 and 700 g/m^2, increases in gas loading corresponded to decreases in filtration efficiency.
- With dust loading of 100 g/m^2, increases in gas loading corresponded to increased filtration efficiency (very small, about 0.1%) for the following combinations:
  ET-30 and cement dust
  PT-15 and cement and coal dusts.

- For fabric F-tor 5 with coal dust load of 100 g/m^2, gas loading at 80 m^3/m^2/hour resulted in a minimum level of filtration efficiency.
- Fabric ET-4 in combination with both cement and coal dusts showed changes in filtration efficiency to be closely related to changes in gas loading, starting from gas load of 80 m^3/m^2/hour. Also noted for this fabric was dust cake breaking and the formation of ducts/canals (see Figures A-27, A-31, A-53 and A-57).
- Decreased filtration efficiency at gas loadings of 60 m^3/m^2/minute for some combinations of dusts and fabrics was probably related to the continuance of the filtration process after cessation of dust feeding (for Dust Filtration Type I), which would have an evident effect on the mean recorded filtration efficiency.

NOTE: Observed abnormalities of the filtration efficiency process during gas loading were verified by second measurements, under the same conditions, producing the same recorded values.

Special changes in filtration efficiency occurred with gas loading of 100 g/m^2 for the combination of fabric F-tor 5 with separated coal dust. These changes were also observed for the combination of fabrics PT-15 and ET-30 with unseparated cement dust. This phenomenon is probably caused by electrostatic effects. During the process of dust layering, the filtration efficiency of all fabrics, except fabric ET-4, increased. In the case of fabric ET-4, filtration efficiency decreased rapidly because of ducts/canals; this can be seen even with a gas loading of 400 g/m^2.

By applying the formula $\eta = f(L)$, it was possible to select the most advantageous gas loading for any given condition of the test. Table 6 shows optimum gas loadings established by the results of this test program.

Table 6. OPTIMUM GAS LOADING OF FABRICS

Fabric	Optimum gas loading, q_g $m^3/m^2/hour$	
	Cement dust	Coal dust
ET-4	80	60
ET-30	120	60
F-tor 5	60	60
PT-15	120	80

These are optimum gas loadings for Dust Filtration Type I. Large-scale testing under Dust Filtration Type III will use fabrics containing residual dust so that optimum gas loadings may be different.

A full analysis of the results will be prepared following large-scale testing and investigation of electrostatic effects.

CONCLUSIONS

- Laboratory testing was of flat fabric specimens under Dust Filtration Type I (unused fabric with no residual dust and no cleaning).
- Though not applicable to Dust Filtration Type III (industrial-scale) testing, Type I test results provide knowledge of particular filtration mechanisms.
- Abnormalities in the $\eta = f(q_g)$ function are caused by electrostatic effects.

SECTION V

BASIC RESEARCH ON A MODEL FOR DUST FILTRATION

INTRODUCTION

Classic filtration theory, first developed by Langmuir, was later expanded to include various filtration media and processes in order to determine optimum filtration structures (fiber filters) for high-efficiency atmospheric air filtration where dust concentration is low (corresponding to real dust concentrations in atmospheric air of from 0.005 to 20/30 mg/m^3). The basic physical model was of an isolated elemental fiber placed in a stream of continuously flowing gas. Observing the flow of gas past the isolated fiber, the following basic mechanisms were identified as indicators of the efficiency of the filtration process:

- Interception,
- Inertial contact, and
- Diffusion.

Further studies, taking into consideration interferential effects (e.g., the influences of adjacent fibers and of aerosol poly-dispersion) indicated other filtration mechanisms, such as electrostatic forces, thermophoresis, etc.

The derivation of empirical or semiempirical equations suitable for aplication to industrial operations necessitated simplications (e.g., omission of some of the filtration mechanisms). Thus, some of the results were of limited applicability.

For organizing both theoretical and experimental studies of air filtration with fiber filters, two types of filtration are defined:

- Stationary filtration, which includes all processes taking place between the dust particles and the clean filtration structure; and

- Nonstationary filtration, which includes those processes occurring between the filtration structure and the "settled" adjacent dust particles.

Stationary filtration is the first phase of the complete filtration process. Nonstationary filtration occurs subsequently when the filtration structure is filled with dust particles. The lower the dust concentration in the dispersed medium, the longer the duration of fiber utilization and the longer the duration of the stationary filtration phase.

For dust filtration, conditions are quite different. In dust filtration, there is a much greater particle concentration (50 to 60 g/m^3), with variation in shape and in physical and chemical properties often present. The construction of the spatial structure of the filtration media is another very important differentiation between air and dust filtration processes. Generally, a pure filtration medium structure is not a characteristic of the dust filtration process; rather the structure becomes filled with dust.

It is difficult to classify portions of the dust filtration process solely as to the occurrence and duration of stationary or nonstationary filtration phases. It is possible, however, to identify distinct stages in the complete process. These are designated as Dust Filtration Types I, II, and III, as depicted in Figure A-60.

Dust Filtration Type I

This is the initial phase of the complete process, when the fabric first begins operation as a filtration medium. This phase ends when the pressure drop characterizing the dust-to-fabric ratio reaches a predetermined level. This phase includes:

- Stationary filtration during the initial capture of dust particles (corresponding to classic filtration theory),
- Nonstationary filtration when the fabric structure is being filled, and

- "Ductive" filtration when the dust cake is being formed and as it becomes a filter layer for successive impinging dust particles.

Dust Filtration Type II

This second phase continues until the fabric is fully filled with dust (i.e., a stabilized quantity of residual dust remains in the fabric structure after its regeneration).

The duration of Dust Filtration Type II depends on the properties of both dust and fabric and on the intensity of regeneration. This phase includes:

- Nonstationary filtration,
- "Ductive" filtration.

Dust Filtration Type III

This phase occurs when a stable level of filling of the fabric by dust has been reached and when the pressure drop returns to a constant level during regenerations. As for Dust Filtration Type II, this phase includes:

- Nonstationary filtration,
- "Ductive" filtration.

But Type III differs from Type II in that Type II lasts until the fabric structure is filled with dust to a predetermined amount functionally related to the pressure drop; Type III occurs thereafter.

Particular phases of the dust filtration process correspond to predetermined values in the dust-fabric ratio for:

- Pressure drop,
- Quantity of dust.

The following conditions are postulated:

- Pure fabric structure is characterized by

ΔP, where q_g = constant, $q_p = 0$, and $L = 0$.
where ΔP is the pressure drop for a stated static gas loading of q_g and dust loading $q_p = 0$
L = grams dust/m^2 of fabric.

NOTE: In textile technology, an equivalent parameter is used, such as permeability, which is defined by air flow intensity (which affects pressure drop).

- A fully filled structure is one bearing a certain amount of dust, accumulated during the filtration process or retained during regeneration but which is without a dust cake. This is characterized by:

  ΔP_N, where q_g = constant, q_p = constant, and $L = L_N$, the characteristic value for fabric filled with dust.

- A structure covered with dust is a fully filled structure with a dust cake on its working face. This is described as:

  ΔP_k, where q_g = constant, q_p = constant, $L_p = L_o = L_N + L_p$ = g/m^2 of dust cake, and L_o = the characteristic value for filtration structure covered with dust;

  $L_o = L_N + L_p$.

A pure structure characterizes the condition of the nonworking face of the filter before the onset of Dust Filtration Type I. A built-up structure characterizes the end of nonstationary filtration and the duration of "ductive" filtration during Dust Filtration Type III.

All the intermediate stages of Dust Filtration Types I and II need additional characteristic values, as, for example, L_{NR} = built-up fabric after regeneration.

For describing all these intermediate stages during experimentation and to facilitate comparison of test results, the concept of "fabric-filling" (with dust) is set forth according to:

$$\beta_i = \frac{L_i}{L_N}$$

where L_N = fabric filling for a given regeneration schedule (Dust Filtration Type III),

L_i = fabric filling at point i during Dust Filtration Types I and II,

β_i = fabric filling amount for cycle i.

These definitions and characterizations of the dust filtration process have particular physical significance and can provide means for rational selection of experimental materials.

From a practical point of view, the most important dust filtration type is Type III, under which the parameters determine hydraulic characteristics and dust removal efficiency.

STUDY OF FILTER MEDIUM PARAMETERS

Introduction

Fabrics exhibit both spatial and superficial features of their structure. These features result from the method of fabric manufacture, generally a weaving of fill threads into the longitudinal warp threads. The result is a spatial structure of the intersections of fill and warp threads. Differences between fill and warp threads and in the configuration of the weaving distinguish one weave from another and one type of fabrics from another.

Fabrics are manufactured from:

- Natural fibers such as wool and cotton;
- Synthetic fibers such as elane, torlen, etc.;
- Inorganic fibers such as glass;, and
- Metallic fibers.

A single fiber has a distinctive length, diameter, surface structure, etc., all of which are important to basic filtration mechanisms. It should be noted that when considering fiber structure, individual properties of the fiber can cause unexpected effects in the filtration process.

From a technical point of view, the characteristic parameters of fabric are:

- The yarn count,[see ASTM D 1907], which determines the linear density of the thread

$$N_m = \frac{n \times ln}{m}$$

where n = number of weighed threads,
ln = length of thread (straight),
m = mass of weighed threads.

- Density of warp and fill as determined by the number of threads along the warp and the fill.
- Weave, which defines the way the threads are crossed.

These parameters affect the thickness of the fabric, its weight, strength, elasticity, etc.

Additionally, the following structural parameters can be specified:

- Relative packing of warp and fill,
- Superficial packing of yarns,
- Degree of packing of yarn within the fabric,
- Thickness of fabric,
- Porosity of fabric,
- Measurement of open (interstitial) area, and
- Observed volume of fabric.

It should be noted that the structure of filtration fabrics is sufficiently variable that it is difficult to arrive at a standard classification for all structures or even to compare one with another.

The main purpose of this project is to define structural parameters and to correlate them to technological parameters. For that reason, initial efforts concentrated on investigating clean air flows through various fabric structures.

Fabric Selection

The following Polish fabrics were selected for study:

- Natural fiber fabrics:
  - Wool: WT-201, WT-202, WT-203, WT-207
  - Cotton: BT-57, BWA-1539
  - Wool/Cotton: WBT-208, WBT-210.
- Synthetic fiber fabrics:
  - Polyester: ET-1, ET-2, ET-3, ET-4, ET-30.
- Inorganic fiber fabrics:
  - Glass: ST-1, ST-13, ST-41.

Figures A-61 through A-70 are illustrations of the superficial structures and sections across warp and fill for fabrics representative of those listed above.

Equipment and Procedures

The study of a clean air flow through selected fabric structures was performed for low and high values of gas loading. Measurements were taken using the equipment described in Appendixes B-F.

For greater accuracy, the ASUKANIA micromanometer was used for low-value air flow testing. The results of 30 measurement tests are shown in Figures A-71 through A-100. Detailed protocols of these tests will be included in the final report. The resultant definitions of structural parameters of tested fabrics (using Polish standards) are shown in Tables 7 through 10 (at the end of this section).

Results and Discussion

The testing of air flow through pure filtration structures for high values

of gas loading, with application of $\Delta P = f(q_g) = f(v)$(where v = average velocity of the air flow before reaching the filtration structure), proved the parabolic character of the function.

Also studied, on the basis of empirical data, was the variation in flow velocity for particular classes of pressure drop, by application of the λ KOLMOGOROW test. After reduction of the variations measured, it was proven that velocity variation is statistically normal, with a confidence level of 0.01.

This fact substantiates the claim that an air flow through fabric is a composite process, with a definite density function. An appropriate mathematical explanation will be presented later (as part of the report on the second phase of this project) because of its size. Further studies in this area will be based on a large amount of statistical data (from additional testing) pertinent to the following problems:

- Functional dependences for particular kinds of fabric,
- An analogy for structural measurements in the air flow process,
- Correlation of technological and functional parameters of the structure to its physical parameters.

Under high gas loading, changes of pressure drop, as a function of flow velocity, indicate turbulent air flow through the filtration medium structure. Under low gas loading, $\Delta P = f(v)$ curves are almost linear, indicating a different type of air flow.

Conclusions

- The flow of clean air through a filtration fabric structure is a stochastic process.
- In certain values of pressure drop, variations in air flow velocity (measured in front of the fabric structure) are normally distributed.
- Air flows differ under low and high gas loading values, having differing definite physical aspects from the point of view of spatial structure.

Table 7. STRUCTURAL PARAMETERS OF WOOL FIBER FABRICS

PARAMETER		KIND OF FABRIC			
		WT-201	WT-202	WT-203	WT-207
1		2	3	4	5
Count of yarn	Nmo	6.0335	7.9713	11.2913	6.7016
		5.9619	8.6168	10.6126	6.9662
		5.9416	8.3543	9.9406	6.9459
		6.4465	7.9475		7.4919
Average		6.0950	8.2224	10.6148	7.0264
	Nmw	6.0432	9.4694	11.5705	9.5156
		6.4622	9.7966	10.7549	9.8639
		5.4574	9.9045	9.7087	9.0570
		5.8286	10.9660		10.2812
Average		5.9479	10.0341	10.6780	9.6794
Proportion between warp count of yarn and fill count of yarn		0.9984	0.8419	0.9759	0.7043
		0.4226	0.8797	0.9868	0.7062
		1.0887	0.8435	1.0239	0.7669
	Nmo/Nmw	1.1060	0.7247		0.7287
Average		0.9039	0.8225	0.9955	0.7265

Table 7 (continued)

1		2	3	4	5
Number of threads on 10 cm	no	124	179	196	170
		124	179	195	171
		121	177	176	171
		120	176		173
Average		122	178	189	171
	nw	95	154	177	165
		95	155	173	168
		94	157	153	161
		96	159		167
Average		95	156	168	165
Yarn density (no/nw)		1.3053	1.1623	1.1073	1.0303
		1.3053	1.1419	1.1272	1.0179
		1.2872	1.1274	1.1503	1.0621
		1.2500	1.0069		1.0359
Average		1.2870	1.1096	1.1283	1.0366
Relative warp and fill packing	Zo	68.66	86.23	79.33	89.30
		69.06	82.94	81.40	88.12
		67.50	83.29	75.91	88.26
		64.28	84.91		85.96
Average		67.38	84.34	78.88	87.91

Table 7 (continued)

1		2	3	4	5
Relative warp and fill packing	Zw	52.56	68.07	70.76	72.74
		50.83	67.35	71.73	72.74
		54.73	67.85	66.78	72.77
		54.08	65.29		70.82
Average		53.05	67.14	69.76	72.27
Superficial packing with yarn	Zt	85.13	95.60	93.96	97.08
		84.75	94.43	94.74	99.76
		85.29	94.63	92.00	96.80
		83.60	94.76		95.90
Average		84.69	94.86	93.57	97.39
Complete packing of yarn in fabric	Eo	102.97	125.79	118.52	126.78
		102.23	121.85	121.82	125.80
		102.72	121.53	114.31	126.92
		98.08	121.03	118.22	122.66
Average		101.50	122.55	118.22	125.54
	Ew	78.87	105.17	99.73	116.06
		77.28	103.25	107.84	116.04
		80.93	104.79	106.58	114.32
		77.79	103.64		112.32
Average		78.82	104.21	104.72	114.69

Table 7 (continued)

1		2	3	4	5
Distance between axis of threads	lo	0.8064	0.5586	0.5102	0.5882
		0.8064	0.5586	0.5128	0.5848
		0.8264	0.5650	0.5682	0.5848
		0.8333	0.5682		0.5780
Average		0.8181	0.5626	0.5304	0.5840
	lw	1.0526	0.6493	0.5650	0.6061
		1.0526	0.6452	0.5780	0.5952
		1.0638	0.6369	0.6536	0.6211
		1.0417	0.5682		0.5988
Average		1.0527	0.6249	0.5989	0.6053
Diameter of yarns	do	0.5537	0.4817	0.4048	0.5253
		0.5569	0.4634	0.4174	0.5153
		0.5578	0.4706	0.4313	0.5161
		0.5356	0.4824		0.4969
Average		0.5512	0.4745	0.4178	0.5134
	dw	0.5533	0.4420	0.3998	0.4408
		0.5360	0.4345	0.4146	0.4330
		0.5822	0.4321	0.4364	0.4520
		0.5634	0.4106		0.4241
Average		0.5587	0.4298	0.4169	0.4375

Table 7 (continued)

1		2	3	4	5
Length and width inside FA between threads	ko	0.2527	0.0769	0.1054	0.0629
		0.2494	0.0852	0.0954	0.0695
		0.2686	0.0944	0.1369	0.0687
		0.2877	0.0858		0.0811
Average		0.2646	0.0856	0.1126	0.0706
	kw	0.4993	0.2073	0.1652	0.1653
		0.5173	0.2707	0.1634	0.1622
		0.4816	0.2048	0.2172	0.1691
		0.4783	0.2183		0.1747
Average		0.4941	0.2253	0.1819	0.1678
Free area		0.1262	0.0159	0.0174	0.0104
		0.1291	0.0201	0.0156	0.0113
		0.1293	0.0193	0.0297	0.0116
		0.1424	0.0187		0.0142
Average		0.1318	0.0185	0.0209	0.0119
Free area for 100 cm^2		14.87	4.40	6.04	2.92
		15.22	5.57	5.26	3.24
		14.72	5.37	8.01	3.20
		16.40	5.24		4.10
Average		15.30	5.15	6.44	3.37

Table 7 (continued)

1	2	3	4	5
Thickness of fabric in millimeters	1.41 1.61 1.47 1.56	1.48 1.50 1.47 1.46	1.46 1.48 1.49	1.54 1.56 1.60 1.51
Average	1.51	1.48	1.48	1.55
Porosity of fabric (by mercury)	54.75 56.55 54.89 55.91		84.37 84.33 84.58	81.00 80.30 80.46 81.81
Average	55.53		84.43	80.89
Apparent specific volume of fabric 100 g/cm^2	3.63	2.48	3.50	3.43
50 g/cm^2	4.384	3.551	4.64	4.094
Proportion of warp and fill plaiting	0.54 0.58 0.52 0.60	0.72 0.72 0.75 0.81	0.48 0.47 0.86	0.97 0.97 1.00 0.94
Average	0.56	0.75	0.60	0.97

Table 8. STRUCTURAL PARAMETERS OF COTTON FIBER FABRICS

PARAMETER		KIND OF FABRIC			
		BT-47	BWA-1539	WBT-208	WBT-210
1		2	3	4	5
Count of yarn	Nmo	6.4191	30.4000	16.7251	28.0976
		6.1299	33.5962	17.3094	25.5213
		6.0999	33.9936	17.7294	28.1565
		5.9573	28.8108	17.8849	27.1990
					23.5457
					23.8865
					24.9655
Average		6.1516	31.7002	17.4122	25.9103
	Nmw	6.3506	29.4086	8.1086	12.4784
		6.4935	27.5757	6.7595	12.2585
		6.1982	25.7970	8.1710	11.8907
		6.1918	26.9458	7.4271	11.5486
					12.0617
					11.6877
					11.9916
Average		6.3085	27.6818	7.6166	11.9882

Table 8 (Continued)

1	2	3	4	5
Proportion between warp count of yarn and fill count of yarn Nmo/Nmw	1.0108 0.9440 0.9841 0.9631	1.0337 1.2183 1.2686 1.0692	2.0631 2.5608 2.1698 2.4081	2.2517 2.0819 2.3688 2.5552 1.9521 2.0437 2.0819
Average	0.9755	1.1475	2.3005	2.1908
Number of threads on 10 cm				
no	122 120 122 122	371 371 372 376	224 224 216 216	168 193 183 186 187 183 184
Average	122	373	220	183
nw	107 108 108 106	216 215 218 220	164 158 164 162	280 270 254 258 246 288 277
Average	107	217	162	267

Table 8 (Continued)

1		2	3	4	5
Yarn density	no/nw	1.1402	1.7176	1.3659	0.6000
		1.1111	1.7256	1.4172	0.6655
		1.1296	1.7064	1.3171	0.7291
		1.1509	1.7091	1.3333	0.7209
					0.7602
					0.6352
					0.6643
Average		1.1330	1.7147	1.3583	0.6836
Relative warp and fill packing	Zo	60.18	84.10	68.46	39.71
		60.58	80.01	67.31	47.75
		61.74	79.76	64.13	43.82
		62.47	87.55	63.83	44.57
					48.18
					46.81
					43.03
Average		61.24	82.86	65.93	44.84
	Zw	53.07	49.79	78.34	107.61
		52.98	51.18	82.65	112.65
		54.22	52.64	78.01	99.00
		53.25	52.98	80.85	103.26
					96.33
					114.56
					106.82
Average		53.38	51.65	79.96	105.75

Table 8 (Continued)

1		2	3	4	5
Superficial packing with yarn	Zt	81.31	92.02	93.17	104.60
		81.47	90.24	94.33	106.61
		82.49	90.42	92.11	99.44
		82.46	94.15	93.07	101.81
					98.10
					107.75
					103.68
Average		81.93	99.71	93.17	103.14
Complete packing of yarn in fabric	Eo	90.44	118.33	121.96	71.93
		90.02	115.36	127.05	85.24
		92.38	115.68	115.50	80.51
		93.12	115.68	117.72	81.79
					84.80
					83.20
					82.14
Average		91.49	116.26	120.56	81.37
	Ew	79.49	69.37	103.41	140.83
		80.25	69.72	106.79	148.55
		81.50	71.32	102.37	128.56
		80.40	71.32	104.79	134.16
					128.02
					151.35
					141.23
Average		80.40	75.03	104.34	138.96

Table 8 (Continued)

1		2	3	4	5
Distance between axis of threads	lo	0.8197	0.2695	0.4464	0.5952
		0.8333	0.2695	0.4464	0.5181
		0.8197	0.2688	0.4630	0.5376
		0.8197	0.2659	0.4630	0.5376
					0.5347
					0.5464
					0.5435
Average		0.8231	0.2684	0.4547	0.5447
	lw	0.9346	0.4630	0.6097	0.3571
		0.9259	0.4651	0.6329	0.3448
		0.9259	0.4587	0.6097	0.3984
		0.9434	0.4545	0.6173	0.3876
					0.4065
					0.3472
					0.3676
Average		0.9325	0.4603	0.6174	0.3727
Diameter of yarns	do	0.4933	0.2267	0.3056	0.2358
		0.5048	0.2157	0.3056	0.2474
		0.5061	0.2144	0.2969	0.2356
		0.5121	0.2329	0.2955	0.2396
					0.2576
					0.2558
					0.2501
Average		0.5041	0.2224	0.3009	0.2460

Table 8 (Continued)

1		2	3	4	5
Diameter of yarn	dw	0.4960	0.2305	0.4777	0.3850
		0.4906	0.2380	0.5231	0.3885
		0.5020	0.2414	0.4757	0.3944
		0.5024	0.2408	0.4991	0.4002
					0.3916
					0.3978
					0.3927
Average		0.4978	0.2377	0.4939	0.3929
Length and width inside FA between threads	ko	0.3264	0.0428	0.1408	
		0.3285	0.0538	0.1408	0.3020
		0.3136	0.0544	0.1661	
		0.3076	0.0330	0.1675	0.2771
Average		0.3190	0.0460	0.1538	0.2896
	kw	0.4386	0.2325	0.1320	0.0040
		0.4353	0.2271	0.1098	
		0.4329	0.2173	0.1340	0.0149
		0.4410	0.2137	0.1182	
Average		0.4347	0.2770	0.1233	0.0095

Table 8 (Continued)

1	2	3	4	5
Free area	0.1432	0.0099	0.0186	
	0.1420	0.0122	0.0155	0.0012
	0.1320	0.0118	0.0223	
	0.1356	0.0070	0.0198	0.0041
Average	0.1387	0.0102	0.0191	0.0027
Free area for 100 cm^2	18.69	7.98	6.83	0.57
	18.54	9.75	5.47	
	17.52	9.59	7.84	1.90
	17.54	5.84	6.93	
Average	18.07	8.29	6.77	1.24
Thickness of fabric in millimeters	1.09	0.50	1.48	
	1.06	0.51	1.49	1.08
	1.07	0.49	1.50	1.10
	1.08	0.52	1.53	1.10
				1.08
				1.09
				1.09
Average	1.08	0.51	1.50	1.09

Table 8 (Continued)

1	2	3	4	5
Porosity of fabric (by mercury)	73.83 73.11 76.16 76.24	75.55 76.32 77.71 75.85	83.51 83.40 83.36 83.37 83.06	82.20 80.82 79.40 80.64 84.06
Average	74.84	76.11	83.34	81.42
Apparent specific volume of fabric 100 g/cm^2	2.39	2.18	3.45	3.56
50 g/cm^2	2.419	2.486	4.043	4.601
Proportion of warp and fill plaiting	1.03 1.23 1.15 1.05	0.68 0.71 0.67 0.70	0.82 0.79 0.79 0.77	0.61 0.48 0.87 0.76 1.16 0.73 0.57
Average	1.12	0.69	0.79	0.74

Table 9. STRUCTURAL PARAMETERS OF POLYESTER FIBER FABRICS

PARAMETER		KIND OF FABRIC				
		ET-1	ET-2	ET-3	ET-4	ET-30
1		2	3	4	5	6
Count of year	Nmo	9.4897	10.6249	9.7466	11.4172	24.0044
		9.7401	10.9467	10.0348	10.8564	21.4031
		9.8546	10.5413	9.3603	11.2745	22.5833
		9.6558	10.7829	9.7118	11.0512	22.5727
Average		9.6558	10.7829	9.7118	11.0512	22.5727
	Nmw	5.0331	5.3376	5.1710	5.3791	22.7111
		5.0749	5.5390	4.5130	5.3791	22.7111
		5.9312	5.7394	4.7089	5.8032	22.9240
		5.3777	5.5221	5.1487	6.0520	21.9914
Average		5.3542	5.5345	5.8854	5.6092	22.7459
Proportion between warp count of yarn and fill count		1.8855	1.9906	1.8849	2.1225	1.0569
		1.8995	1.9763	2.2235	1.8708	0.0569
		1.6615	1.8367	1.9878	1.9428	0.9851
	Nmo/Nmw	1.7923	1.9954	1.8851	1.7609	1.0140
Average		1.8097	1.9498	1.9953	1.9243	0.9931

Table 9 (continued)

1		2	3	4	5	6
Number of threads on 10 cm	no	185	183	212	177	246
		200	184	220	176	246
		196	182	212	176	248
		186	184	201	176	249
Average		192	183	211	176	247
	nw	141	96	124	124	278
		141	93	124	120	276
		140	95	125	124	276
		139	94	125	125	278
Average		141	95	125	123	277
Yarn density	no/nw	1.312	1.9063	1.7097	1.4274	0.8849
		1.4184	1.9785	1.7742	1.4667	0.8913
		1.4000	1.9158	1.6960	1.4194	0.8986
		1.3381	1.9574	1.6080	1.4080	0.8957
Average		1.3671	1.9395	1.6969	1.4304	0.8926
Relative warp and fill packing	Zo	81.69	76.34	92.35	71.24	68.28
		87.60	75.62	94.44	72.64	72.32
		84.92	76.23	94.22	71.28	71.43
		81.47	75.40	87.76	73.33	71.72
Average		83.92	75.90	92.19	72.12	70.94

Table 9 (continued)

1		2	3	4	5	6
Relative warp and fill packing	Zw	85.54	56.52	74.16	72.72	79.33
		85.11	53.75	79.40	71.55	77.67
		78.19	53.92	78.34	70.00	80.61
		81.52	54.40	74.92	69.10	80.61
Average		82.57	56.65	76.71	70.84	79.56
Superficial packing with yarn	Zt	97.34	89.71	98.02	92.16	93.44
		98.15	88.73	98.86	92.22	93.82
		96.71	89.05	98.86	91.38	94.46
		96.58	88.78	96.93	91.76	94.52
Average		97.20	89.07	98.18	91.88	94.06
Complete packing of yarn in fabric	Eo	137.75	130.22	155.75	123.13	91.66
		147.96	128.79	164.90	125.10	95.40
		139.64	127.89	160.64	120.68	94.46
		136.00	128.64	148.00	121.98	95.78
Average		140.34	128.89	157.32	122.94	94.33
	Ew	115.59	76.54	101.18	97.67	105.03
		116.59	72.86	106.06	96.31	104.72
		108.51	73.82	106.11	95.11	105.48
		111.95	73.35	102.21	95.14	107.31
Average		113.26	74.14	103.89	96.06	105.64

Table 9 (continued)

1		2	3	4	5	6
Distance between axis of threads	lo	0.5405	0.5464	0.4717	0.5650	0.4065
		0.5000	0.5435	0.4545	0.5682	0.4065
		0.5102	0.5494	0.4717	0.5682	0.4032
		0.5376	0.5435	0.4975	0.5682	0.4016
Average		0.5221	0.5457	0.4739	0.5674	0.4045
	lw	0.7092	1.0417	0.8064	0.8064	0.3597
		0.7092	1.0753	0.8064	0.8333	0.3623
		0.7143	1.0523	0.8000	0.8064	0.3623
		0.7194	1.0638	0.8000	0.8000	0.3598
Average		0.7130	1.0583	0.8032	0.8115	0.3610
Diameter of yarns	do	0.4415	0.4172	0.4356	0.4025	0.2775
		0.4380	0.4110	0.4293	0.4127	0.2940
		0.4332	0.4188	0.4444	0.4050	0.2862
		0.4380	0.4098	0.4366	0.4167	0.2880
Average		0.4377	0.4142	0.4365	0.4092	0.2864
	dw	0.6061	0.5887	0.5981	0.5864	0.2853
		0.6036	0.5780	0.6403	0.5962	0.2814
		0.5585	0.5676	0.6267	0.5645	0.2840
		0.5864	0.5787	0.5994	0.5528	0.2900
Average		0.5887	0.5782	0.6161	0.5749	0.2852

Table 9 (continued)

1		2	3	4	5	6
Length and width inside FA between threads	ko	0.0990	0.1292	0.0361	0.1625	0.1290
		0.0620	0.1325	0.0252	0.1555	0.1125
		0.0770	0.1306	0.0273	0.1632	0.1170
		0.0996	0.1337	0.0609	0.1515	0.1136
Average		0.0844	0.1315	0.0374	0.1582	0.1180
	kw	0.1031	0.4530	0.2083	0.2200	0.0744
		0.1056	0.4973	0.1661	0.2371	0.0809
		0.1558	0.4850	0.1733	0.2419	0.0757
		0.1330	0.4851	0.2006	0.2472	0.0697
Average		0.1244	0.4801	0.1871	0.2366	0.0751
Free area		0.0102	0.0585	0.0357	0.0075	0.0096
		0.0065	0.0659	0.0369	0.0042	0.0091
		0.0120	0.0633	0.0395	0.0047	0.0089
		0.0132	0.0649	0.0374	0.0122	0.0079
Average		0.0105	0.0632	0.0374	0.0072	0.0089
Free area for 100 cm^2		2.66	10.29	1.98	7.85	6.56
		1.87	11.27	1.14	7.79	6.18
		3.29	10.96	1.25	8.62	6.27
		3.43	11.22	3.07	8.24	5.25
Average		2.81	10.94	1.86	8.13	6.07

Table 9 (continued)

1	2	3	4	5	6
Thickness of fabric in millimeters	1.44	0.84	1.44	0.91	0.62
	1.40	0.83	1.45	0.92	0.61
	1.35	0.82	1.42	0.94	0.62
	1.32	0.81	1.45	0.93	0.60
Average	1.38	0.83	1.44	0.93	0.61
Porosity of fabric (by mercury)	76.66	61.82	79.50	67.74	54.75
	76.06	60.60	79.66	65.84	54.89
	76.34	63.53	81.97	67.66	55.91
	75.32	63.04	79.97	66.64	54.24
Average	76.10	62.25	80.28	66.97	54.95
Apparent specific volume of fabric 100 g/cm^2	2.71	1.065	2.82	2.10	1.98
50 g/cm^2	3.059	0.901	4.14	2.14	1.913
Proportion of warp and fill plaiting	2.32	1.63	0.94	3.04	3.86
	1.81	1.39	0.94	3.44	3.61
	1.77	1.39	0.95	3.41	3.11
	1.79	1.425	0.96	3.21	3.07
Average	1.92	1.46	0.95	3.28	3.41

Table 10. STRUCTURAL PARAMETERS OF GLASS FIBER FABRICS

PARAMETER		KIND OF FABRIC		
		ST-1	ST-13	ST-41
1		2	3	4
Count of yarn	Nmo	7.5362	7.5398	7.5782
		7.6135	7.5636	7.6193
		7.6079	7.5695	7.5789
		7.7094	7.5228	8.3057
Average		7.6168	7.5489	7.7705
	Nmw	7.3200	7.4835	7.5173
		7.5787	7.5221	7.4642
		7.6400	7.6347	7.5844
		7.7599	7.3860	7.7862
Average		7.5747	7.5066	7.5880
Proportion between warp count of yarn and fill count of yarn		1.0295	1.0075	1.0081
		1.0046	1.0063	1.0208
		0.9958	0.9915	0.9993
	Nmo/Nmw	0.9935	1.0185	1.0667
Average		1.0059	1.0060	1.0237

Table 10 (continued)

1		2	3	4
Number of threads on 10 cm				
	no	239	363	244
		240	364	243
		239	364	242
		238	364	244
Average		238	364	243
	nw	110	159	151
		108	156	156
		108	154	150
		112	159	154
Average		110	157	153
Yarn density (no/nw)		2.1727	2.2830	1.6159
		2.2222	2.3330	1.5577
		2.2130	2.3636	1.1633
		2.1250	2.2893	1.5844
Average		2.1832	2.3172	1.4803
Relative warp and fill packing	Zo	61.38	94.48	62.48
		61.33	93.32	62.07
		61.09	93.28	61.97
		60.42	93.55	59.69
Average		61.06	93.66	61.55

Table 10 (continued)

1		2	3	4
Relative warp and fill packing	Zw	28.66 27.66 27.55 28.34	40.97 40.09 39.29 41.24	38.82 40.26 39.40 38.91
Average		28.05	40.40	39.35
Superficial packing with yarn	Zt	72.45 72.03 71.81 71.64	96.74 96.00 95.92 96.21	77.05 77.14 76.57 75.38
Average		71.98	96.22	76.54
Complete packing of yarn in fabric	Eo	92.51 92.04 91.58 90.53	139.95 140.12 139.73 138.95	93.85 93.41 92.96 90.52
Average		91.66	139.69	92.62
	Ew	42.79 41.46 41.35 42.56	61.39 60.09 59.03 61.68	58.16 60.17 57.60 57.75
Average		42.04	60.55	58.42

Table 10 (continued)

1		2	3	4
Distance between axis of threads	lo	0.4184	0.2755	0.4098
		0.4167	0.2747	0.4115
		0.4184	0.2747	0.4132
		0.4202	0.2747	0.4098
Average		0.4184	0.2749	0.4111
	lw	0.9091	0.6289	0.6622
		0.9259	0.6410	0.6410
		0.9259	0.6493	0.6667
		0.8928	0.6289	0.6493
Average		0.9134	0.6370	0.6548
Diameter of yarns	do	0.2568	0.2567	0.2561
		0.2555	0.2564	0.2554
		0.2556	0.2563	0.2561
		0.2539	0.2570	0.2446
Average		0.2555	0.2566	0.2531
	dw	0.2605	0.2577	0.2571
		0.2561	0.2570	0.2580
		0.2551	0.2551	0.2560
		0.2530	0.2594	0.2527
Average		0.2562	0.2573	0.2560

Table 10 (continued)

1		2	3	4
Length and width inside FA between threads	ko	0.1616	0.0188	0.1537
		0.1612	0.0183	0.1561
		0.1628	0.0184	0.1571
		0.1663	0.0177	0.1652
Average		0.1630	0.0183	0.1580
	kw	0.6486	0.3712	0.4051
		0.6698	0.3840	0.3830
		0.6708	0.2942	0.4707
		0.6398	0.3695	0.3966
Average		0.6573	0.3547	0.4139
Free area		0.1048	0.0070	0.0623
		0.1080	0.0070	0.0599
		0.1092	0.0072	0.0645
		0.1064	0.0065	0.0655
Average		0.1071	0.0069	0.0631
Free area for 100 cm^2		27.56	4.02	22.95
		27.98	4.00	22.67
		28.19	4.07	24.06
		28.36	3.79	24.62
Average		28.02	3.97	23.58

Table 10 (continued)

1		2	3	4
Thickness of fabric in millimeters		0.53 0.54 0.55 0.52	0.76 0.79 0.78 0.80	0.61 0.62 0.64 0.60
Average		0.54	0.78	0.62
Porosity of fabric (by mercury)		60.18 59.38 61.58 59.31	67.55 64.25 66.54 65.64	62.34 62.72 62.42 62.02
Average		60.11	66.00	62.38
Apparent specific volume of fabric	100 g/cm^2	1.19	1.13	1.15
	50 g/cm^2	0.903	1.115	1.02
Proportion of warp and fill plaiting		4.0 3.64 4.0 2.67	2.1 2.0 1.7 2.2	4.04 4.00 4.5 4.45
Average		3.58	2.0	4.25

STUDY OF DUST PARAMETERS

Introduction

Dusts have been characterized by various parameters depending upon the extent of data available. Investigation of the structure of a dust cake starts with its size distribution and shape--in other words, the parameters determining the mutual configuration of the particles. Size distribution has been presented mostly by a statistical distribution of the particles and the derivative quantity MMD.

From the dust filtration point of view, of paramount interest is a parameter for dust defining size distribution at two points:

- In suspension in front of the filtration medium surface; and
- In the dusty layer on the filtration structure's surface, with a correlation between these two sets of data.

Variations in a solid body have been linked to its specific surface. This is also true of initial studies on dust parameters which included identifying specific surfaces for selected dusts varying as to size distribution, shape, chemical properties, etc.

Equipment and Procedures

Four kinds of dust were studied for specific surfaces and other parameters linked to size distribution:

- cement,
- coal,
- hydrated lime,
- talc.

Particle size distribution of each of the tested dusts measured by use of the BAHCO centrifugal separator is shown in Figure A-101.

Identified were two sizes of specific surface, depending on this physical aspect:

- kinetics specific surface,
- stationary (static) specific surface.

The kinetics specific surface is the total external surface, including available pores in the particles. Measurement of kinetic specific surfaces has been accomplished by IPWMB using LEA-NURSE apparatus.

Identification of the stationary specific surface was done by the Establishment of Catalysis and Physics of Surface of the Polish Academy of Sciences in Cracow using the BET apparatus and argon or krypton (for hydrated lime) as an adsorbent.

Results and Discussion

Table 11 compares the weighted average of 15 measurements of specific surface sizes (stationary and kinetic), the fractional composition of the dust (MMD in μm), and the size of the d < 20 μm population.

Table 11. COMPARISION OF DUST PARAMETERS

Kind of Dust	Average value of static specific surface (in cm^2/g)	Average value of kinetic specific surface (in cm^2/g)	MMD (in μm)	Part of fraction less than 20 μm (in percent)
Cement	17840 ± 907	3411	32.0	ca 45
Coal	38642 ± 1660	3438	21	ca 48
Talc	37180 ± 3460	5374	12	ca 70
Hydrated Lime	104020 ± 3980	9319	9	ca 80

From these test results, it is noted that:

- Both stationary and kinetic specific surfaces have lowest values for cement dust and highest for hydrated lime;
- The average size of dust particles, MMD, is highest for cement dust and lowest for hydrated lime dust;
- Population of d < 20 μm is greatest for lime dust and least for cement dust.

Stationary specific surface is not strongly dependent on the particle size distribution for particles less than 20 μm in diameter. For example, coal dust and talc, with widely different particle size distributions, exhibit about the same stationary specific surface, but cement and talc exhibit different values for stationary specific surface. Kinetic specific surface correlates somewhat better with particle size distribution. Thus, the hypothesis is advanced that kinetic specific surface is a reliable indicator of particle size distribution in the range below 20 μm.

Conclusions

- Kinetic specific surface is the best parameter for defining size distribution as characterized by the below-20 μm fraction;
- This hypothesis will be proven by later research.

STUDY OF ELECTROSTATIC PROPERTIES OF DUSTS AND FABRICS

Introduction

A literature search and our own research point to the very important role of electrostatic phenomena in the dust filtration process. As a part of work to develop a filtration model, further research must be undertaken in this area so as to fill the gaps in existing empirical information.

Initially under this project, the electrostatic properties of dusts and fabrics in a stationary condition were tested. Later, tests were conducted under the dynamic conditions of a dispersed medium flow. Experiments

were conducted by the Technical Physic of Wroclaw Polytechnic, managed by Dr. Anna Szaynok. The results of these experiments will be included in the report on the second phase of the project.

Dust Electrification

Dust electrification was measured by the Kunkel-Hansen method. The parameters defining the degree of dust cloud electrification are:

- Average charge,
- Standard deviation.

Average charge refers to the quantity of positive or negative charges within a given class of particles. The amount of electrification can be related to the standard deviation of the average charge. Investigation of dust electrification was conducted for nonfractionated dusts and also for the following fractions of dust:

° Cement dust:	0 - 1.7 μm
	1.7 - 2.94 μm
	2.94 - 5.95 μm
° Coal dust:	0 - 2.46 μm
	2.46 - 4.40 μm

Fractionation of the dust was done by the BAHCO centrifugal device. The measurements and separation were performed under laboratory conditions.

Specific Resistivity of Dusts

For unseparated dust samples, specific resistivity was measured between electrodes in a cylindrical chamber. Resistivity was measured under varying electric field intensities and with variable pressures exerted on the dust layer.

Specific Resistivity of Fabrics

Superficial specific resistivity and resistivity across the fabric were measured for the following types of fabrics:

- ET-4
- ET-30

- F-tor 5
- PT-15

Measurements were made in a specially designed set of electrodes. The method of measurement will be described in the report for the second phase of the project.

Discussion and Conclusions

- Measurements of the electrification of unseparated cement dust showed that for the particle size distribution of 4.8 to 8.5 μm, there was a greater number of negative charges (q = ca. 23 e), and the electrification was σ = ca. 70 e. For unseparated coal dust with particle size distribution of 8.60 to 13.0 μm, there was a greater number of positive charges (q = ca. 30 e.), and the electrification was σ ca. 350 e.
- The dependence of the charge of particles on the diameters (within the test range of measurement) is linear for both positive and negative charges.
- Electrification of coal dust is less than that for fractionated cement dusts, probably because of the effect of mechanical separation and the electro insulation properties of the particles.
- Resistivity of dust layers at 105° C temperature is different for dried and undried layers. That of dry dust layers increased (on the average of two magnitudes), suggesting high electrical conductivity of the moisture in undried dusts.
- Resistivity decreased nonlinearly when the intensity of the electrical field was increased.
- Resistivity also decreased nonlinearly with an increase in pressure between electrodes. This function reached a minimum at pressures within the experimental ranged.
- For all fabrics tested, changes in resistivity measured through the fabric were observed with changes in the intensity of the electric field.
- The dependence of fabric resistivity on pressure was clearly observed: as pressure increases, resistivity decreases.
- An influence on the superficial resistivity of fabrics by changes in the intensity of the electric field was not observed.

APPENDIX A

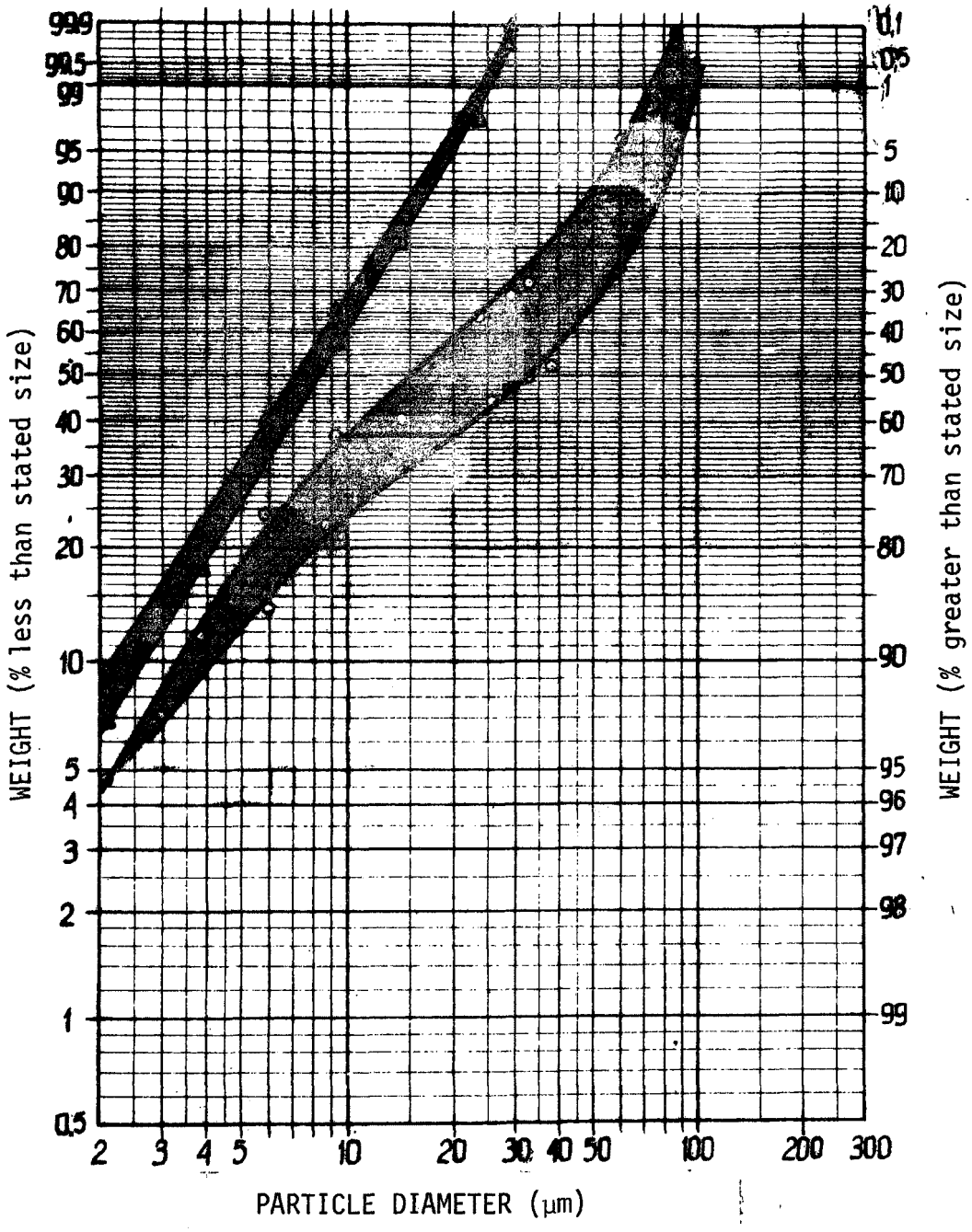


Figure A-1. Particle Size Distribution for Cement Dust (Δ - before separation; O - after separation).

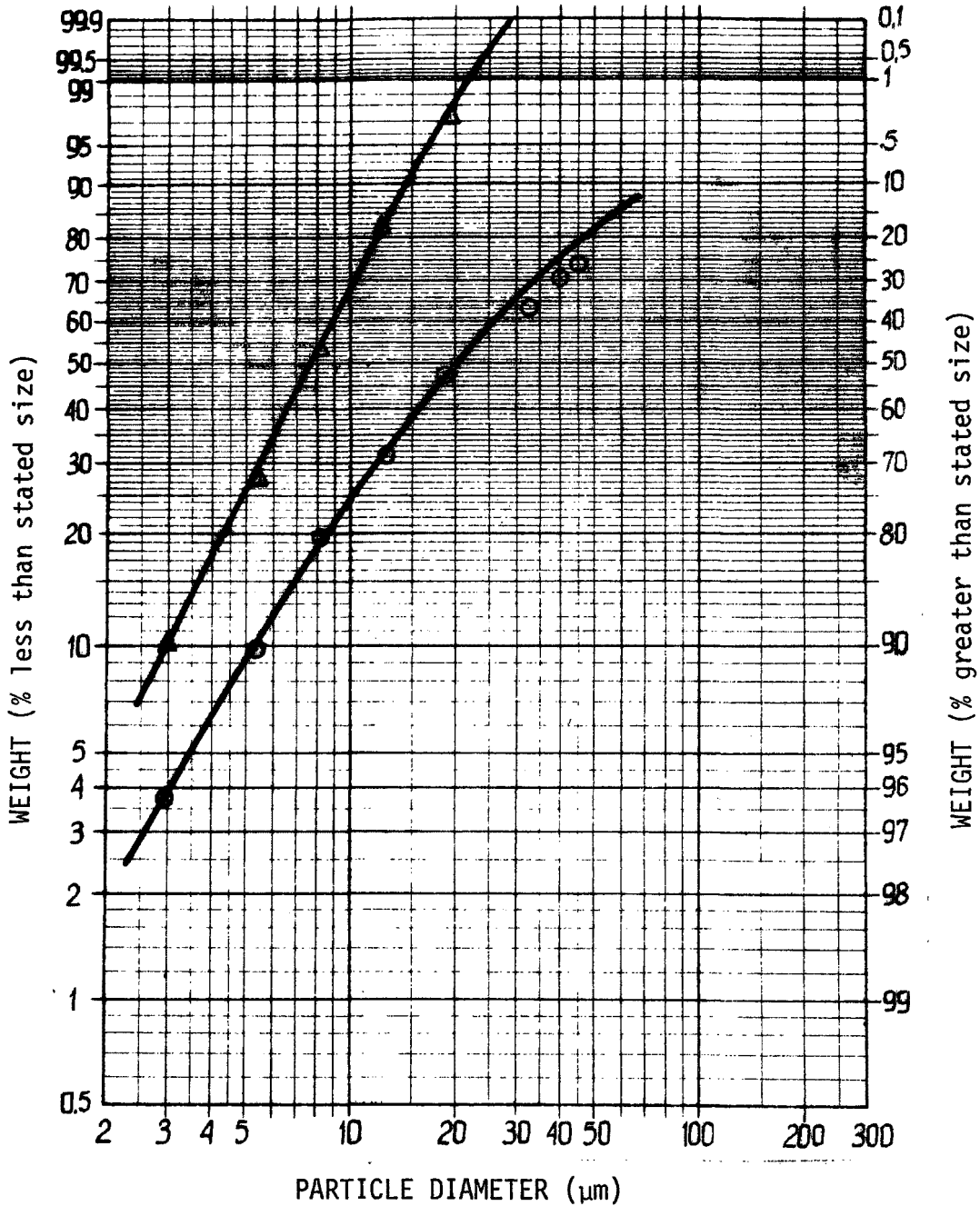


Figure A-2. Particle Size Distribution for Coal Dust (Δ - before separation, O - after separation).

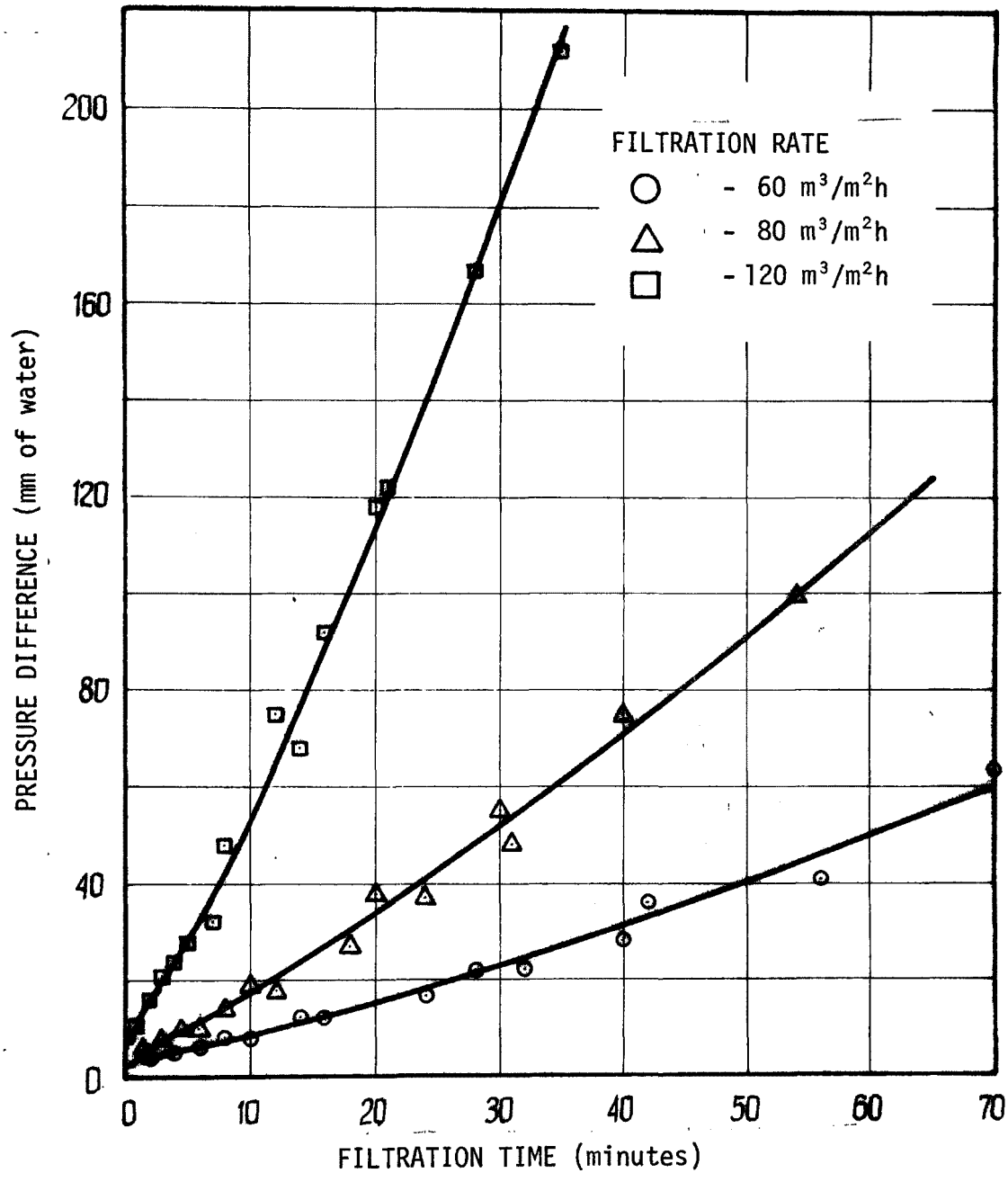


Figure A-3. Pressure Difference vs. Filtration Time for Cement Dust and Fabric ET-4 (separated dust).

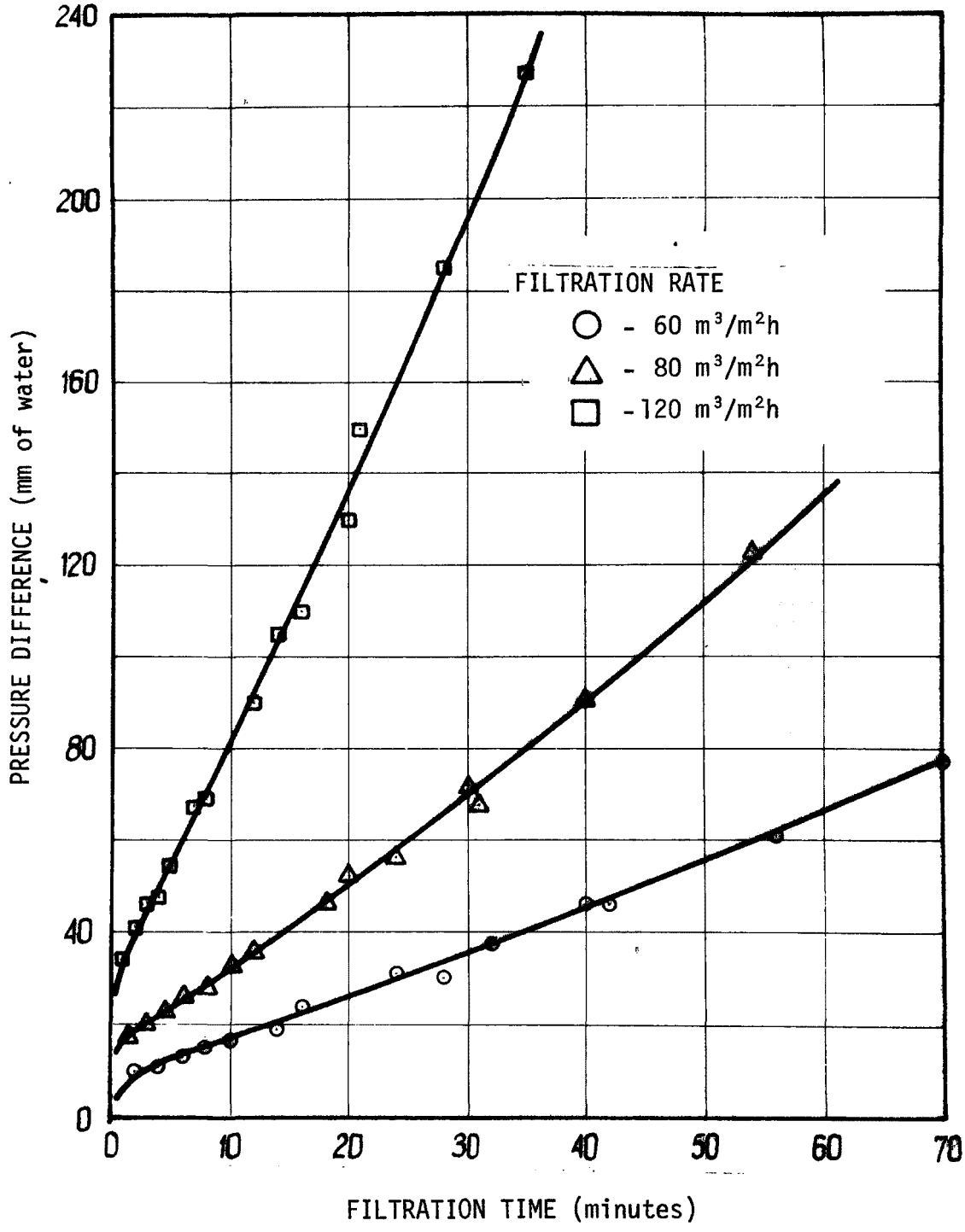


Figure A-4. Pressure Difference vs. Filtration Time for Cement Dust and Fabric ET-30 (separated dust).

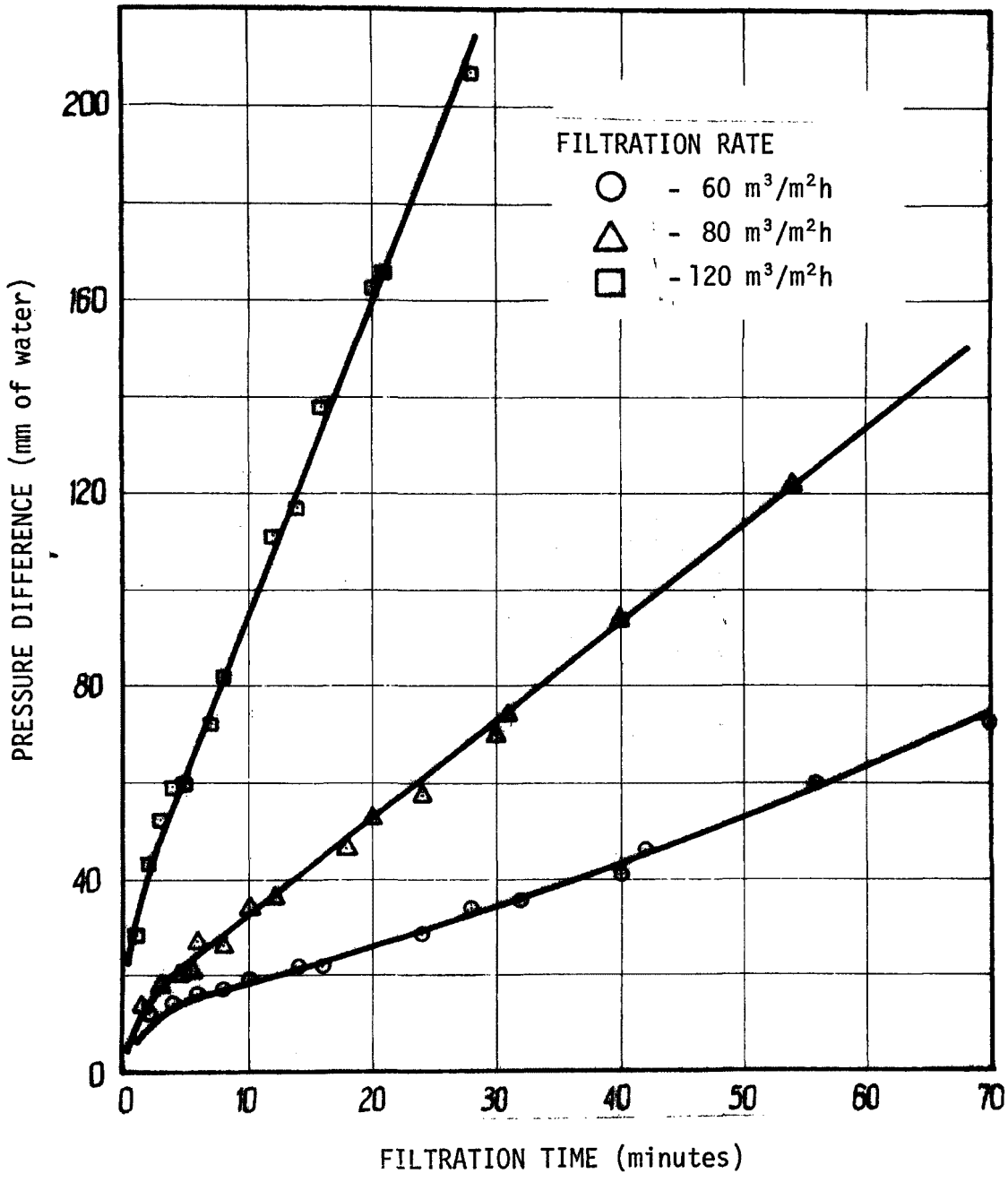


Figure A-5. Pressure Difference vs. Filtration Time for Cement Dust and Fabric F-tor-5 (separated dust).

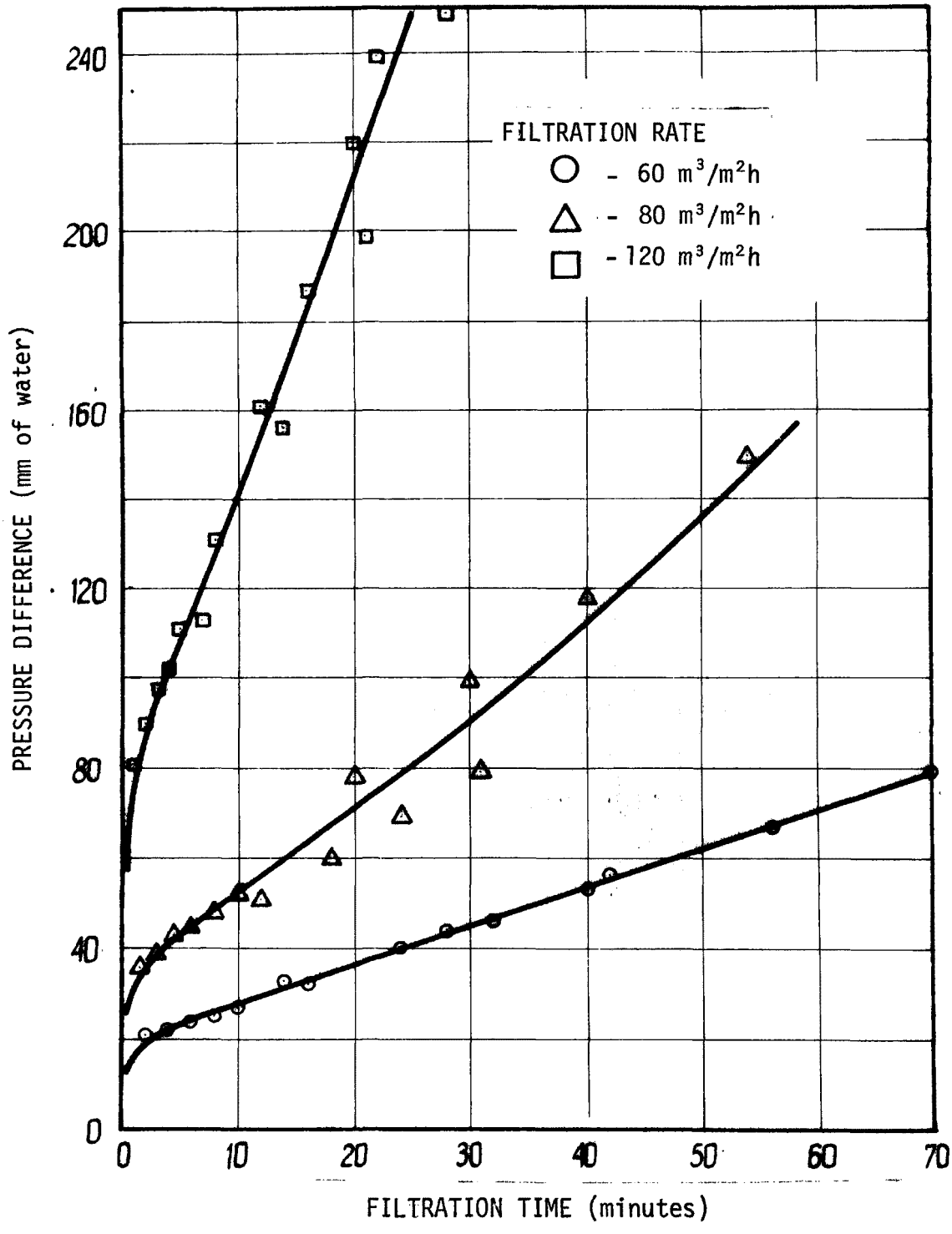


Figure A-6. Pressure Difference vs. Filtration Time for Cement Dust and Fabric PT-15 (separated dust).

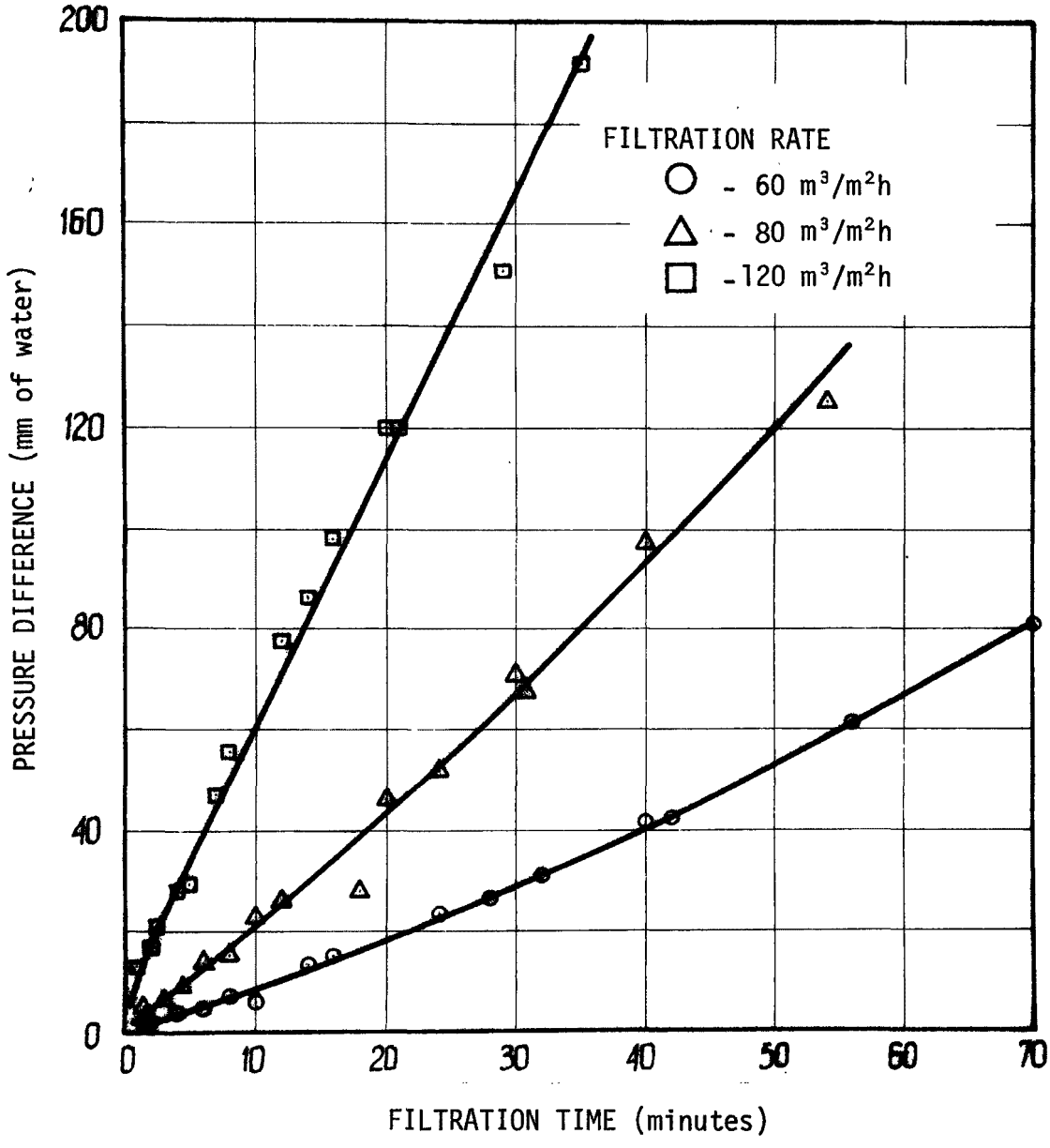


Figure A-7. Pressure Difference vs. Filtration Time for Coal Dust and Fabric ET-4 (separated dust).

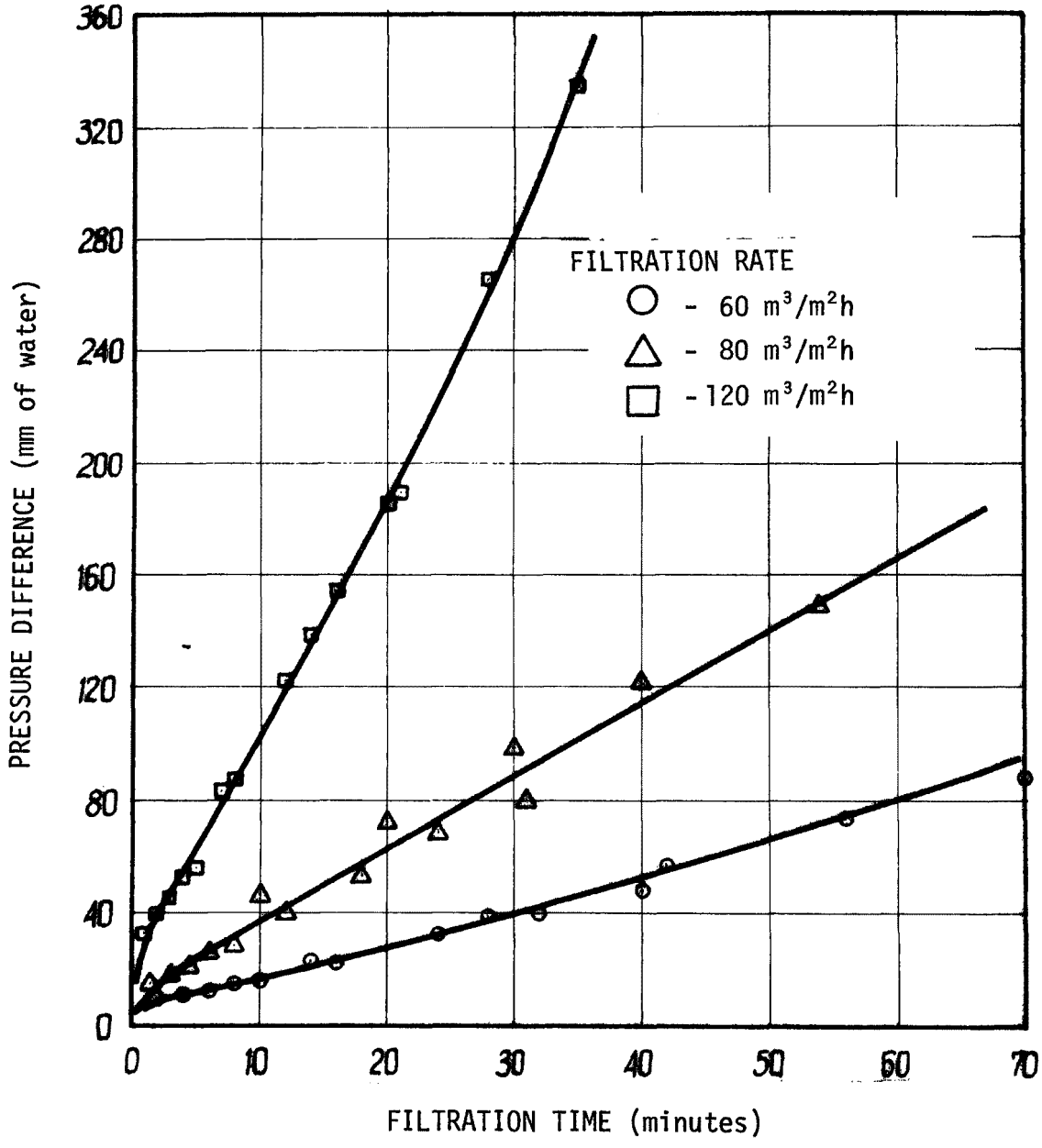


Figure A-8. Pressure Difference vs. Filtration Time for Coal Dust and Fabric ET-30 (separated dust).

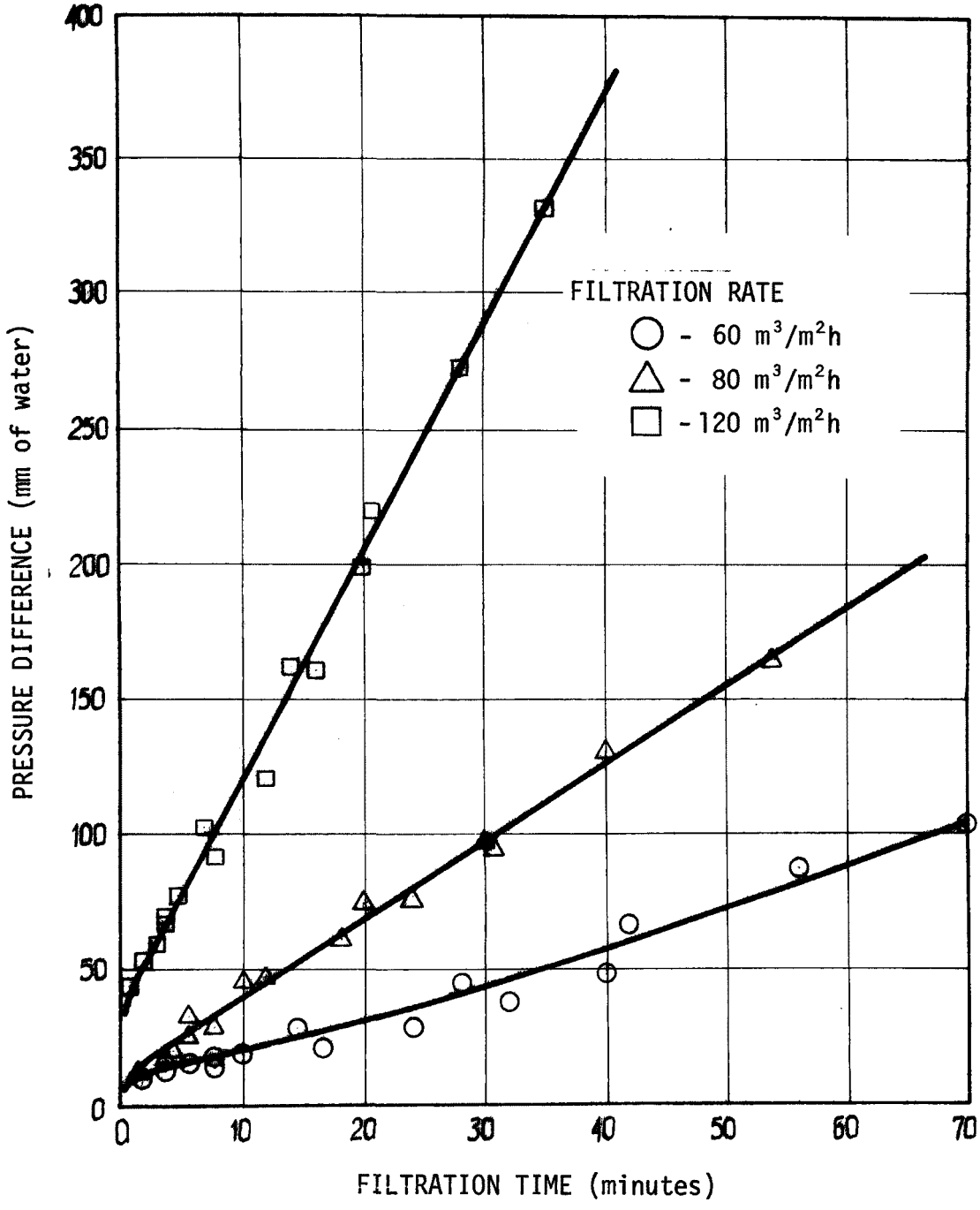


Figure A-9. Pressure Difference vs. Filtration Time for Coal Dust and Fabric F-tor-5 (separated dust).

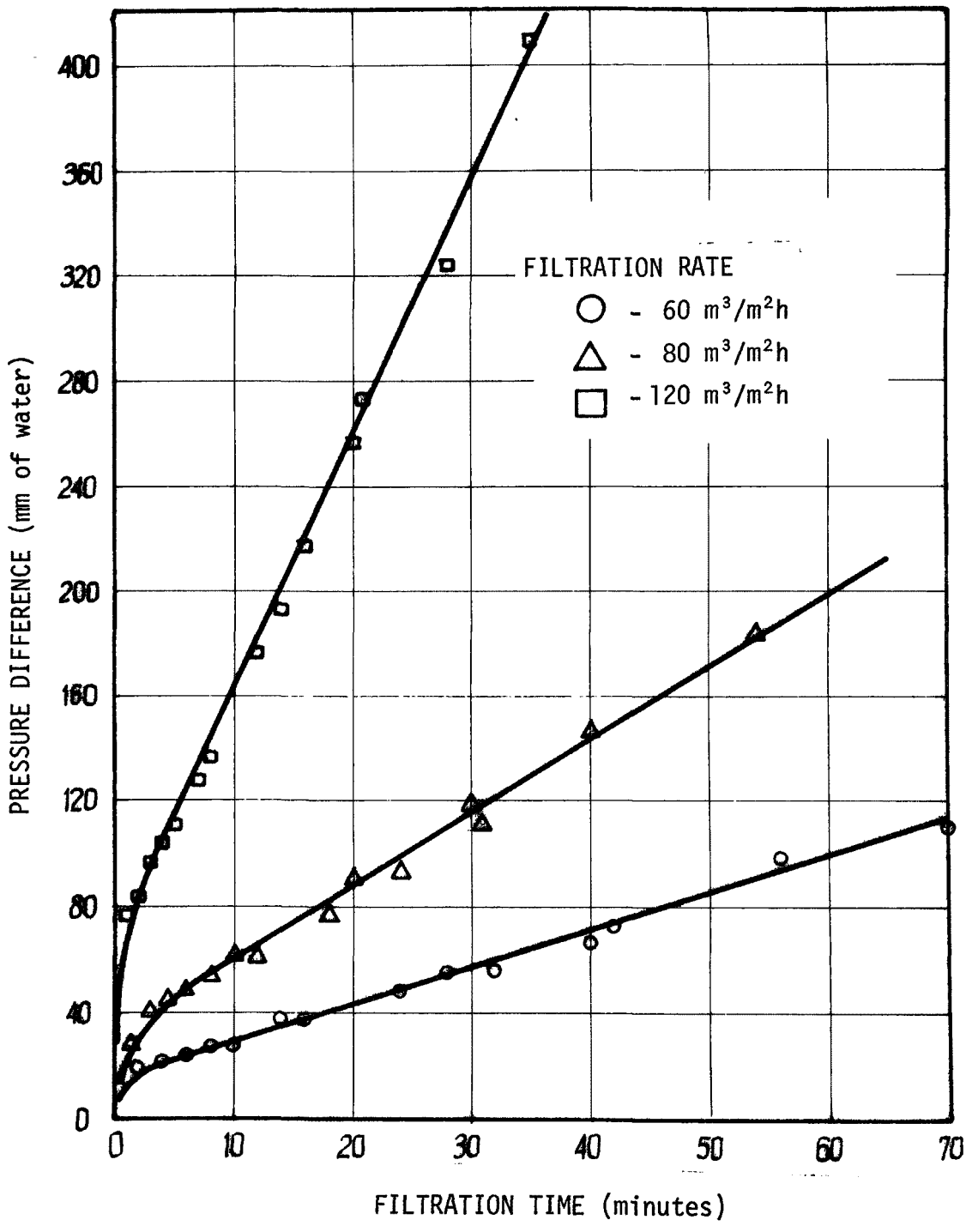


Figure A-10. Pressure Difference vs. Filtration Time for Coal Dust and Fabric PT-15 (separated dust).

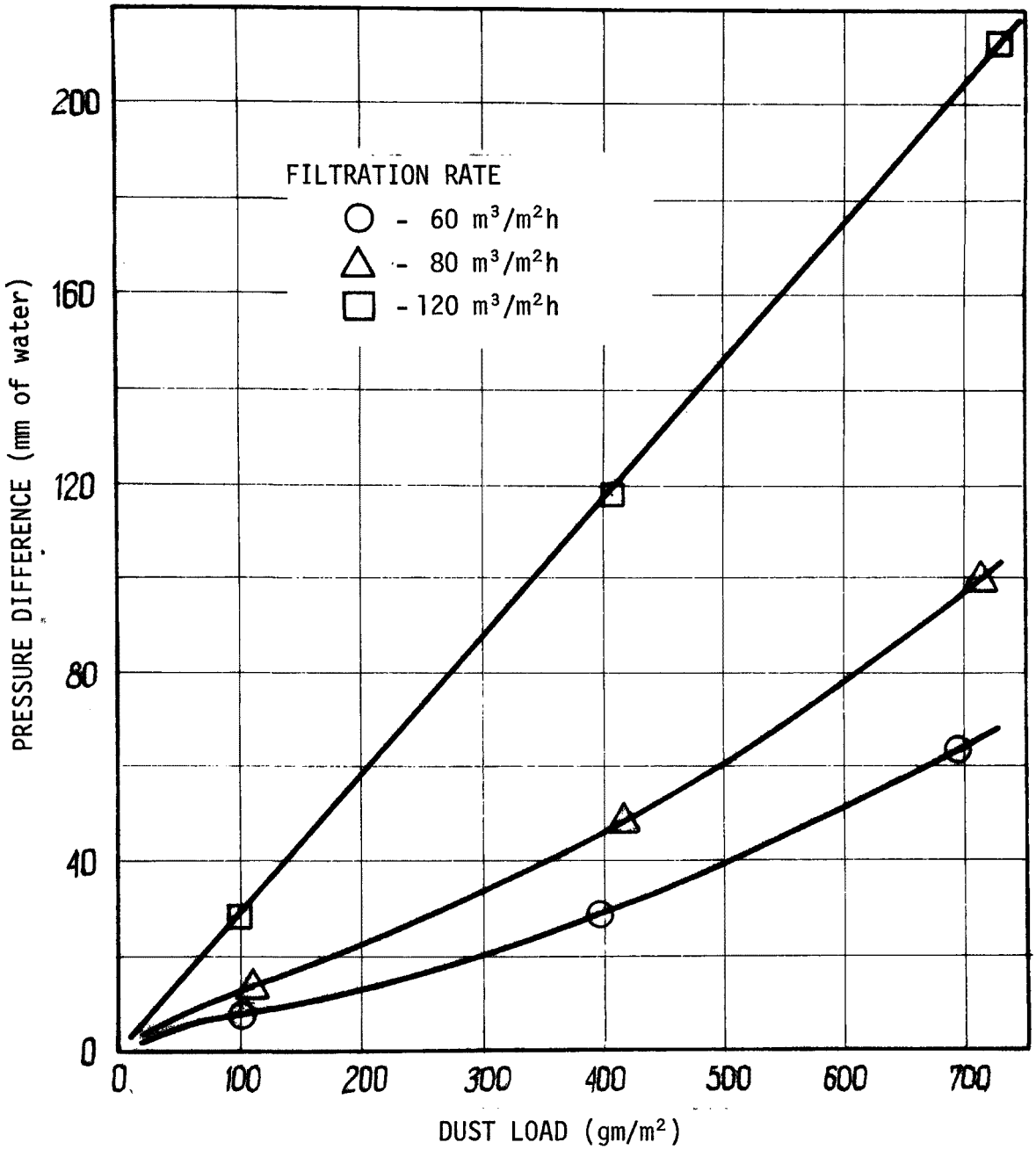


Figure A-11. Pressure Difference vs. Dust Load for Cement Dust and Fabric ET-4 (separated dust).

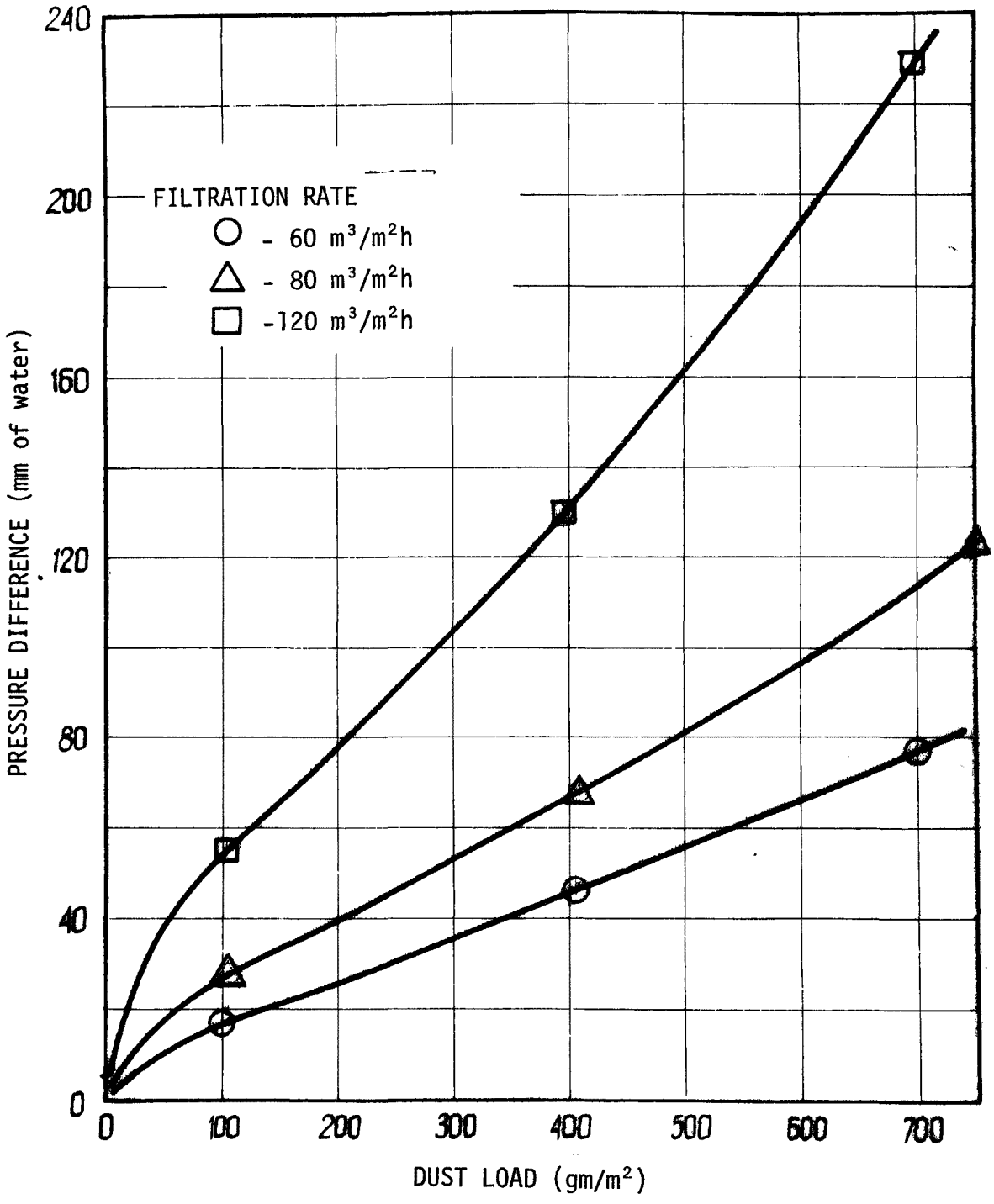


Figure A-12. Pressure Difference vs. Dust Load for Cement Dust and Fabric ET-30 (separated dust).

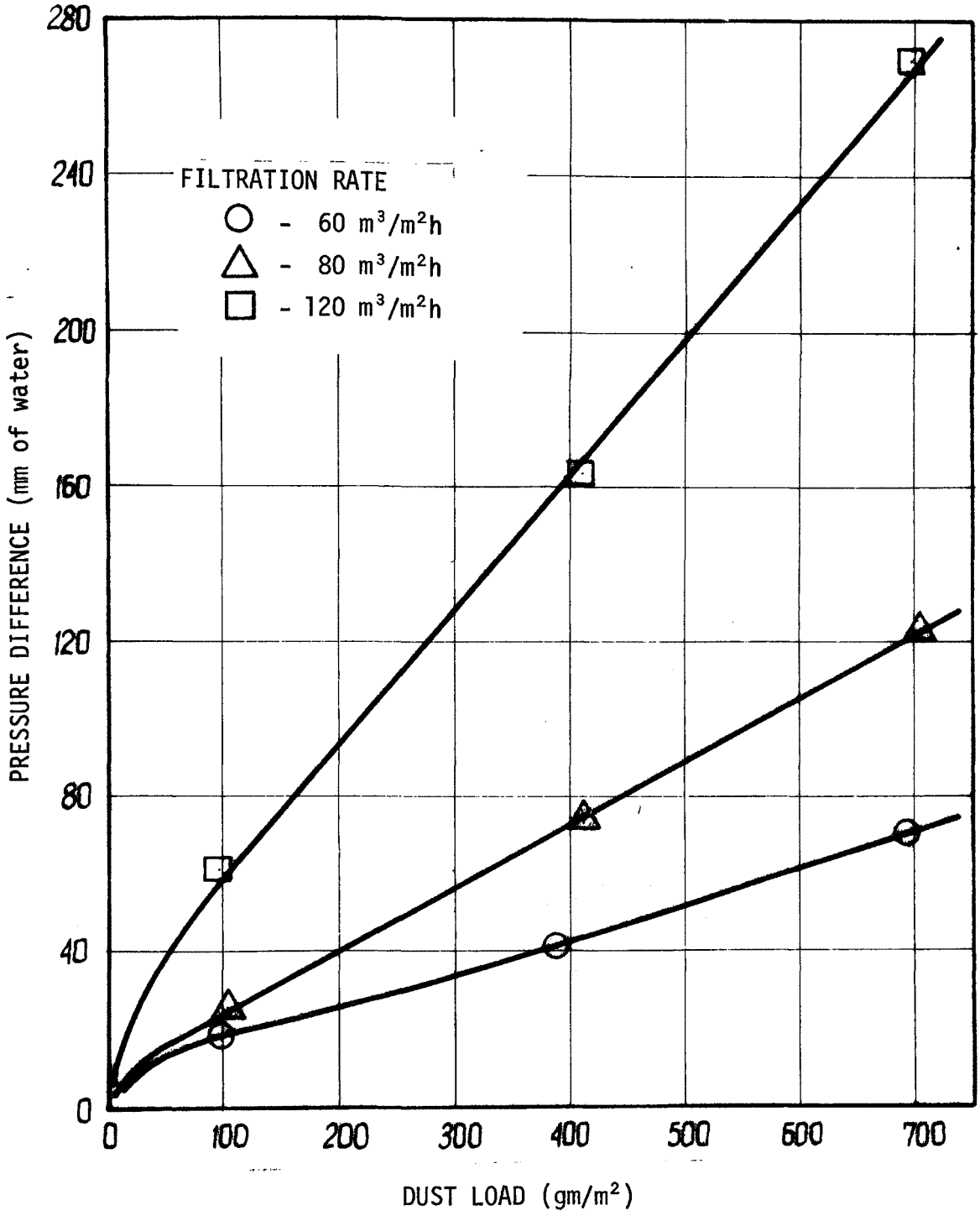


Figure A-13. Pressure Difference vs. Dust Load for Cement Dust and Fabric F-tor-5 (separated dust).

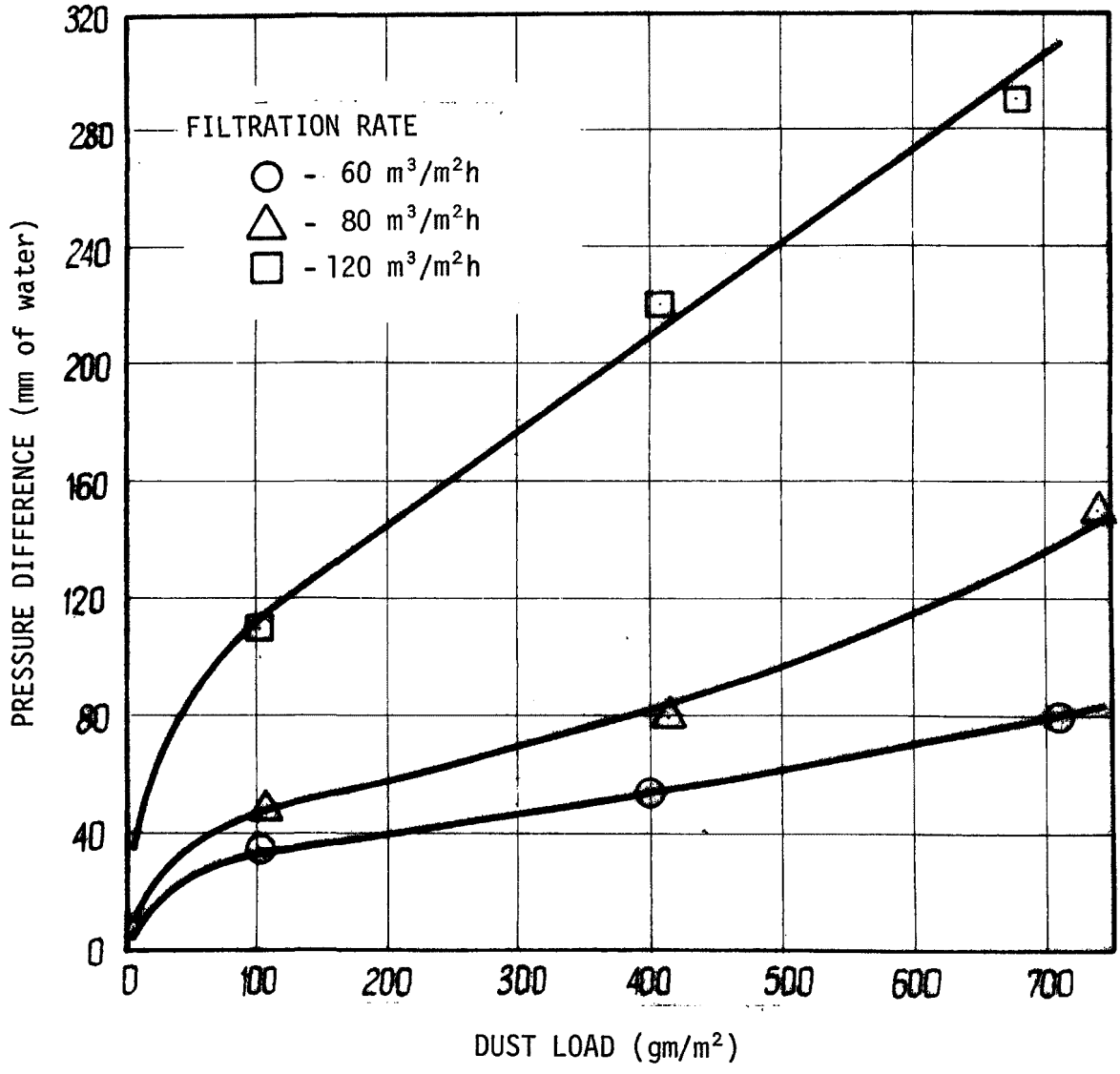


Figure A-14. Pressure Difference vs. Dust Load for Cement Dust and Fabric PT-15 (separated dust).

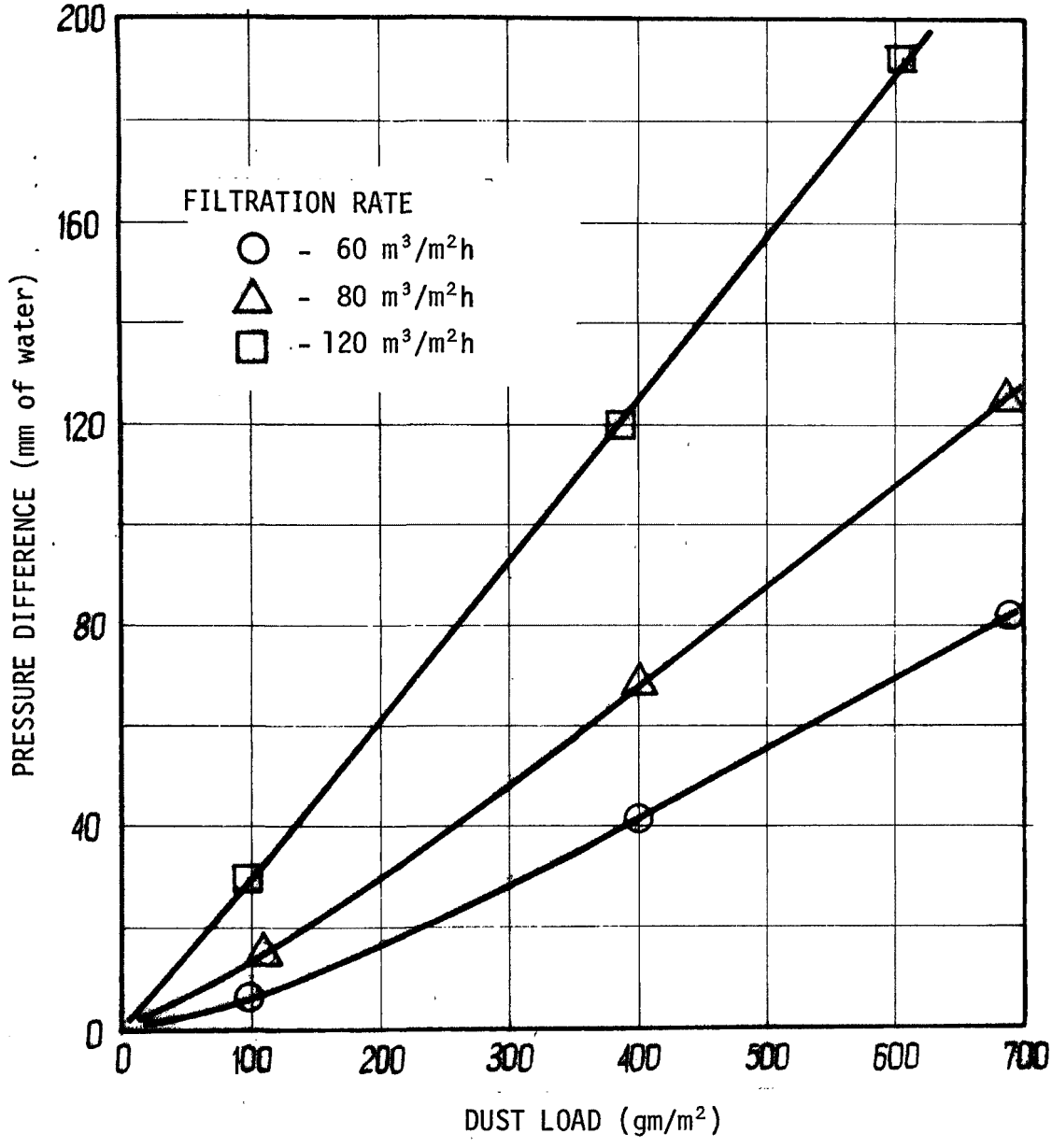


Figure A-15. Pressure Difference vs. Dust Load for Coal Dust and Fabric ET-4 (separated dust).

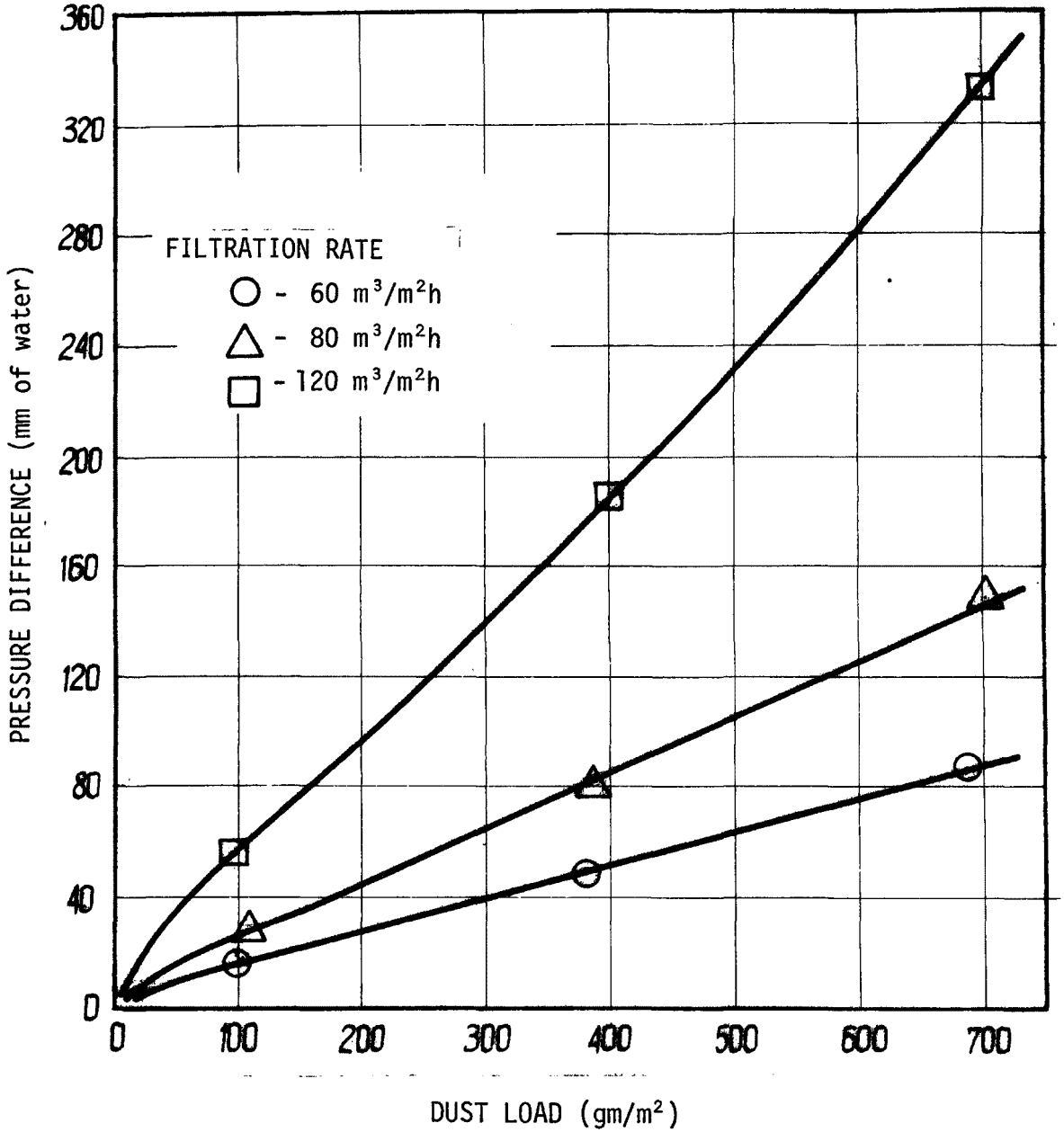


Figure A-16. Pressure Difference vs. Dust Load for Dust and Fabric ET-30 (separated dust).

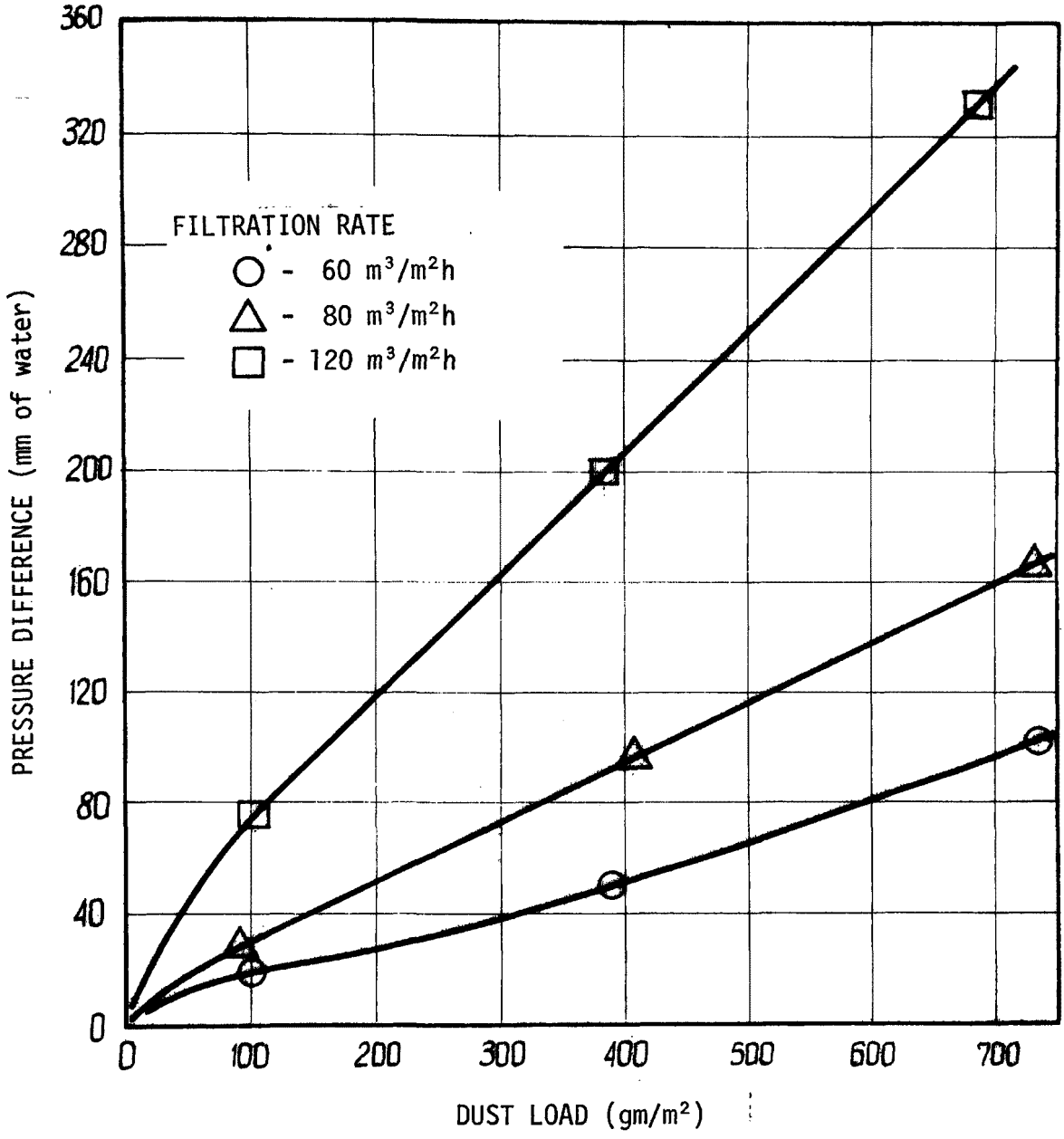


Figure A-17. Pressure Difference vs. Dust Load for Coal Dust and Fabric F-tor-5 (separated dust).

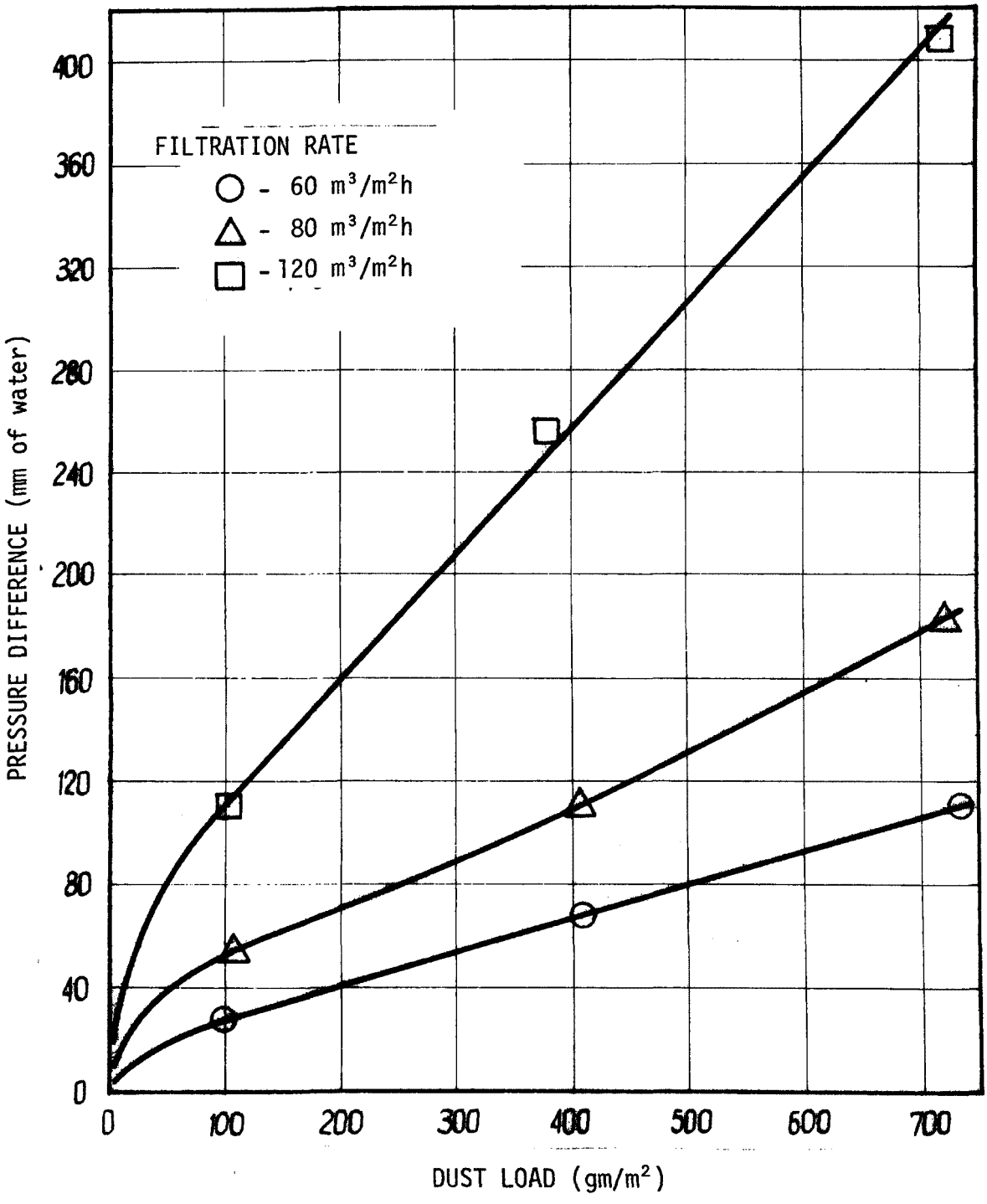


Figure A-18. Pressure Difference vs. Dust Load for Coal Dust and Fabric PT-15 (separated dust).

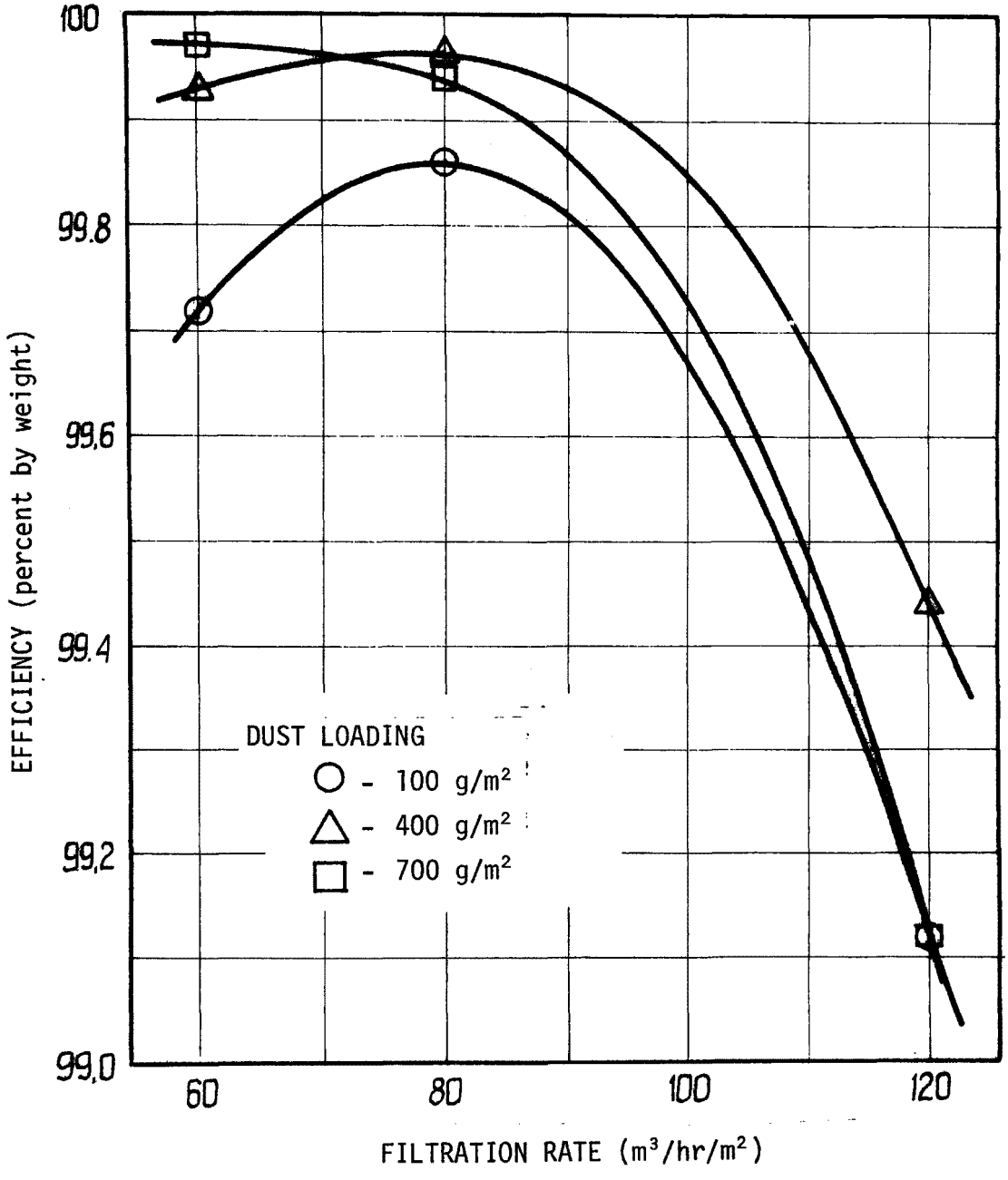


Figure A-19. Efficiency vs. Filtration Rate for Cement Dust and Fabric ET-4 (separated dust).

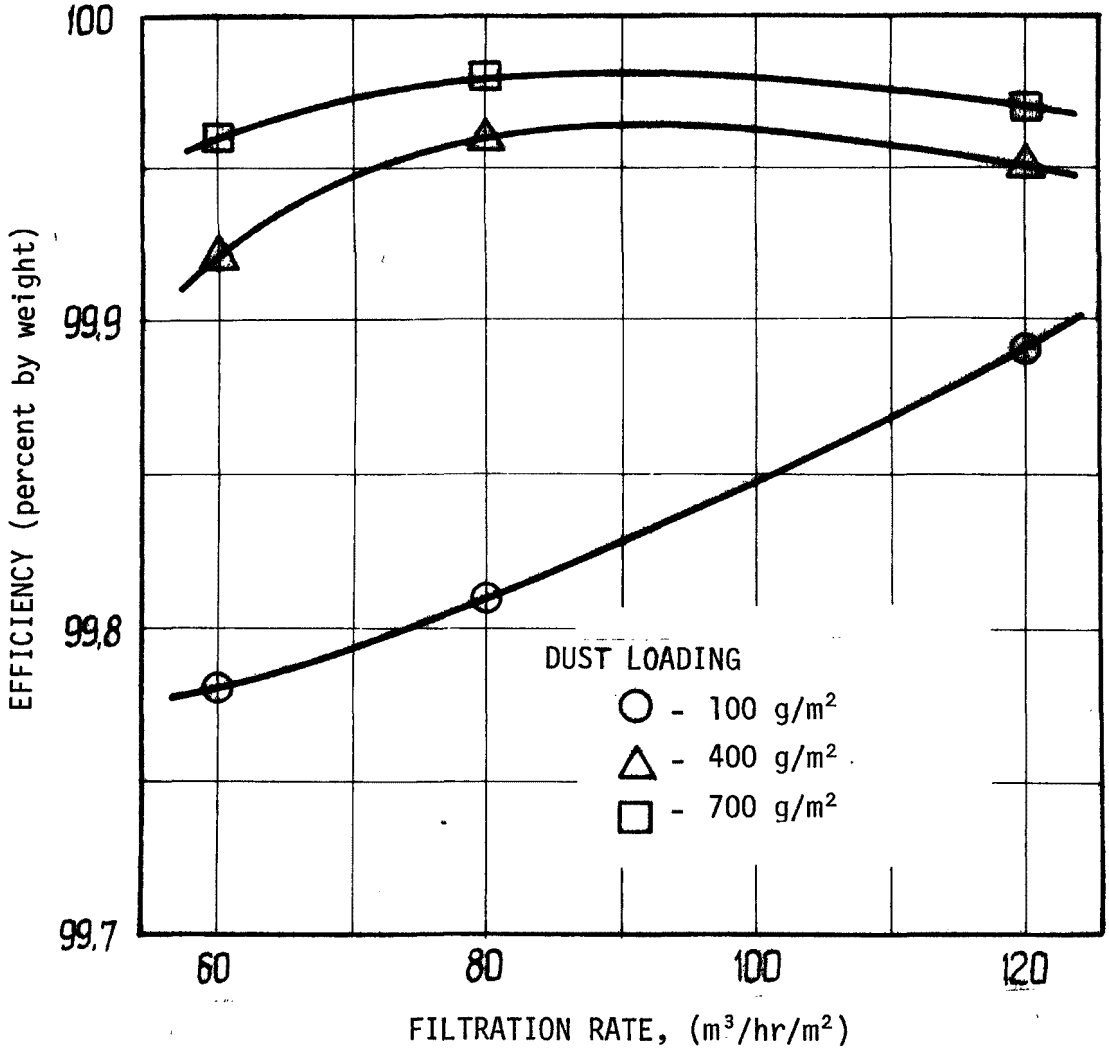


Figure A-20. Efficiency vs. Filtration Rate for Cement Dust and Fabric ET-30 (separated dust).

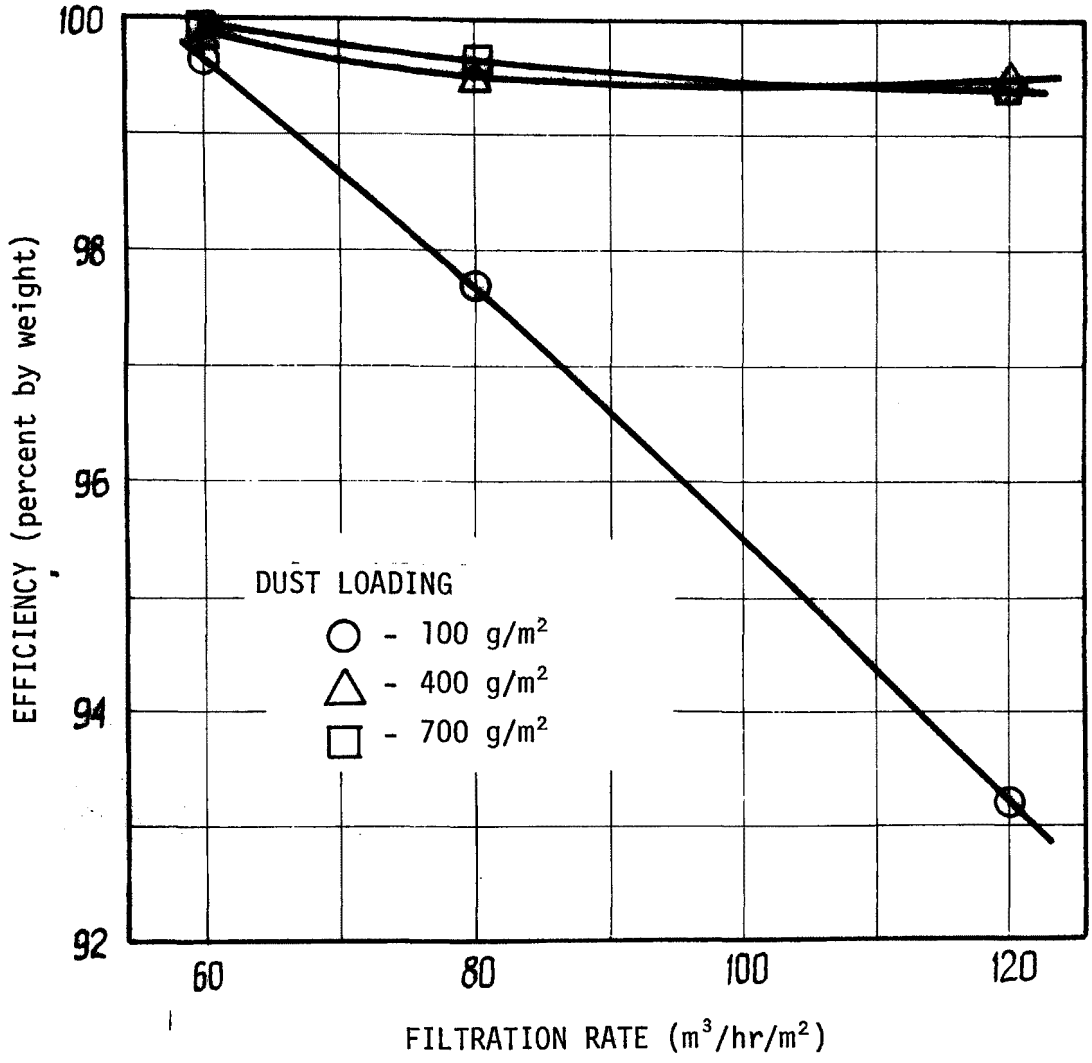


Figure A-21. Efficiency vs. Filtration Rate for Cement Dust and Fabric F-tor-5 (separated dust).

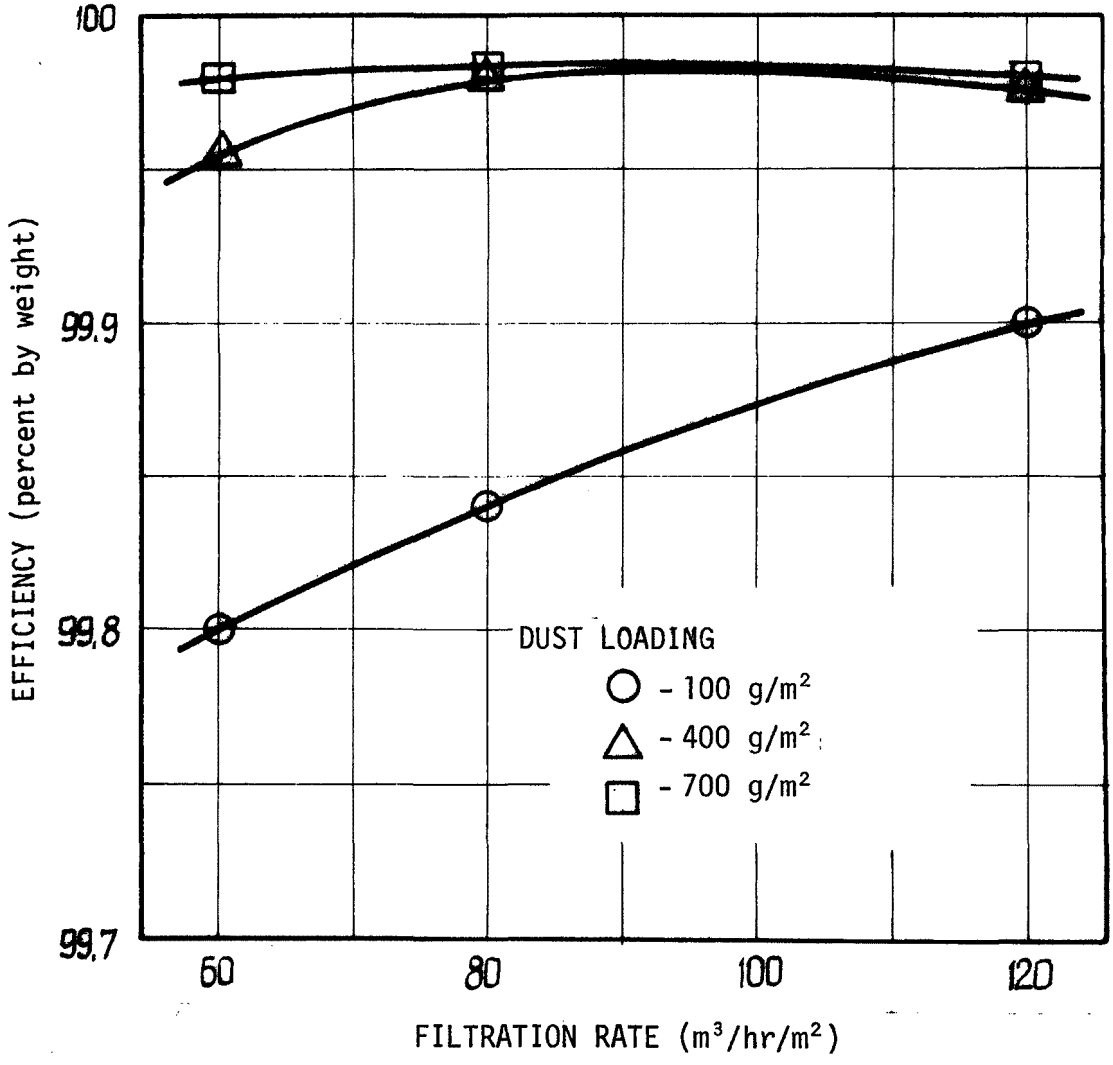


Figure A-22. Efficiency vs. Filtration Rate for Cement Dust and Fabric PT-15 (separated dust).

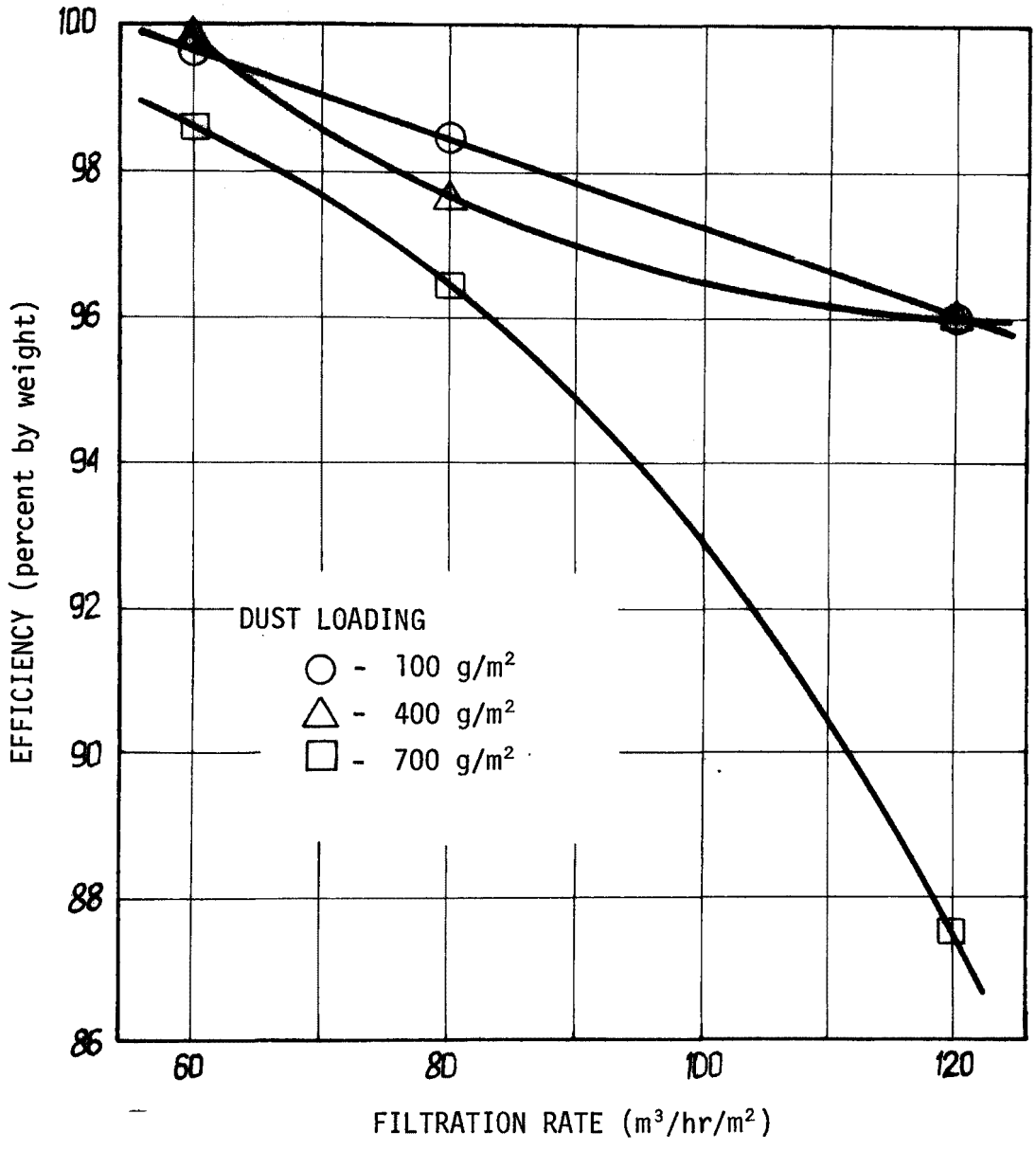


Figure A-23. Efficiency vs. Filtration Rate for Coal Dust and Fabric ET-4 (separated dust).

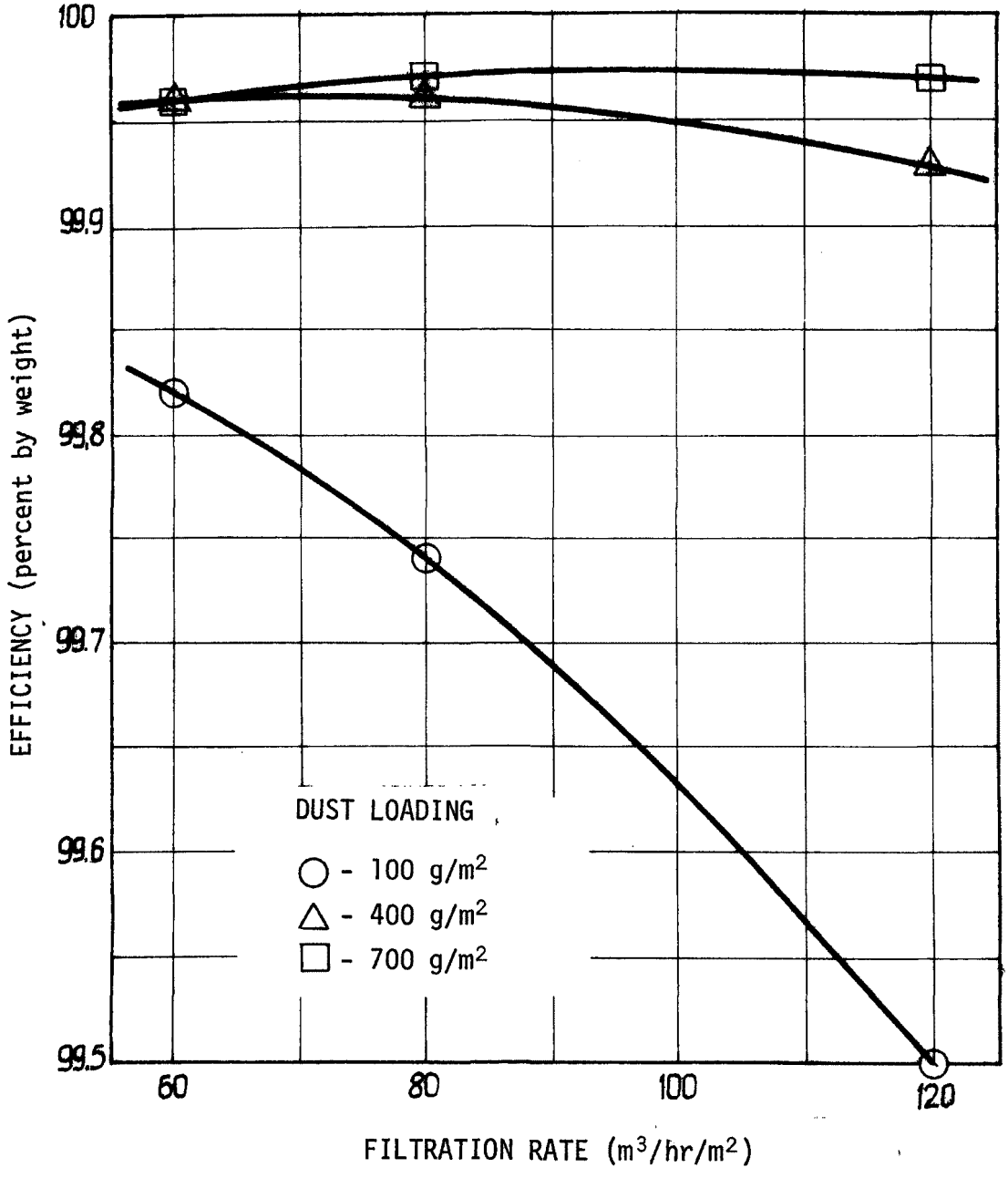


Figure A-24. Efficiency vs. Filtration Rate for Coal Dust and Fabric ET-30 (separated dust).

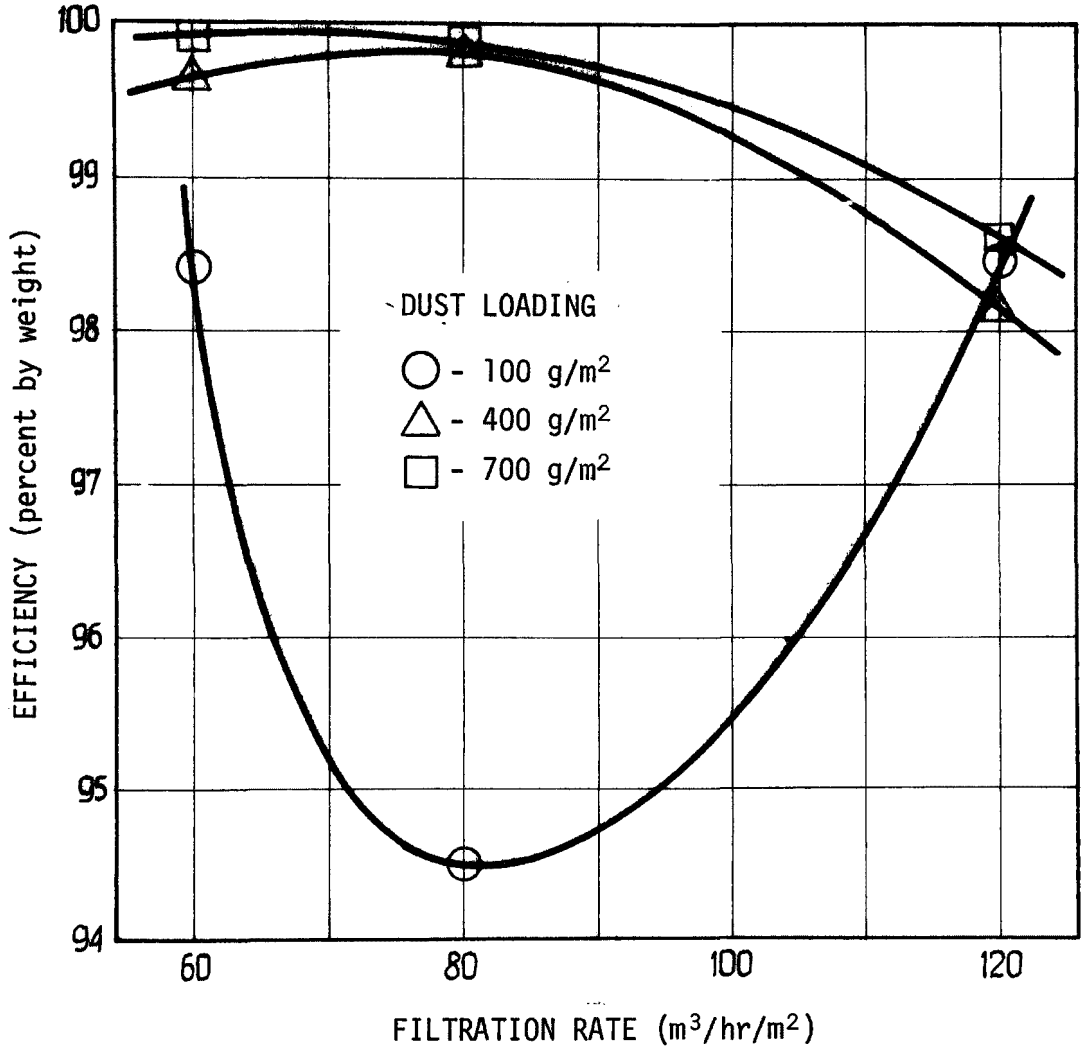


Figure A-25. Efficiency vs. Filtration Rate for Coal Dust and Fabric F-tor 5 (separated dust).

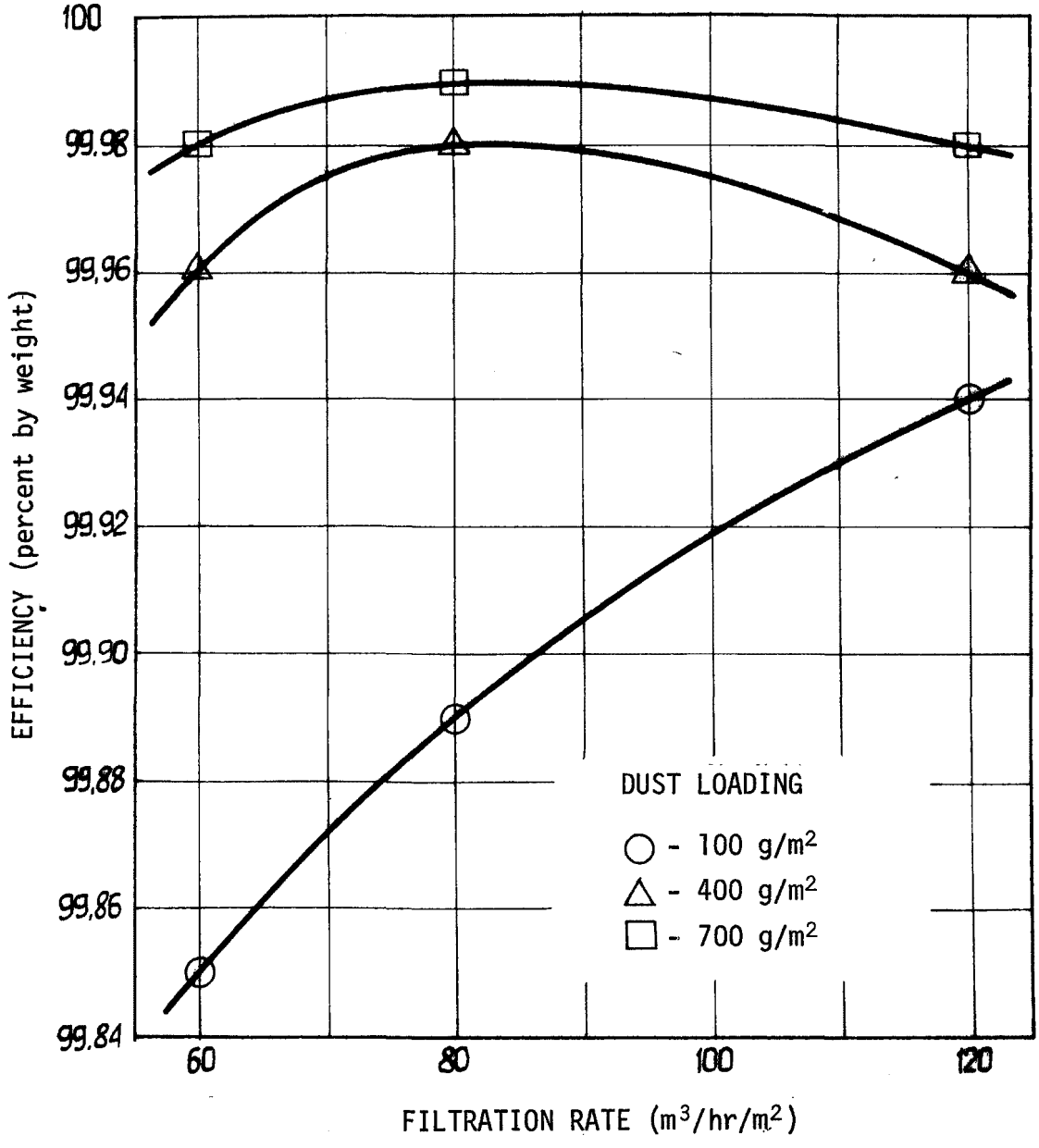


Figure A-26. Efficiency vs. Filtration Rate for Coal Dust and Fabric PT-15 (separated dust).

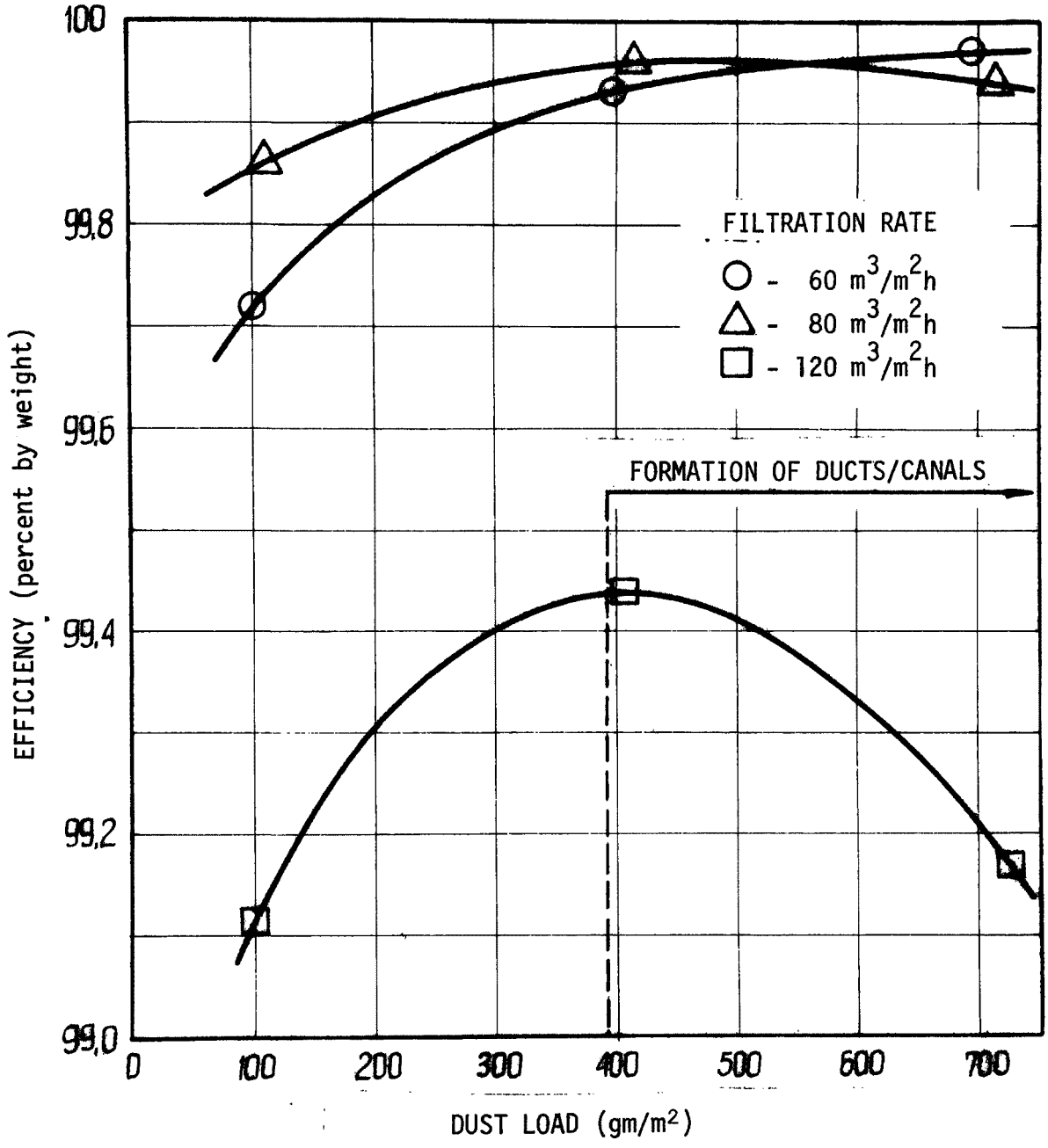


Figure A-27. Efficiency vs. Dust Load for Cement Dust and Fabric ET-4 (separated dust).

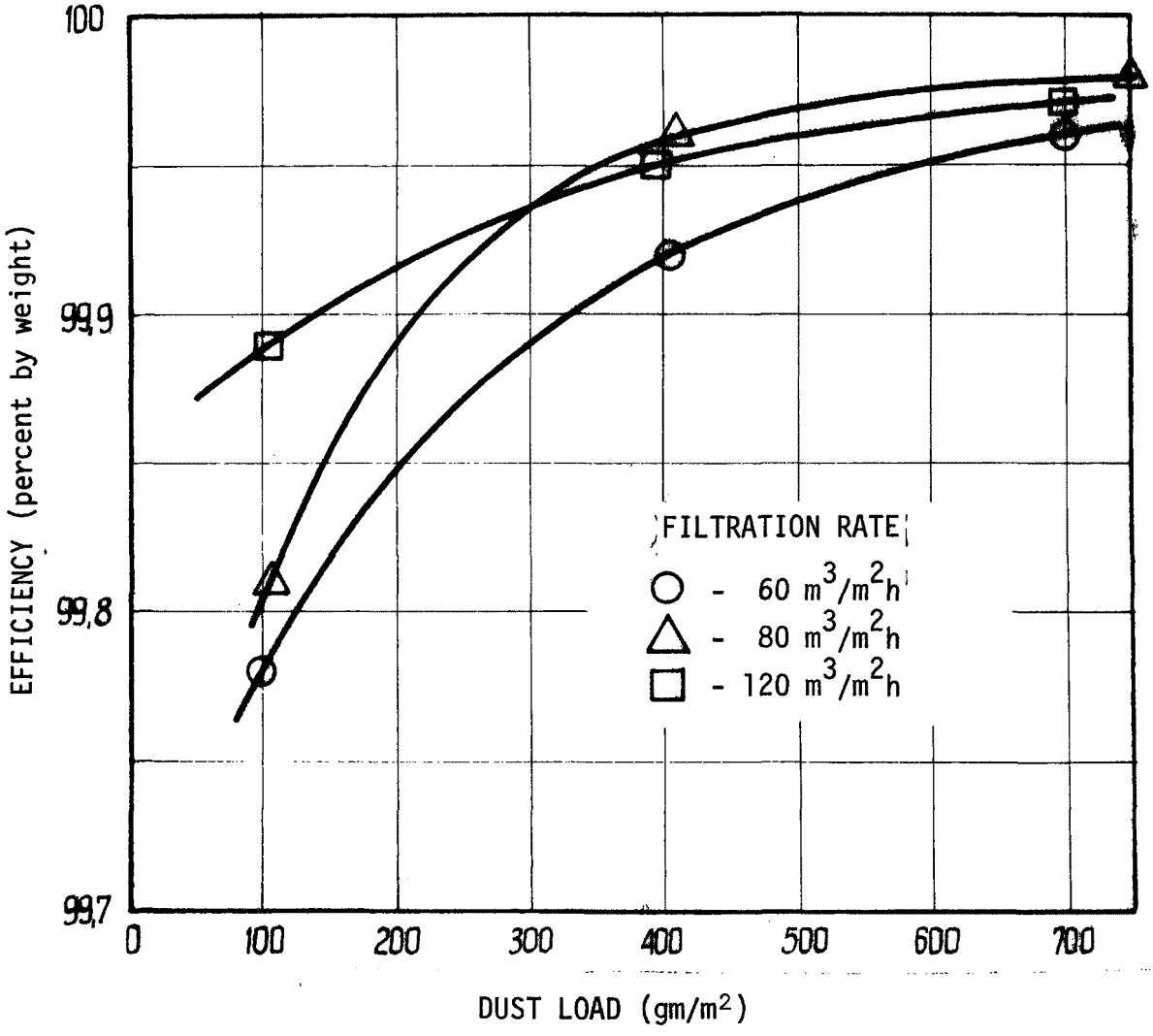


Figure A-28. Efficiency vs. Dust Load for Cement Dust and Fabric ET-30 (separated dust).

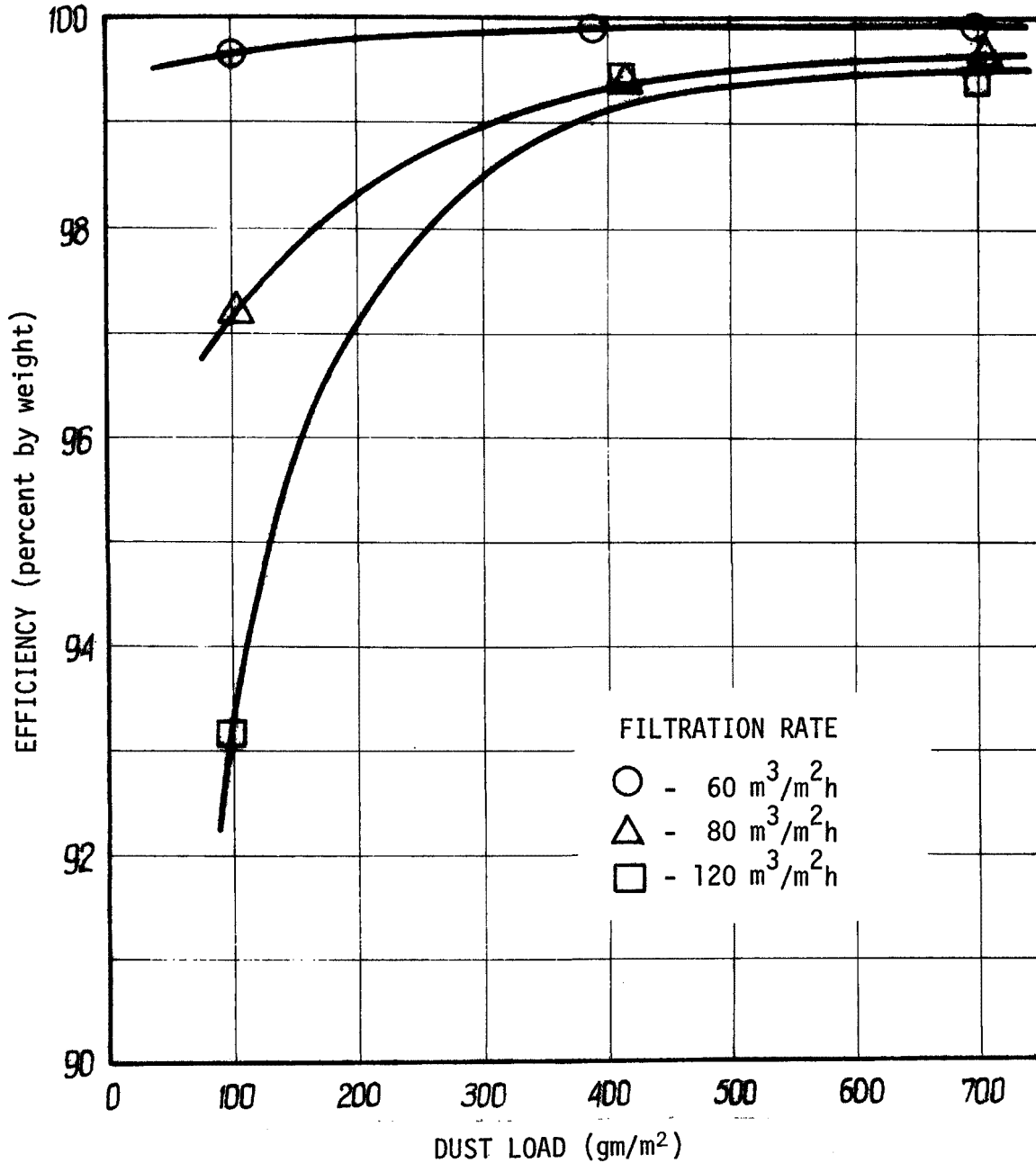


Figure A-29. Efficiency vs. Dust Load for Cement Dust and Fabric F-tor 5 (separated dust).

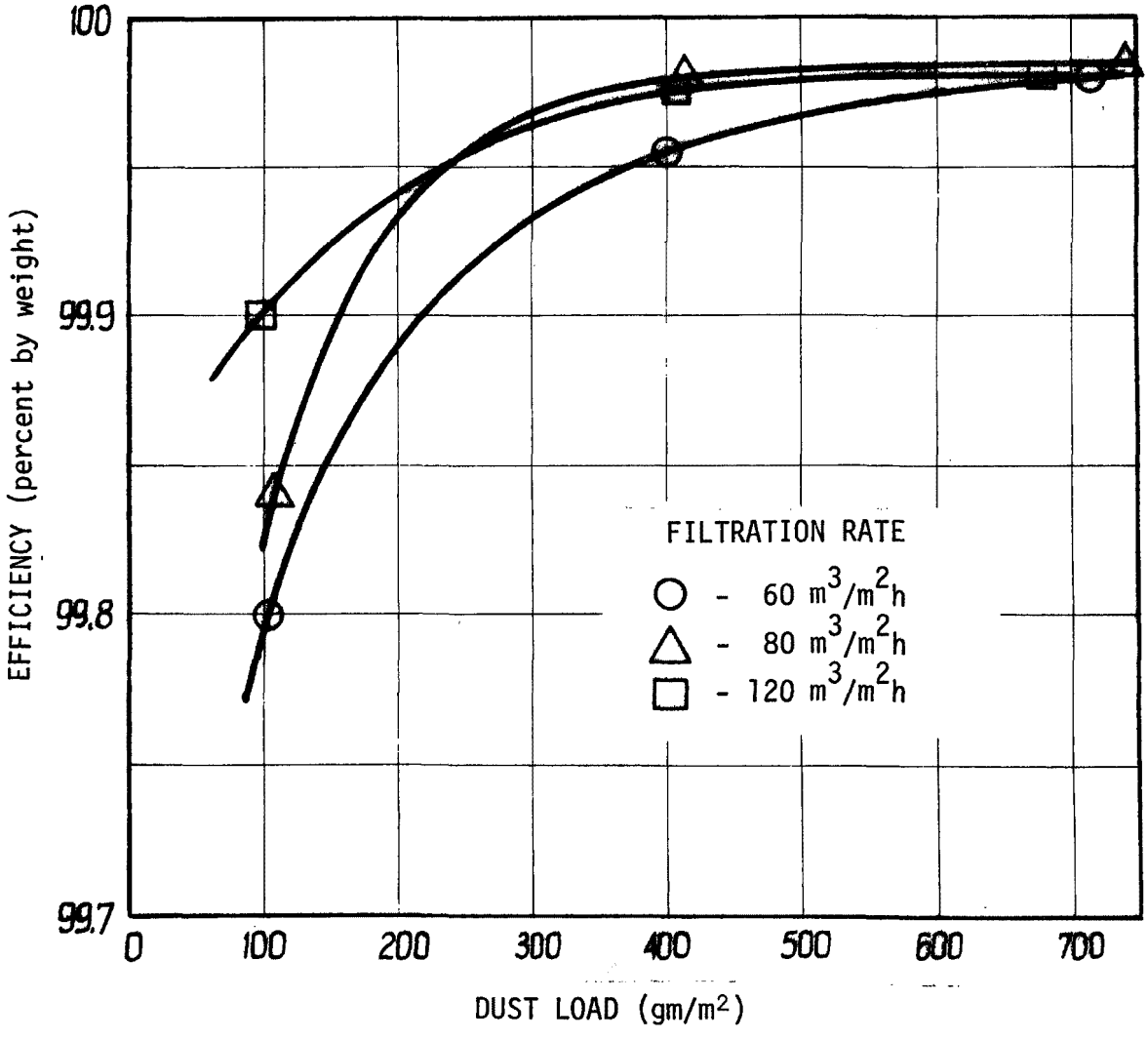


Figure A-30. Efficiency vs. Dust Load for Cement Dust and Fabric PT-15 (separated dust).

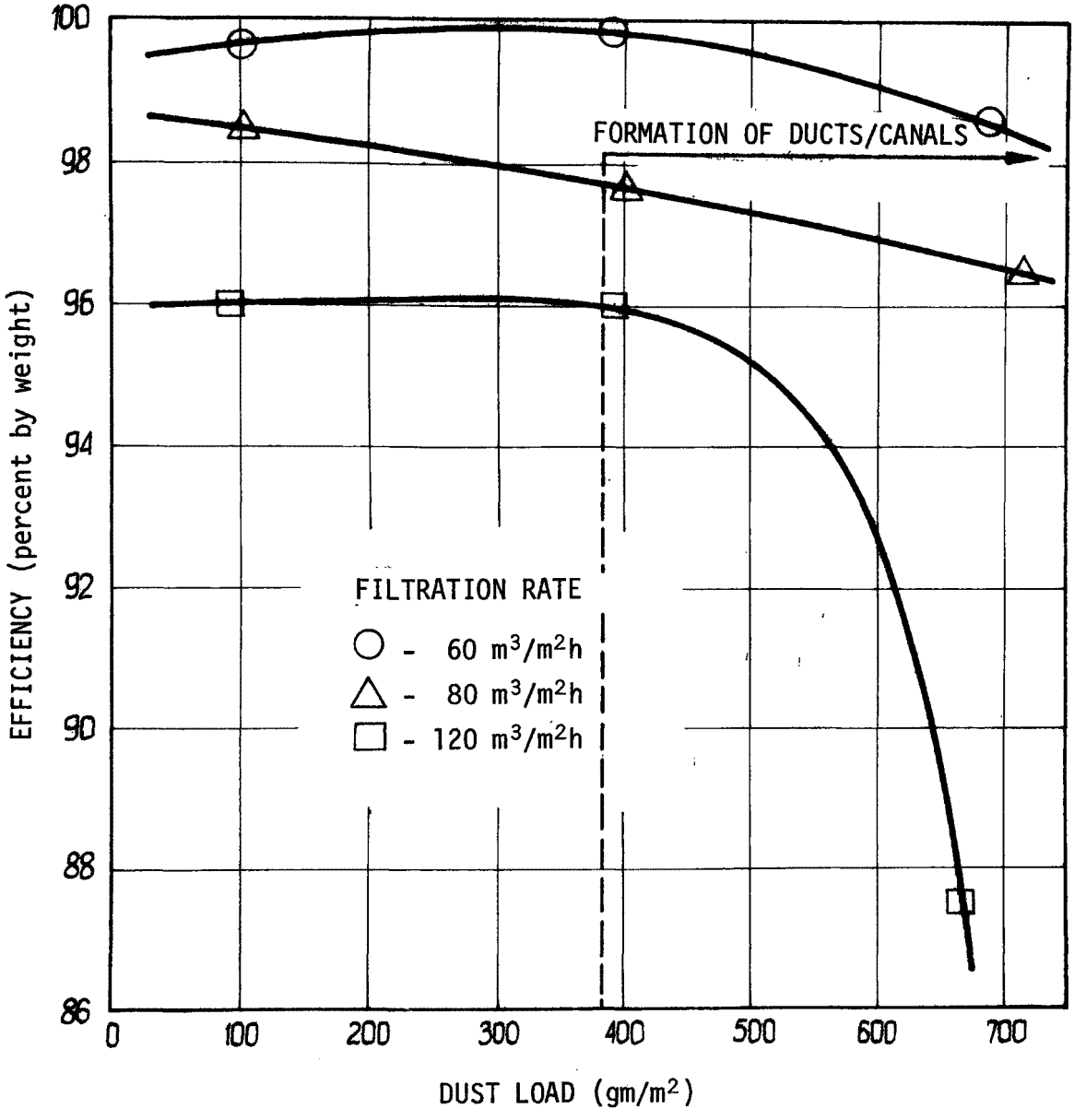


Figure A-31. Efficiency vs. Dust Load for Coal Dust and Fabric ET-4 (separated dust).

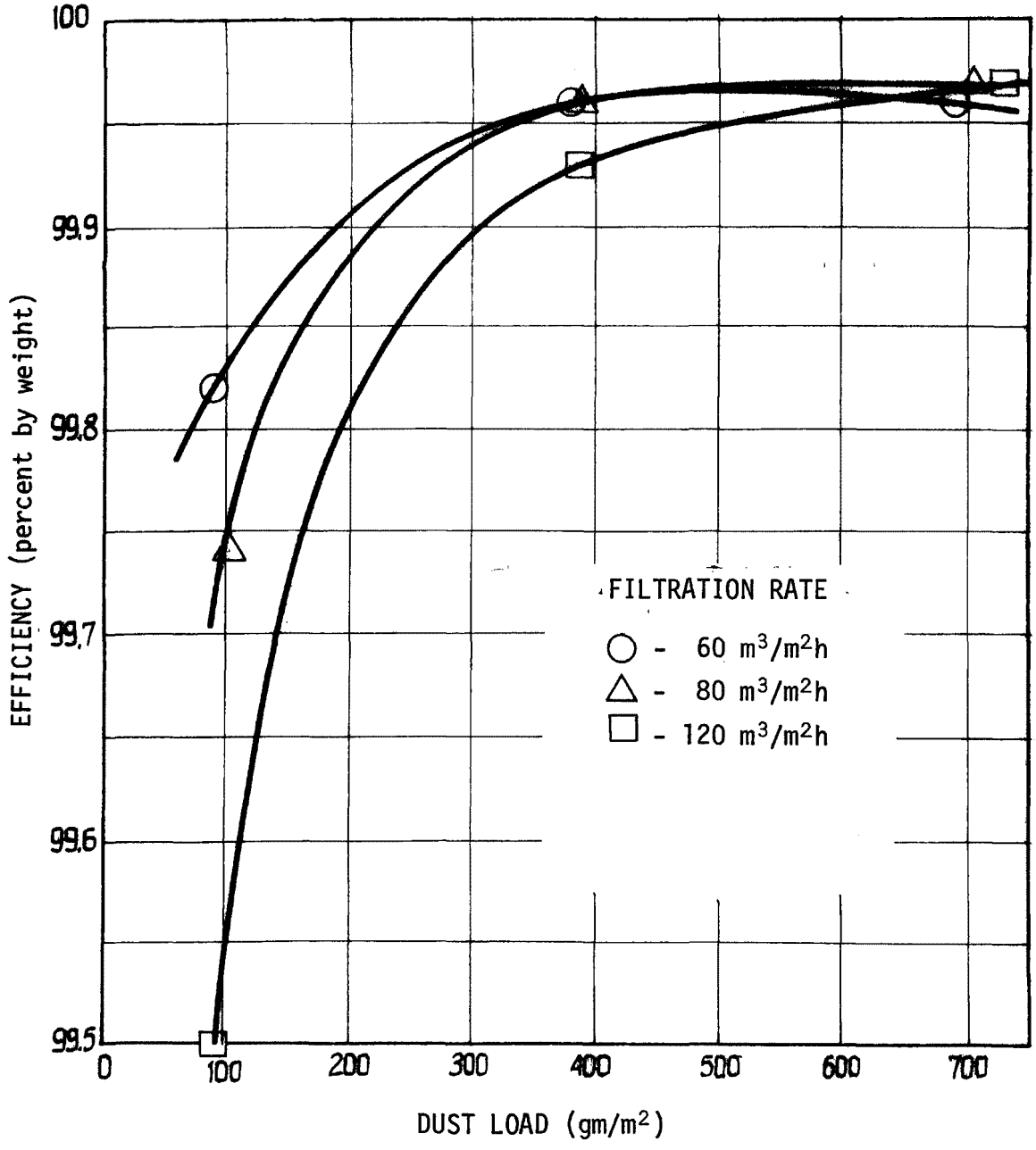


Figure A-32. Efficiency vs. Dust Load for Coal Dust and Fabric ET-30 (separated dust).

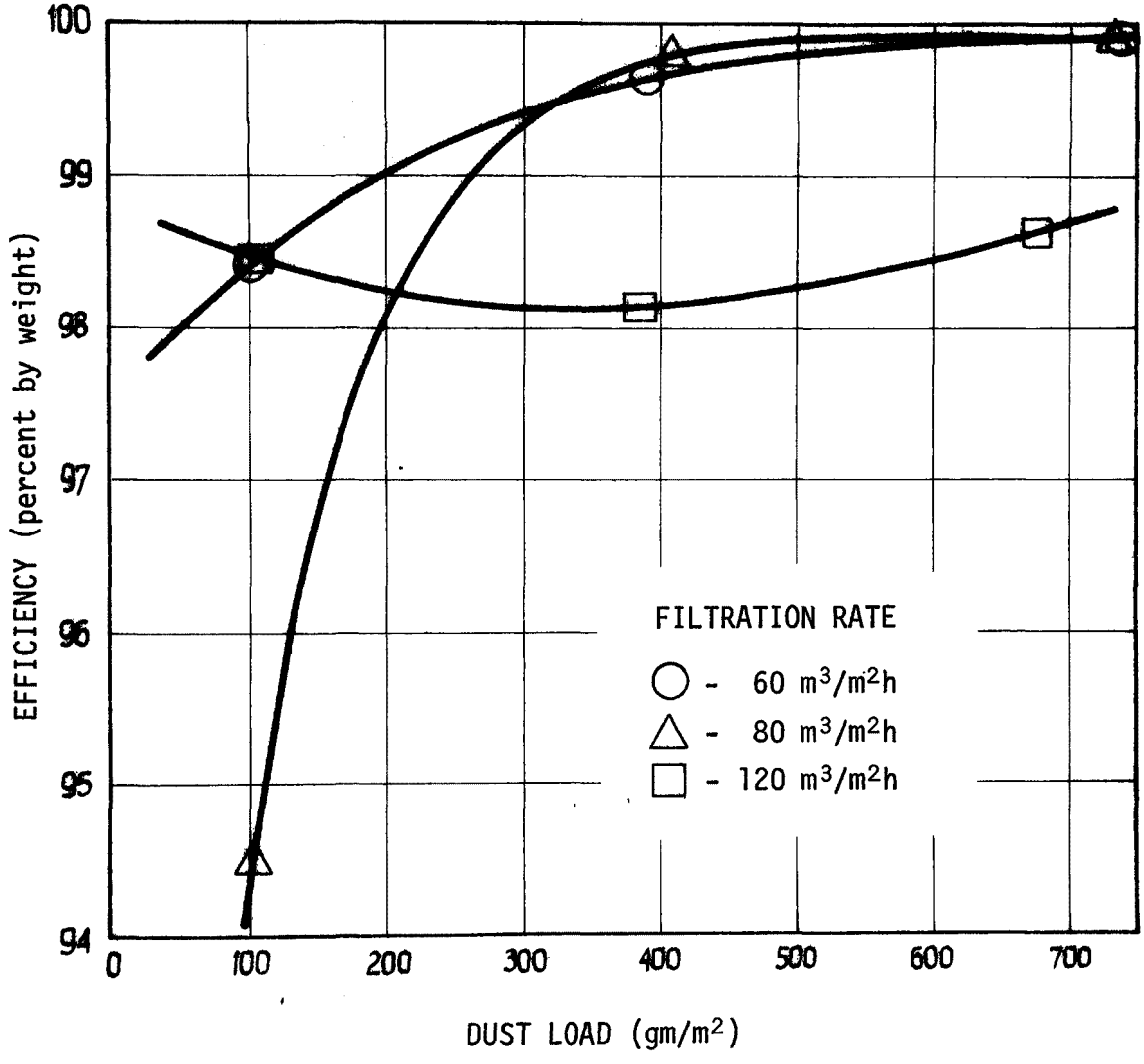


Figure A-33. Efficiency vs. Dust Load for Coal Dust and Fabric F-tor 5 (separated dust).

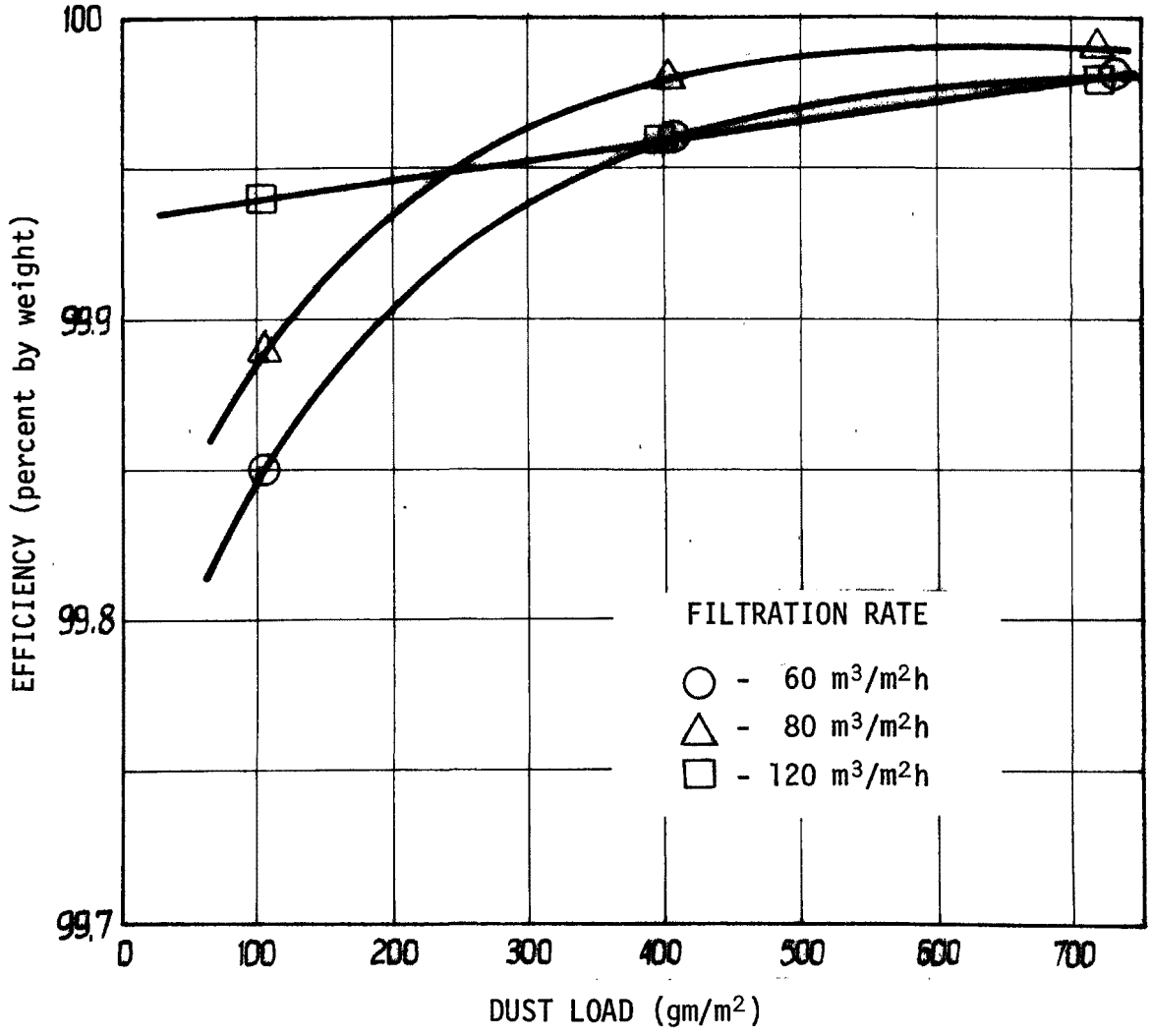


Figure A-34. Efficiency vs. Dust Load for Coal Dust and Fabric PT-15 (separated dust).

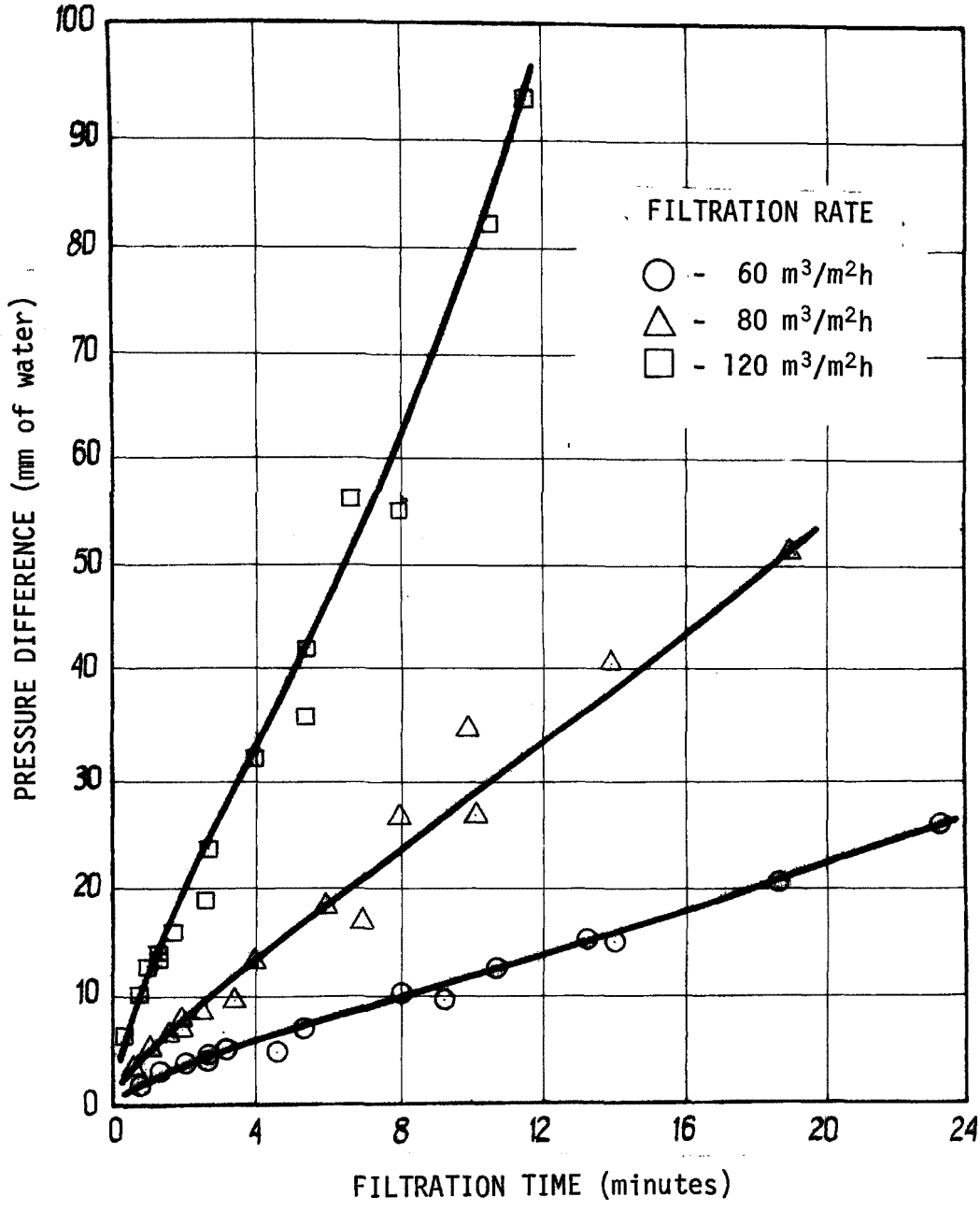


Figure A-35. Pressure Difference vs. Filtration Time for Cement Dust and Fabric ET-4 (unseparated dust).

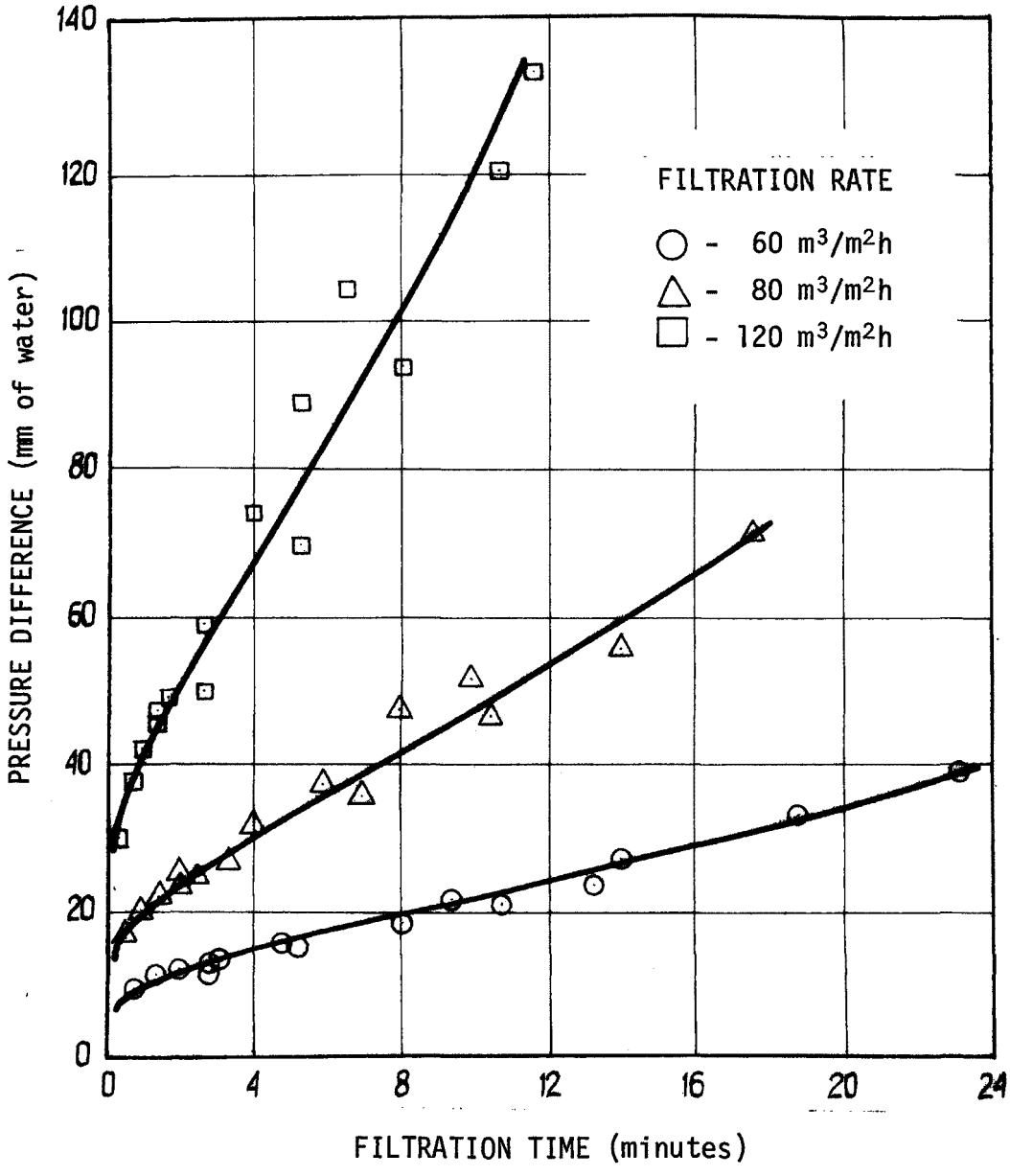


Figure A-36. Pressure Difference vs. Filtration Time for Cement Dust and Fabric ET-30 (unseparated dust).

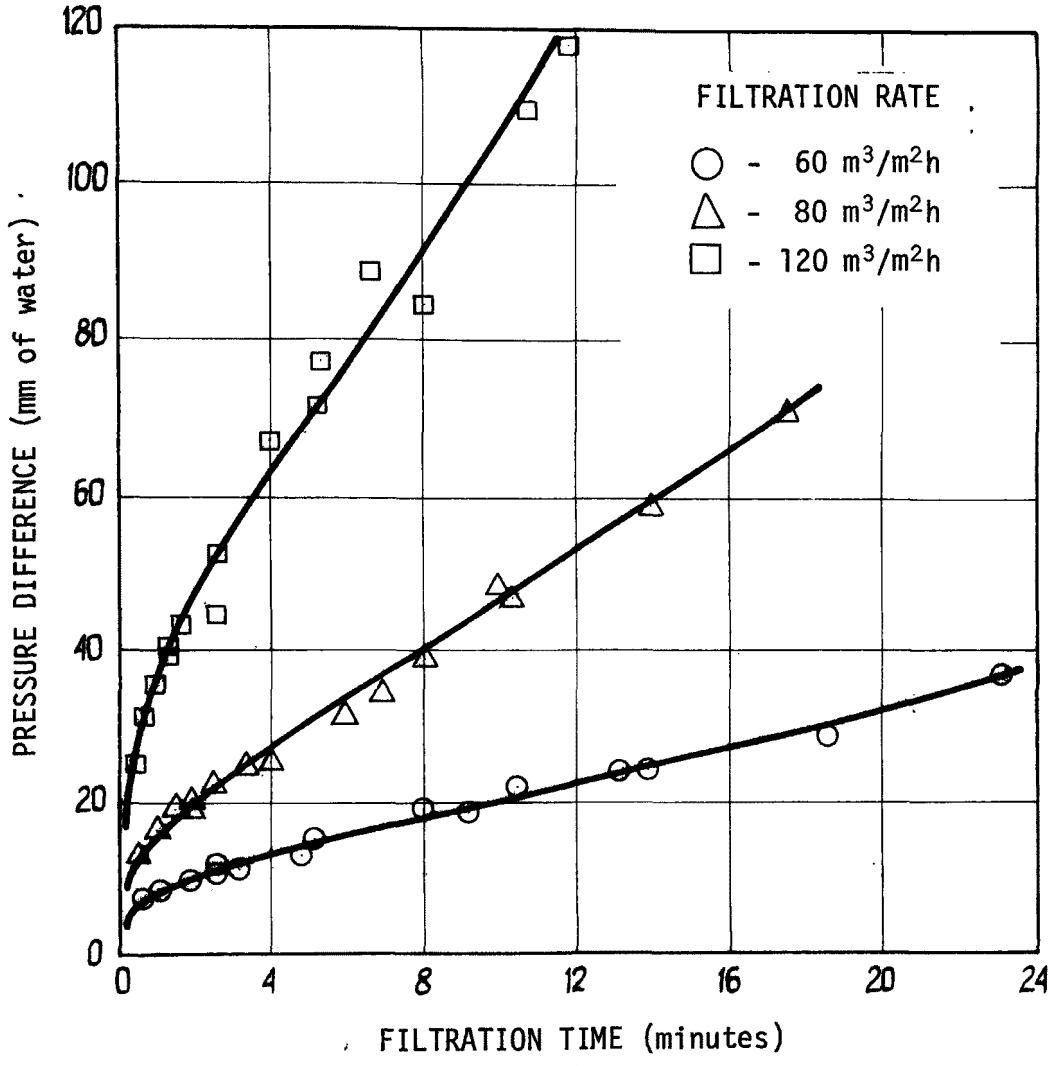


Figure A-37. Pressure Difference vs. Filtration Time for Cement Dust and Fabric F-tor 5 (unseparated dust).

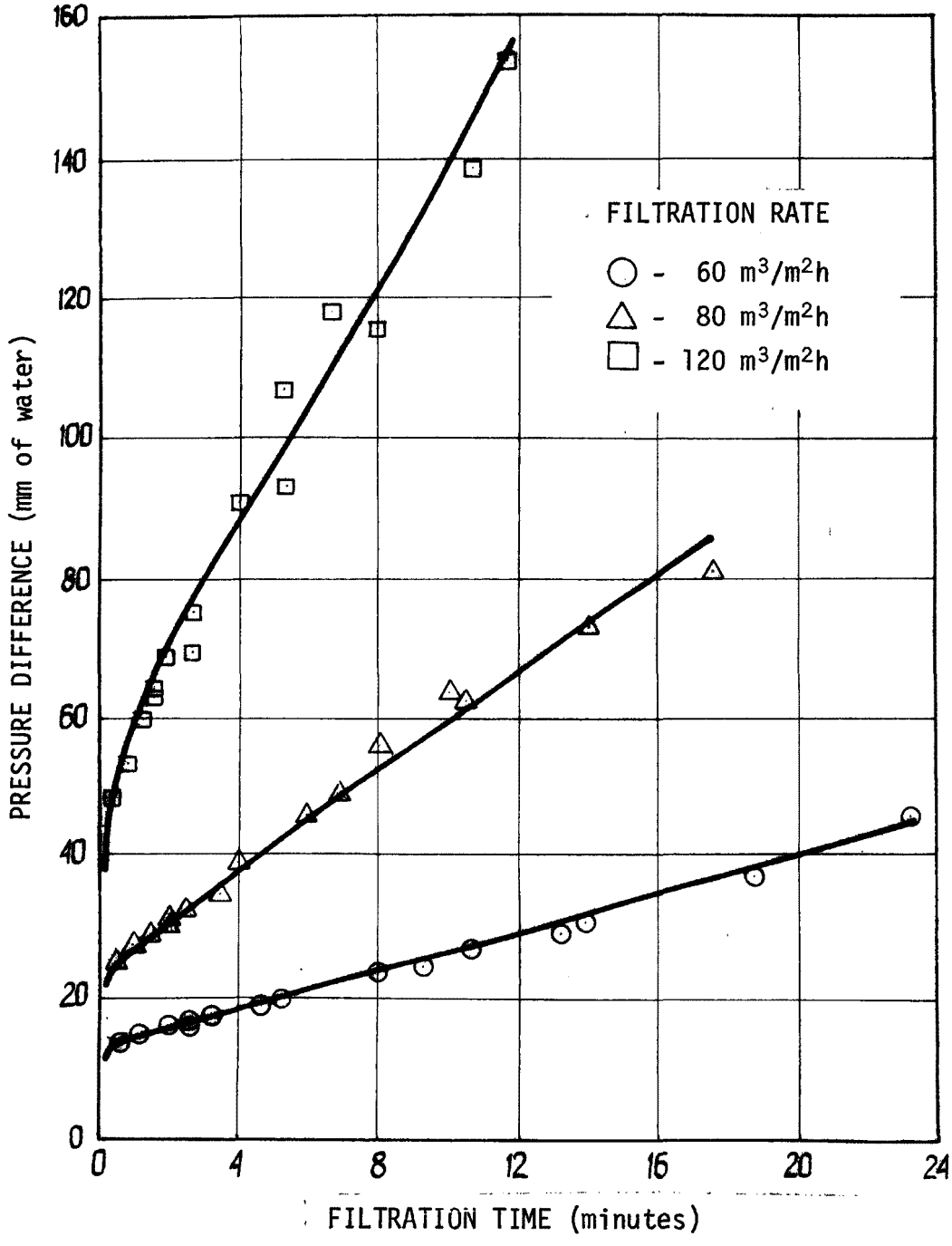


Figure A-38. Pressure Difference vs. Filtration Time for Cement Dust and Fabric PT- 15 (unseparated dust).

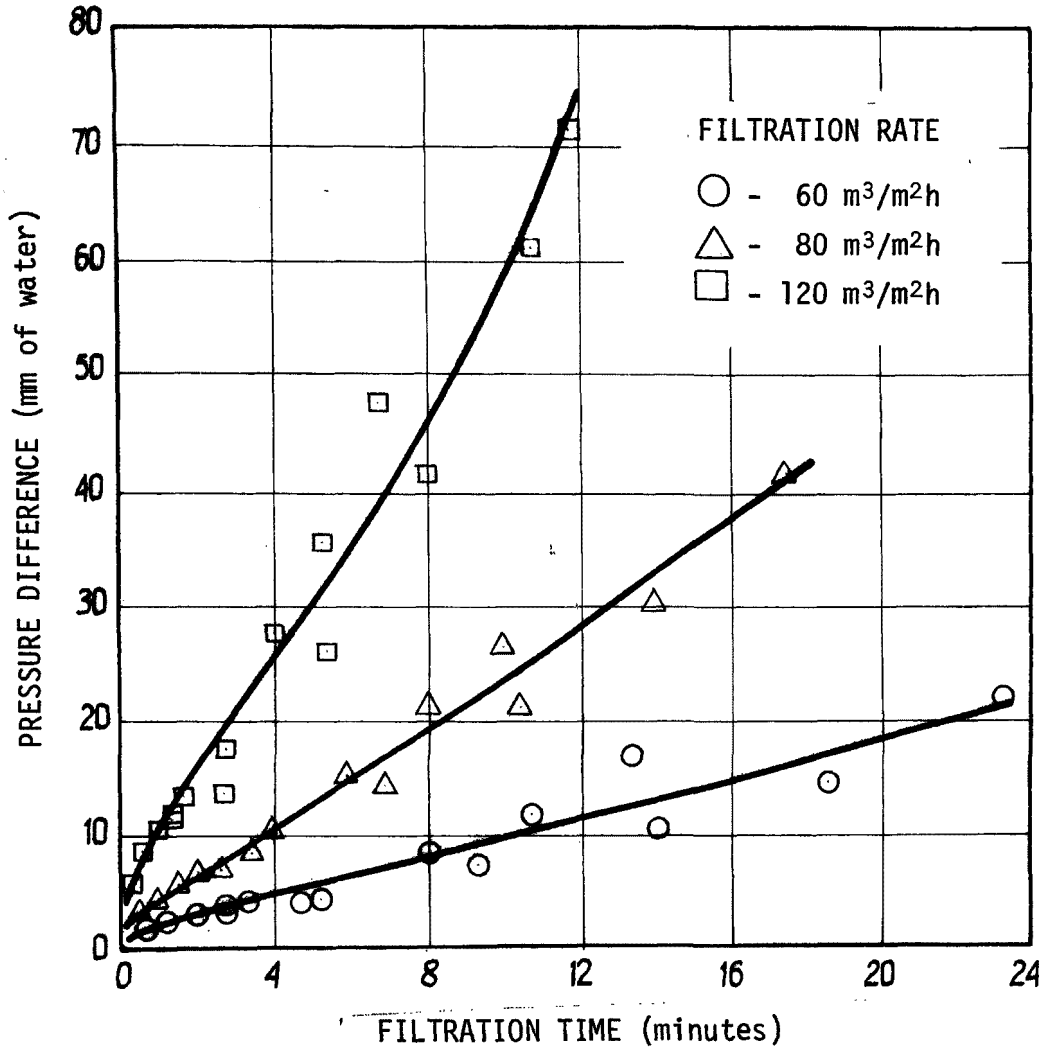


Figure A-39. Pressure Difference vs. Filtration Time for Coal Dust and Fabric ET-4 (unseparated dust).

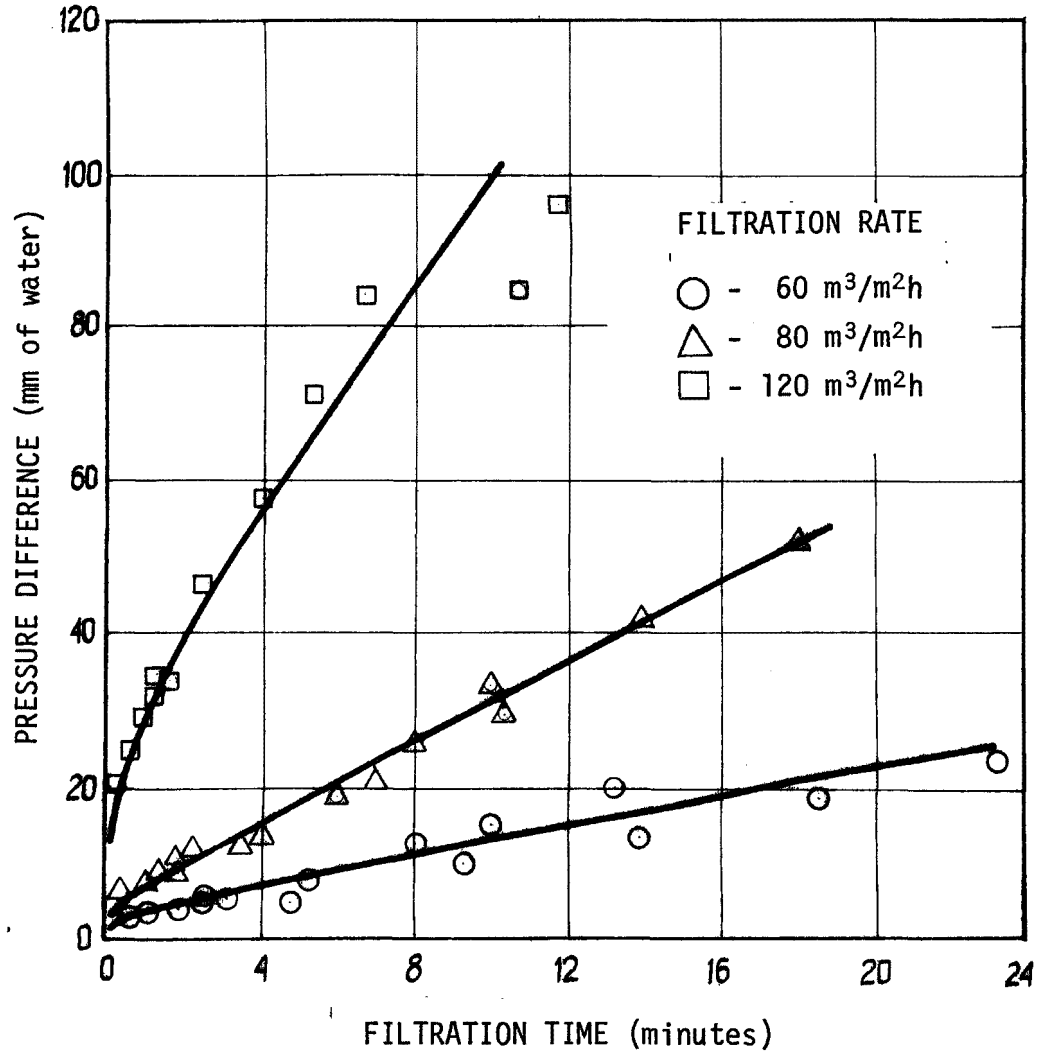


Figure A-40. Pressure Difference vs. Filtration Time for Coal Dust and Fabric ET-30 (unseparate dust).

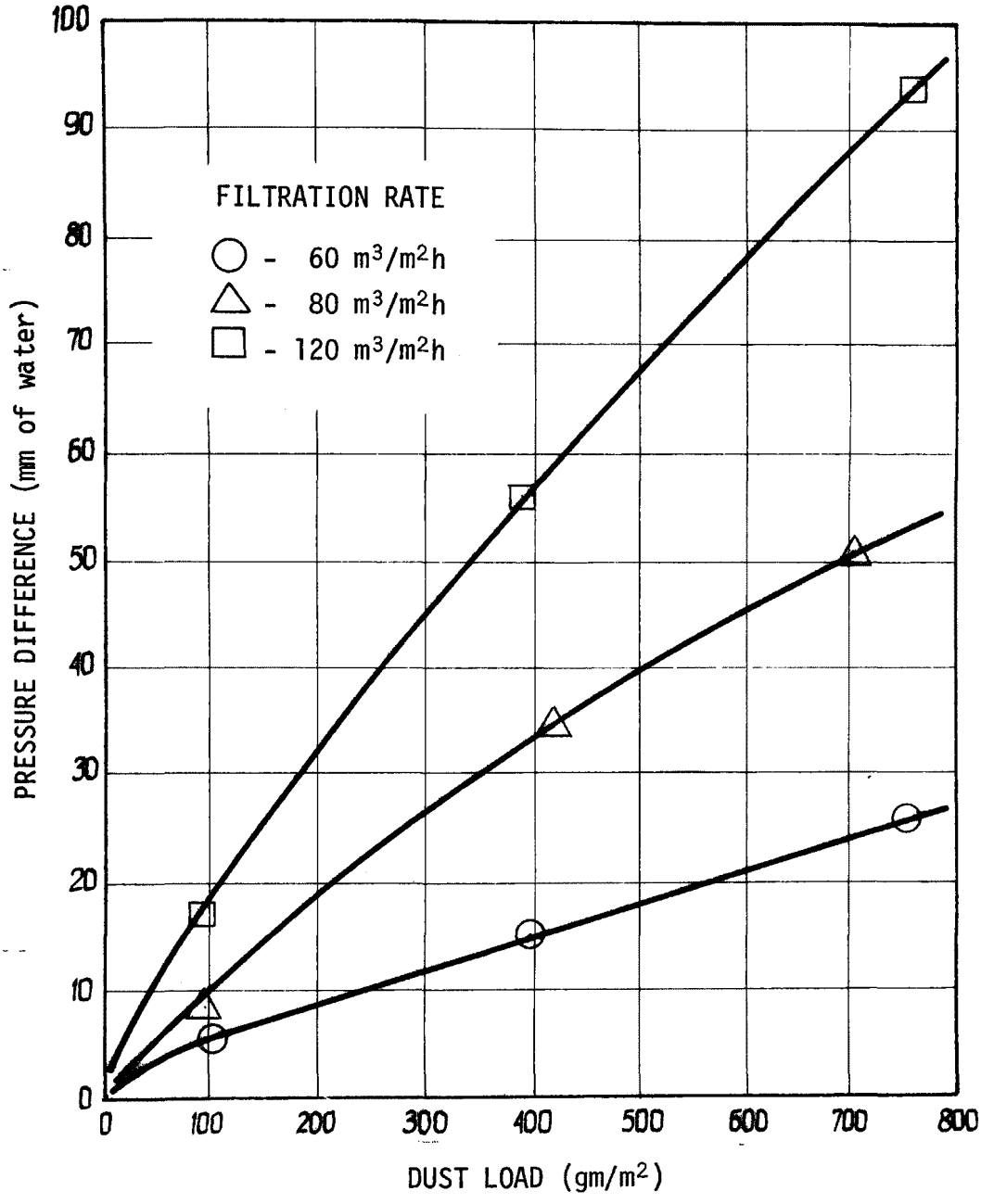


Figure A-41. Pressure Difference vs. Dust Load for Cement Dust and Fabric ET-4 (unseparated dust).

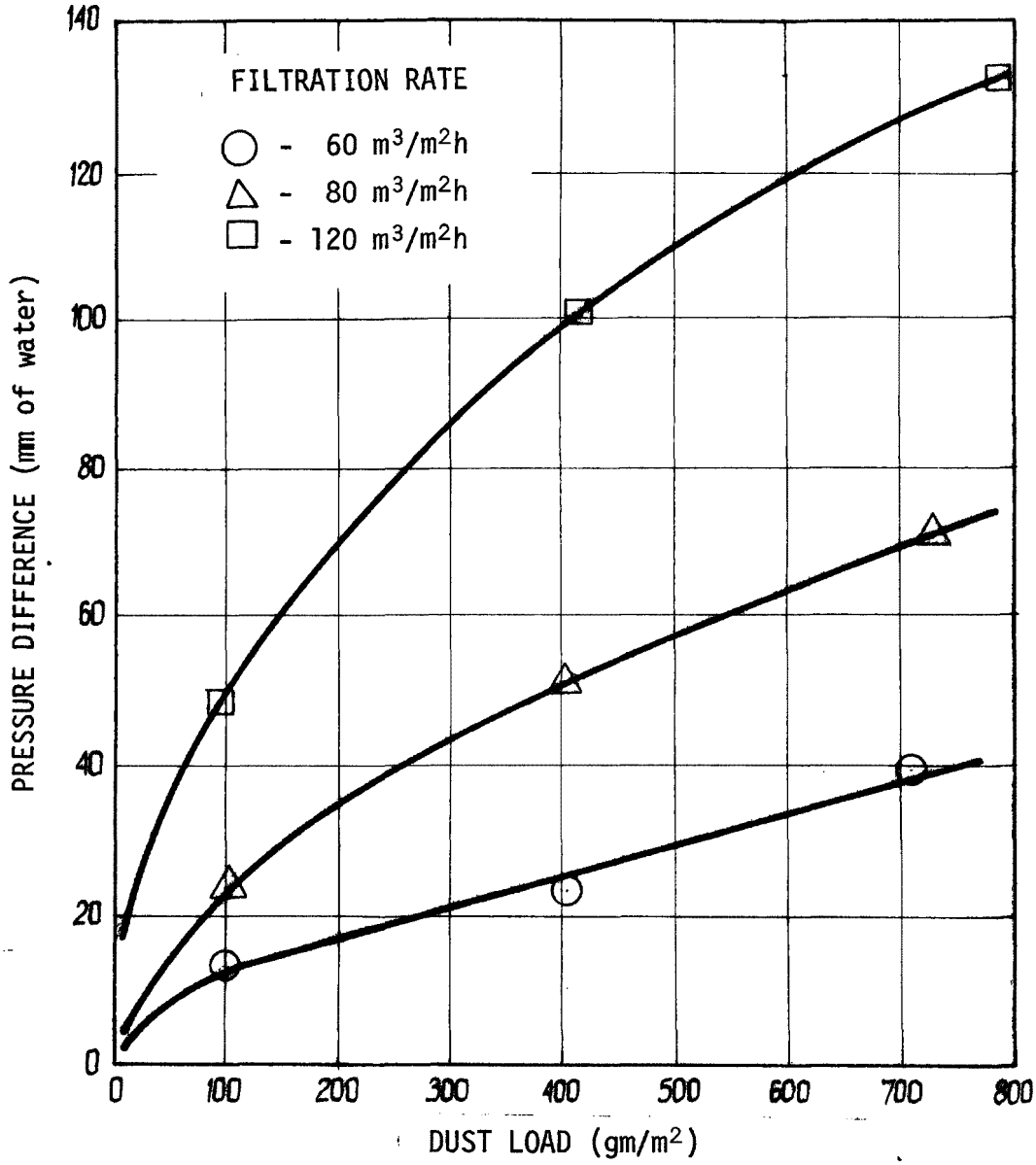


Figure A-42. Pressure Difference vs. Dust Load for Cement Dust and Fabric ET-30 (unseparated dust).

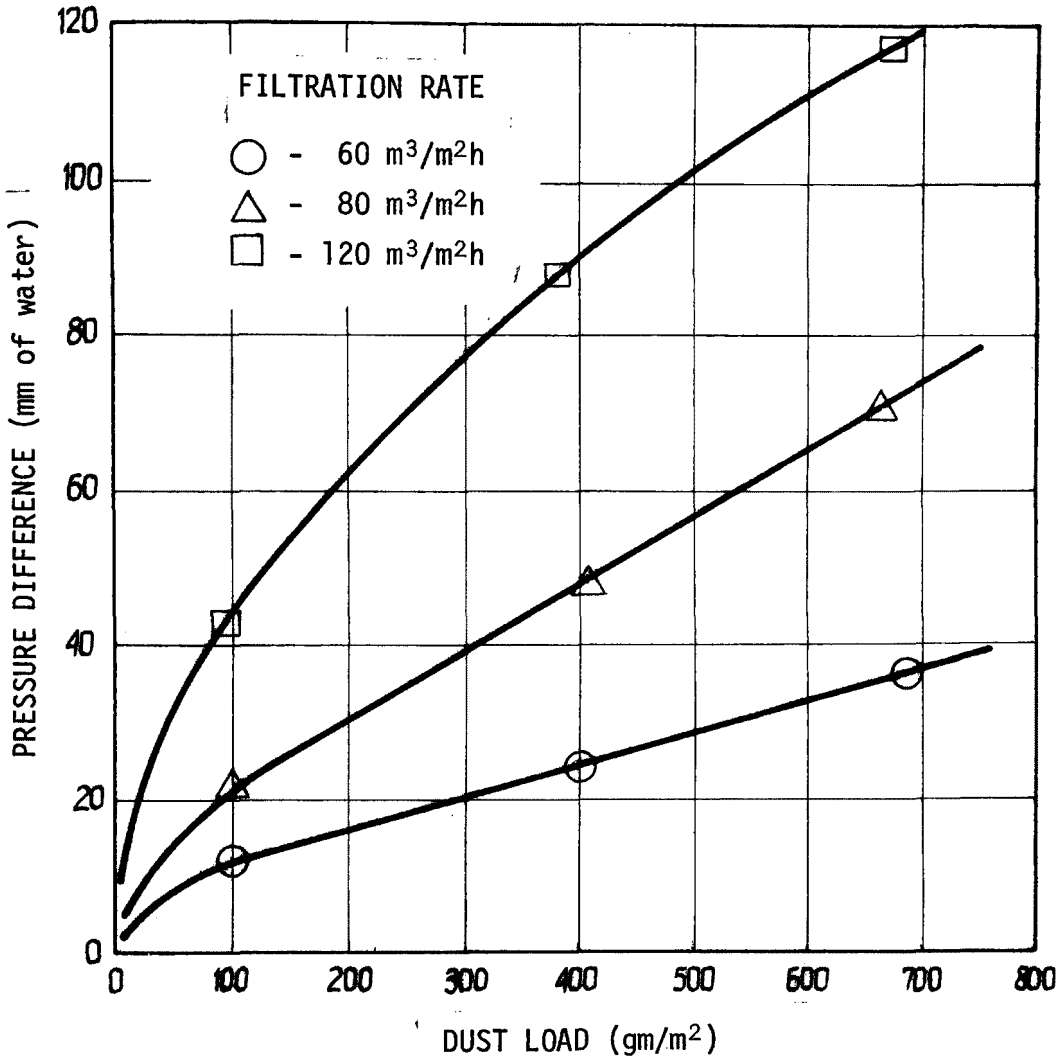


Figure A-43. Pressure Difference vs. Dust Load for Cement Dust and Fabric F-tor 5 (unseparated dust).

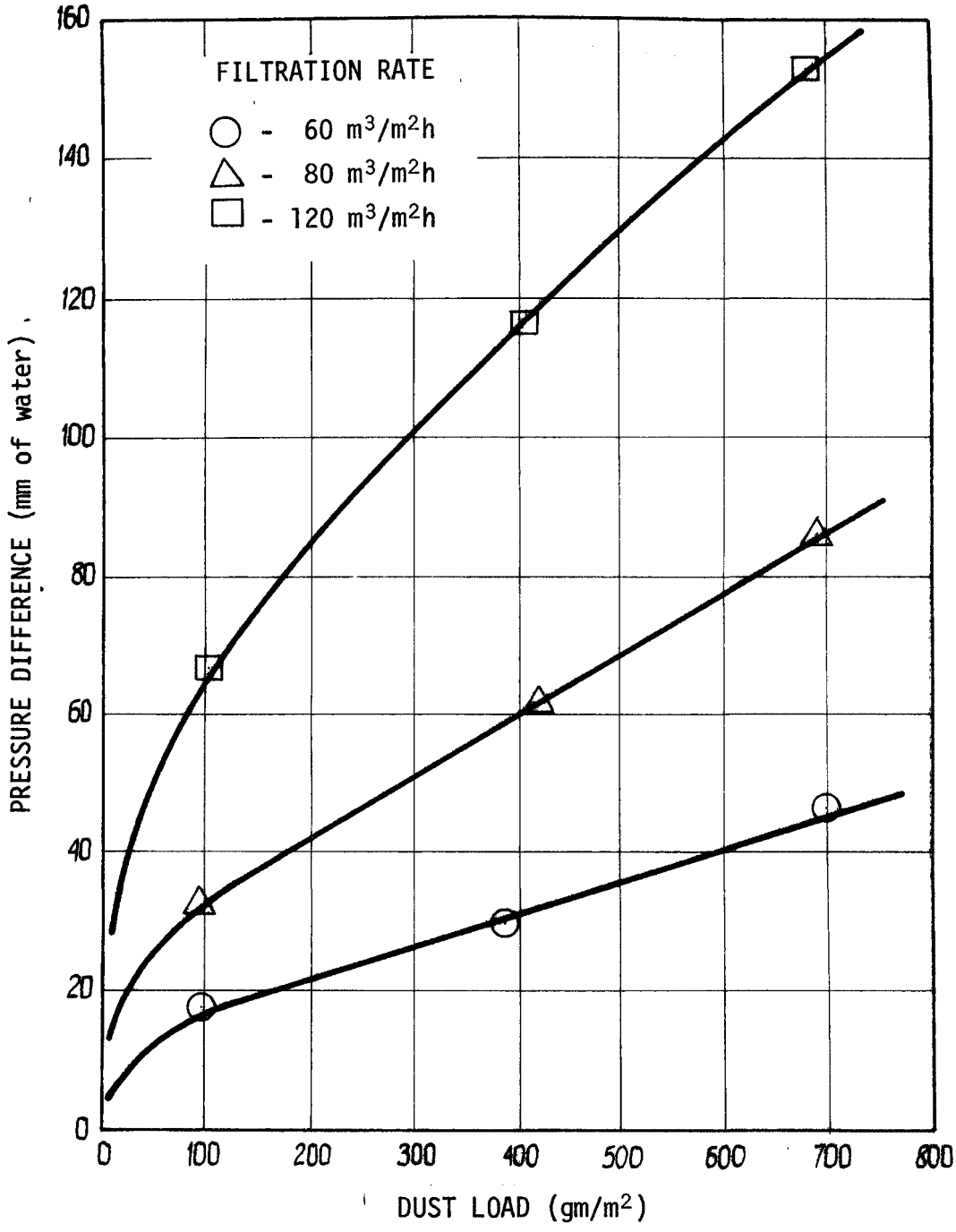


Figure A-44. Pressure Difference vs. Dust Load for Cement Dust and Fabric PT-15 (unseparated dust).

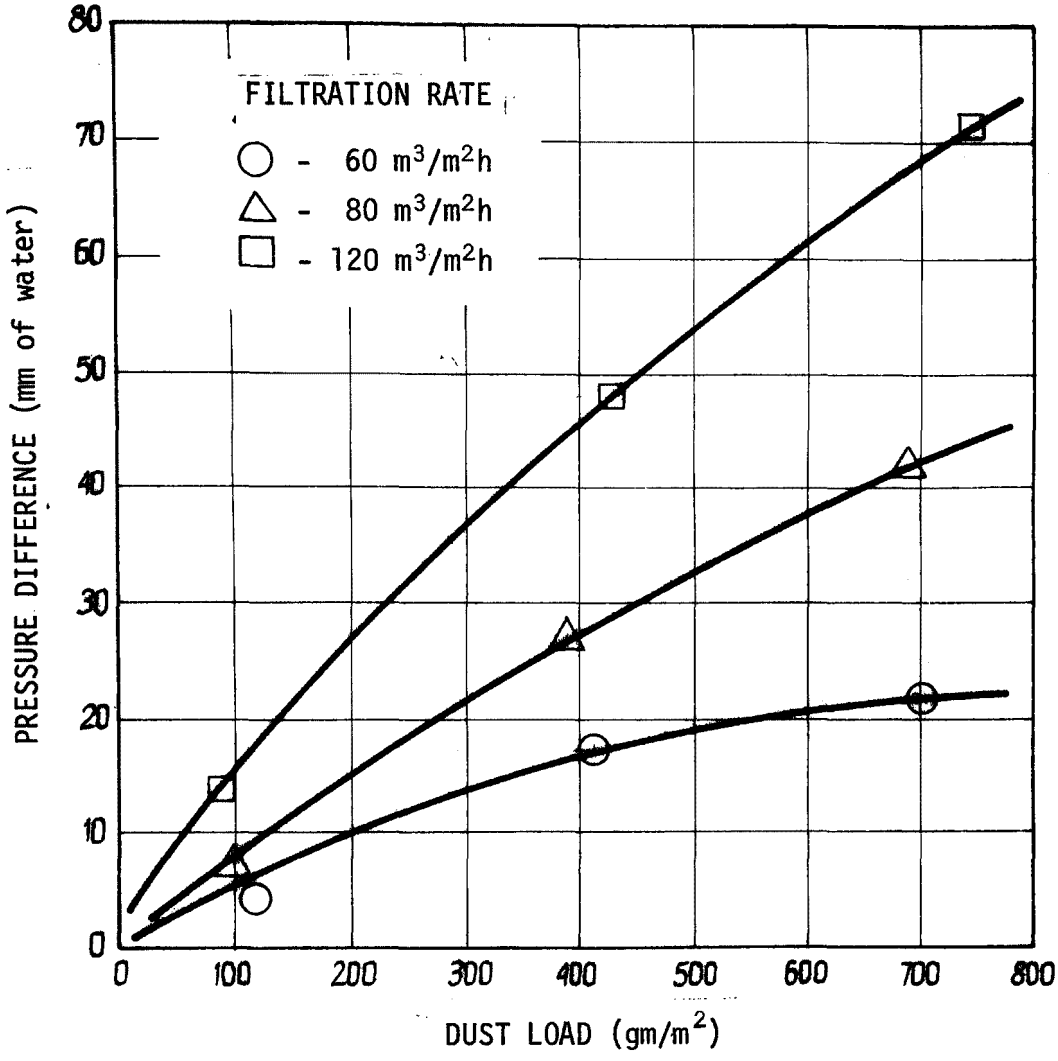


Figure A-45. Pressure Difference vs. Dust Load for Coal Dust and Fabric ET-4 (unseparated dust).

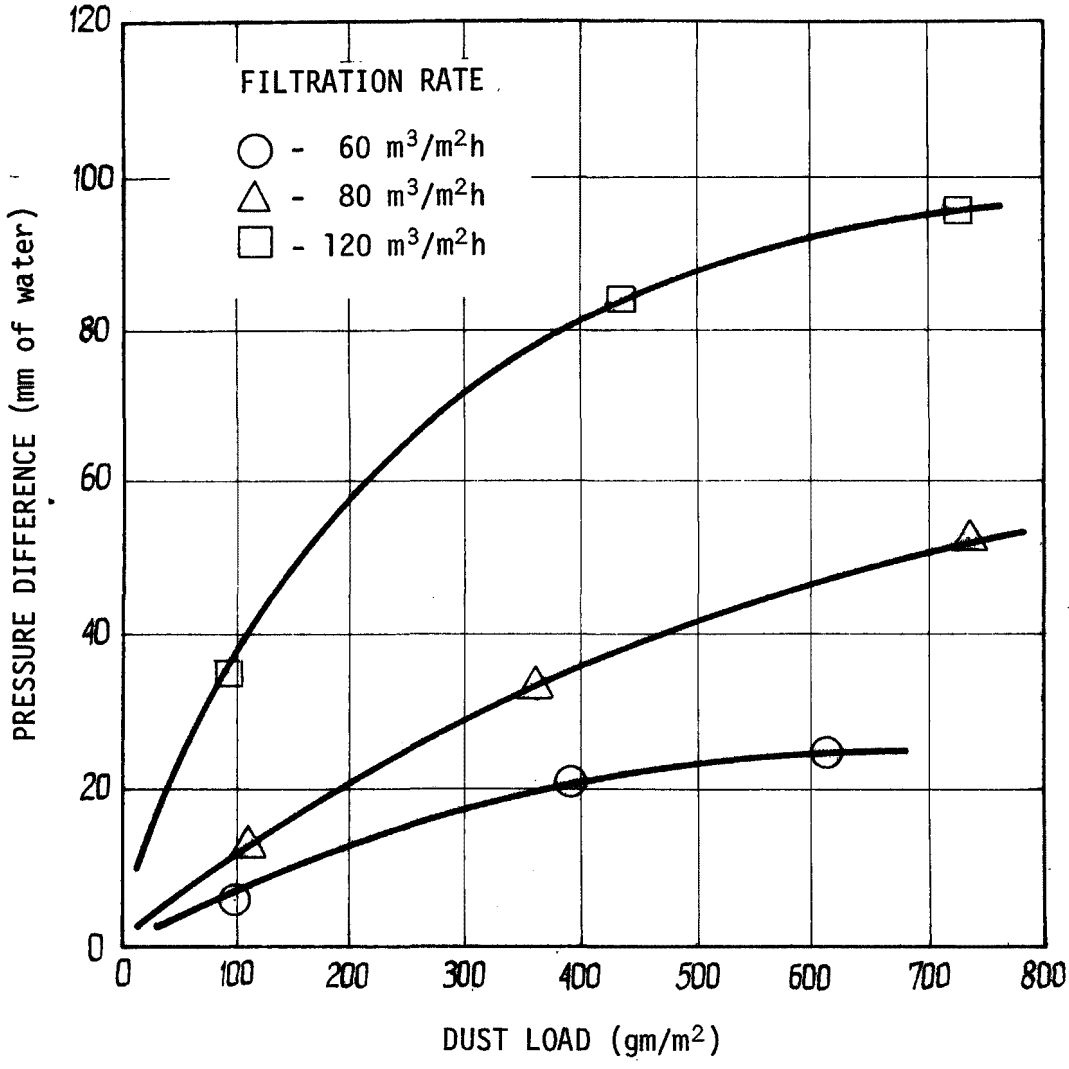


Figure A-46. Pressure Difference vs. Dust Load for Coal Dust and Fabric ET-30 (unseparated dust).

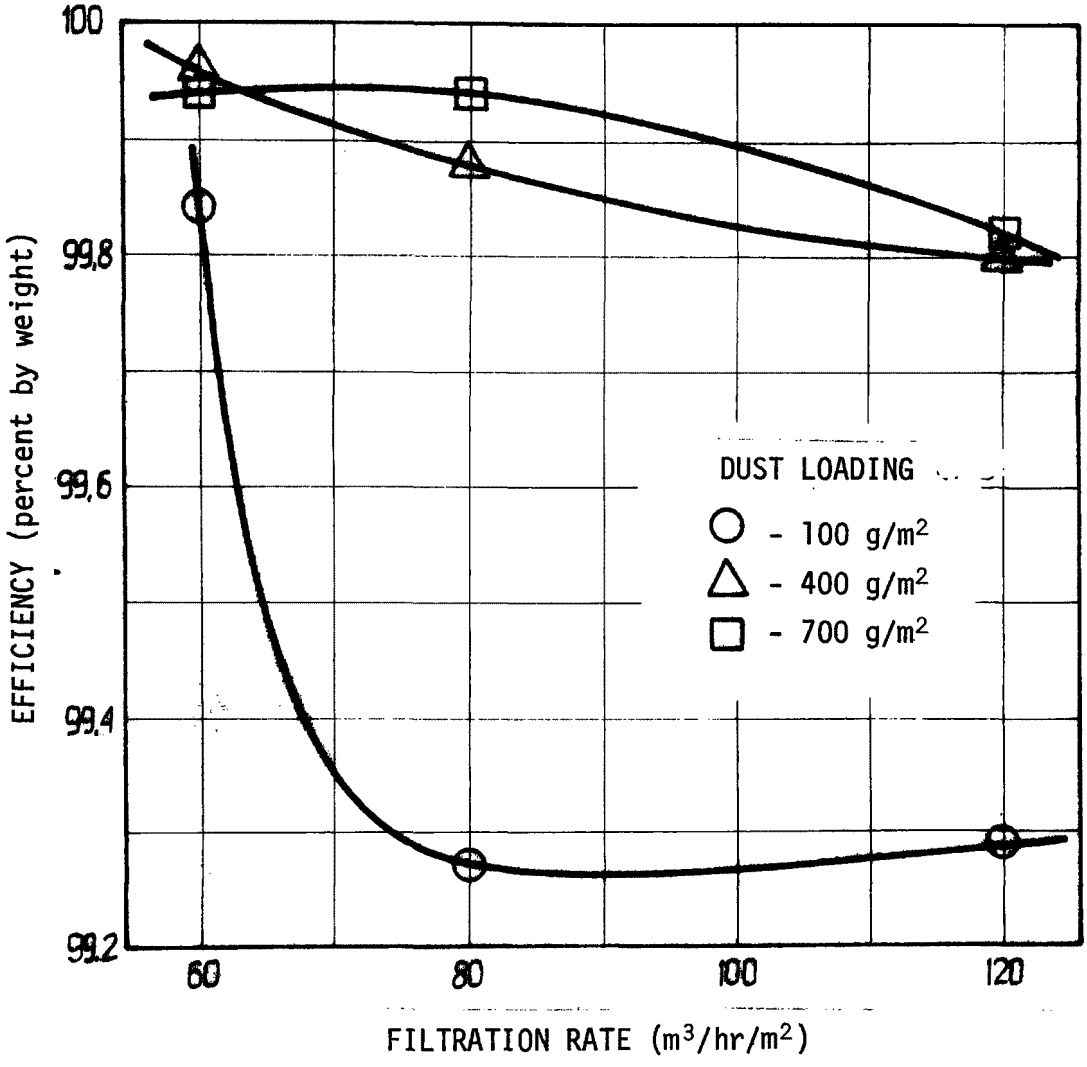


Figure A-47. Efficiency vs. Filtration Rate for Cement Dust and Fabric ET-4 (unseparated dust).

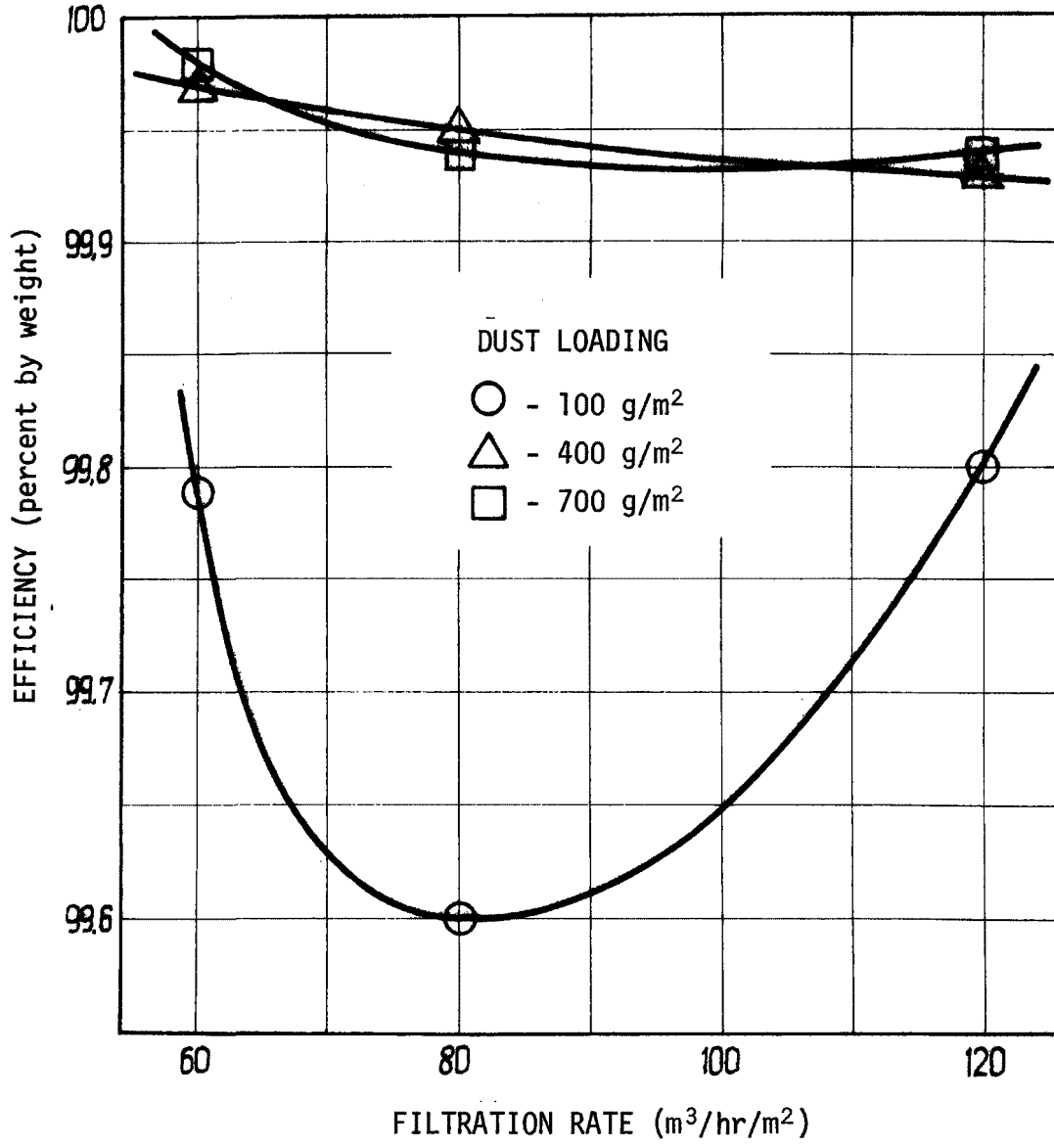


Figure A-48. Efficiency vs. Filtration Rate for Cement Dust and Fabric ET-30 (unseparated dust).

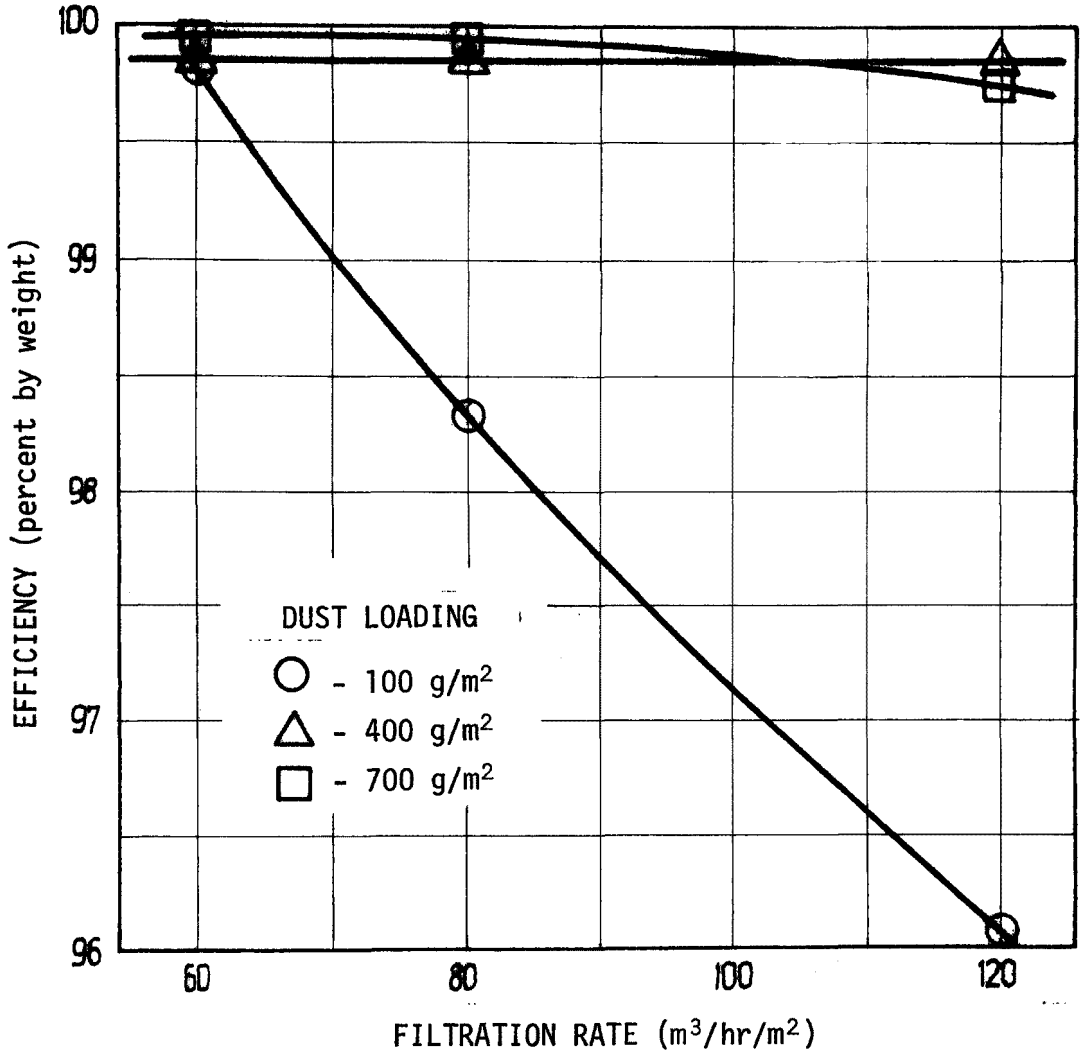


Figure A-49. Efficiency vs. Filtration Rate for Cement Dust and Fabric F-tor 5 (unseparated dust).

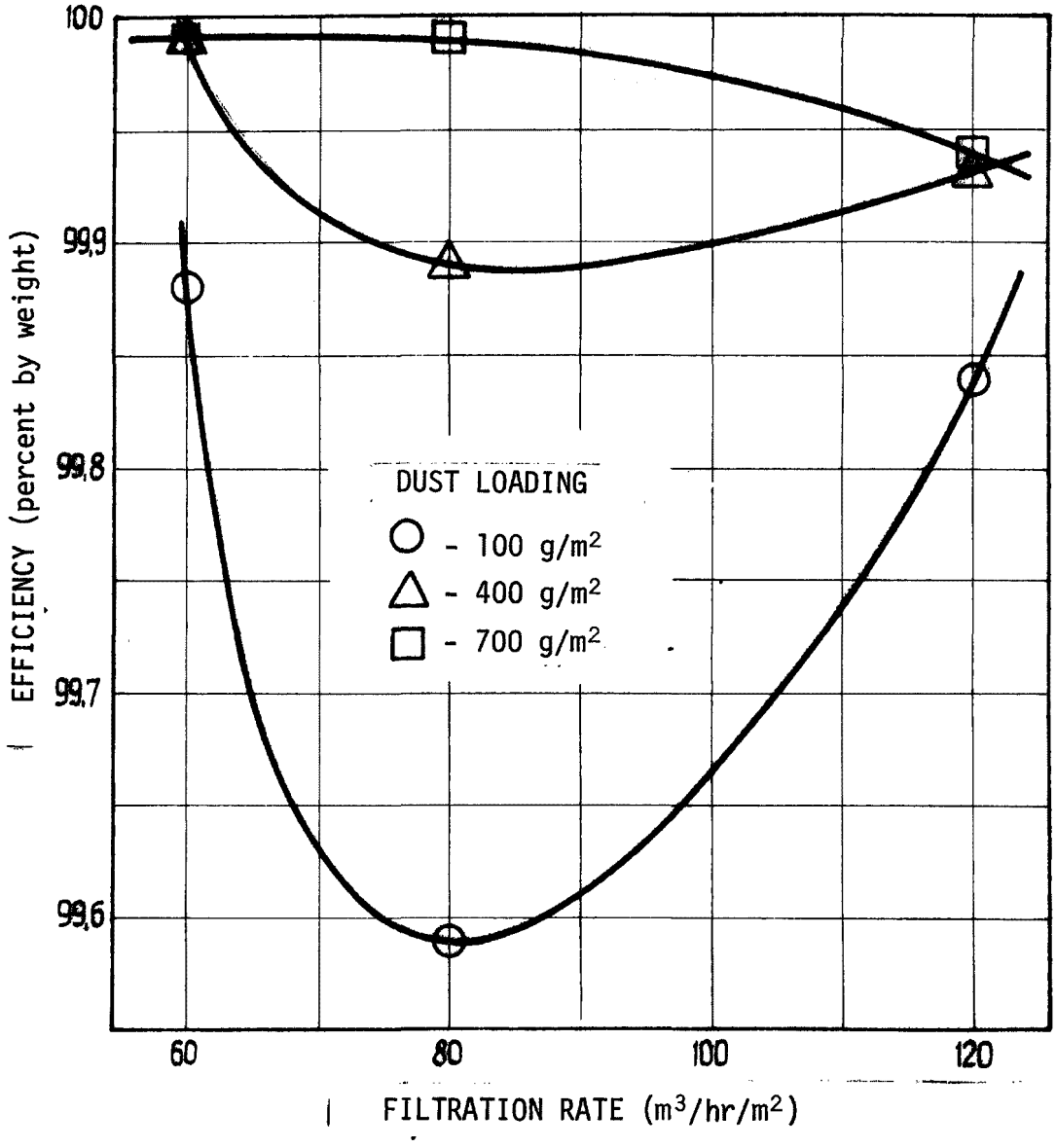


Figure A-50. Efficiency vs. Filtration Rate for Cement Dust and Fabric PT-15 (unseparated dust).

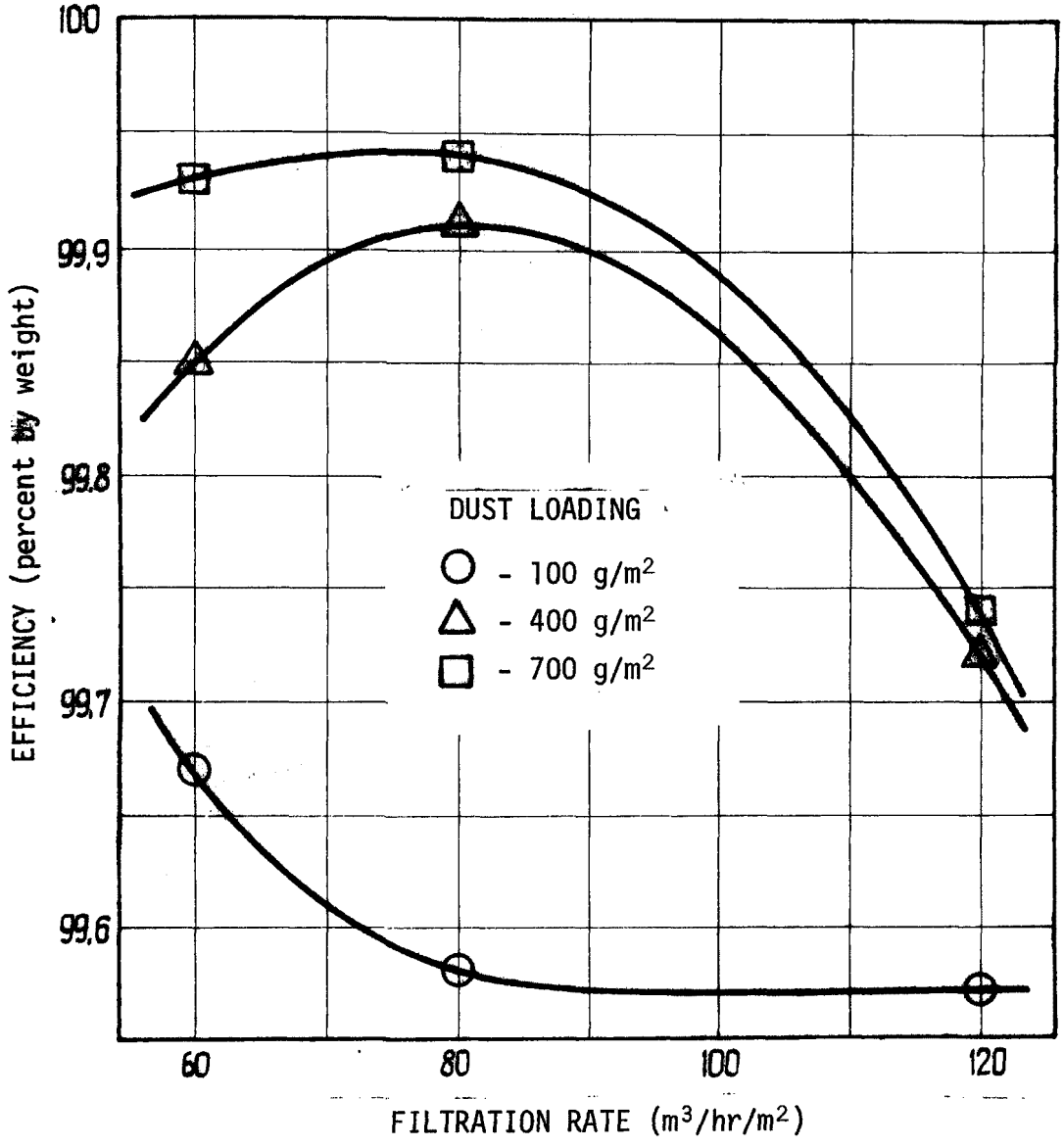


Figure A-51. Efficiency vs. Filtration Rate for Coal Dust and Fabric ET-4 (unseparated dust).

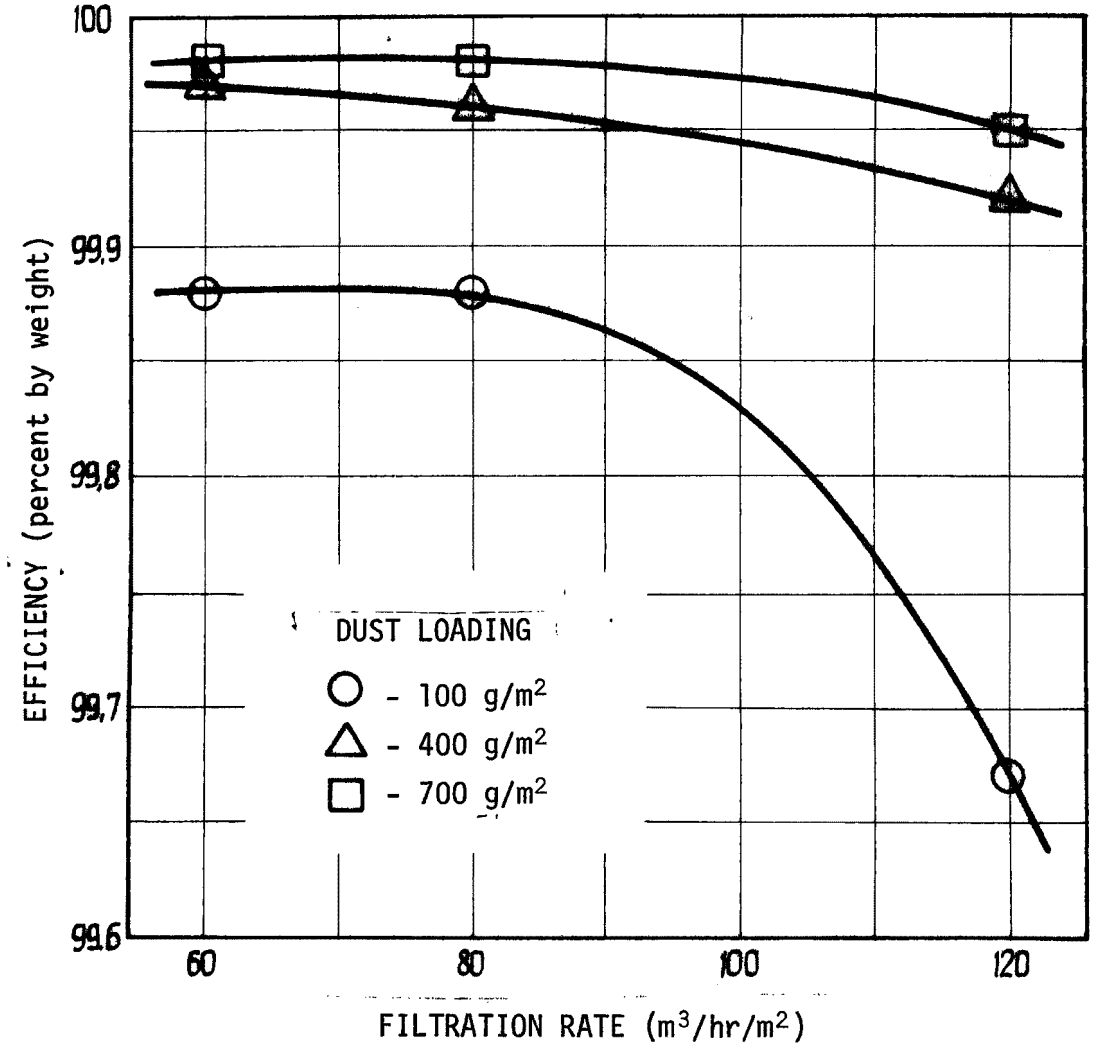


Figure A-52. Efficiency vs. Filtration Rate for Coal Dust and Fabric ET-30 (unseparated dust).

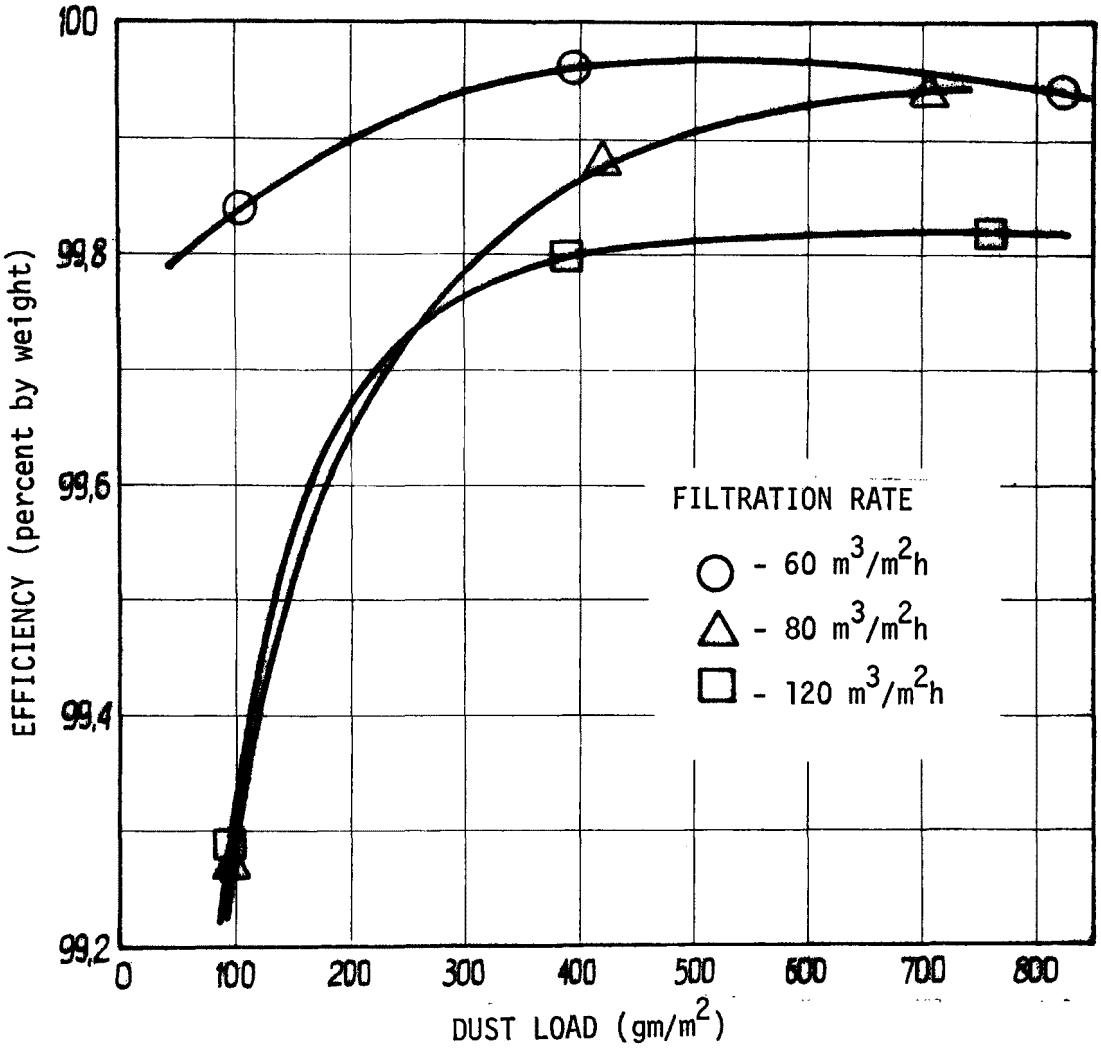


Figure A-53. Efficiency vs. Dust Load for Cement Dust and Fabric ET-4 (unseparated dust).

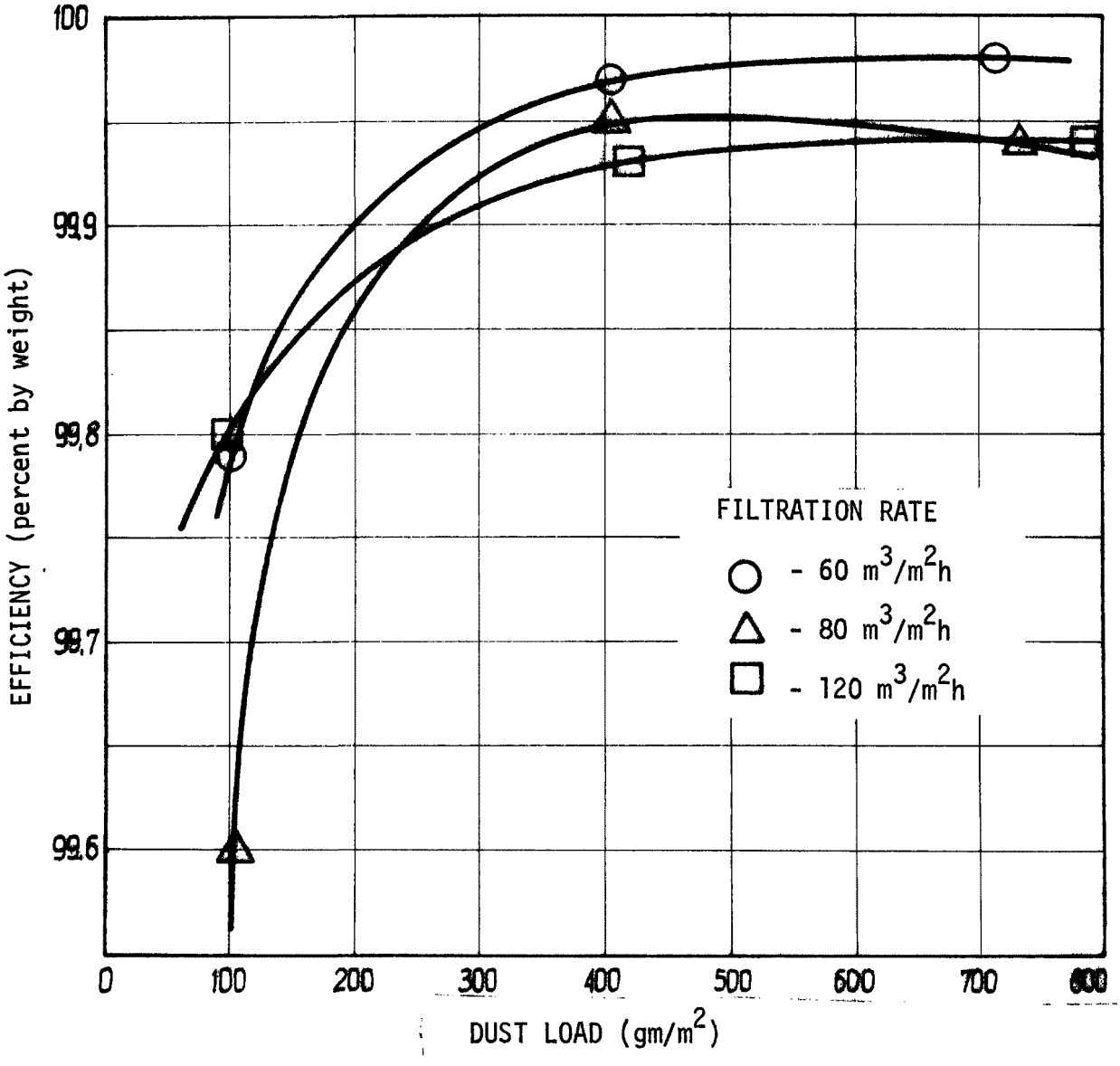


Figure A-54. Efficiency vs. Dust Load for Cement Dust and Fabric ET-30 (unseparated dust).

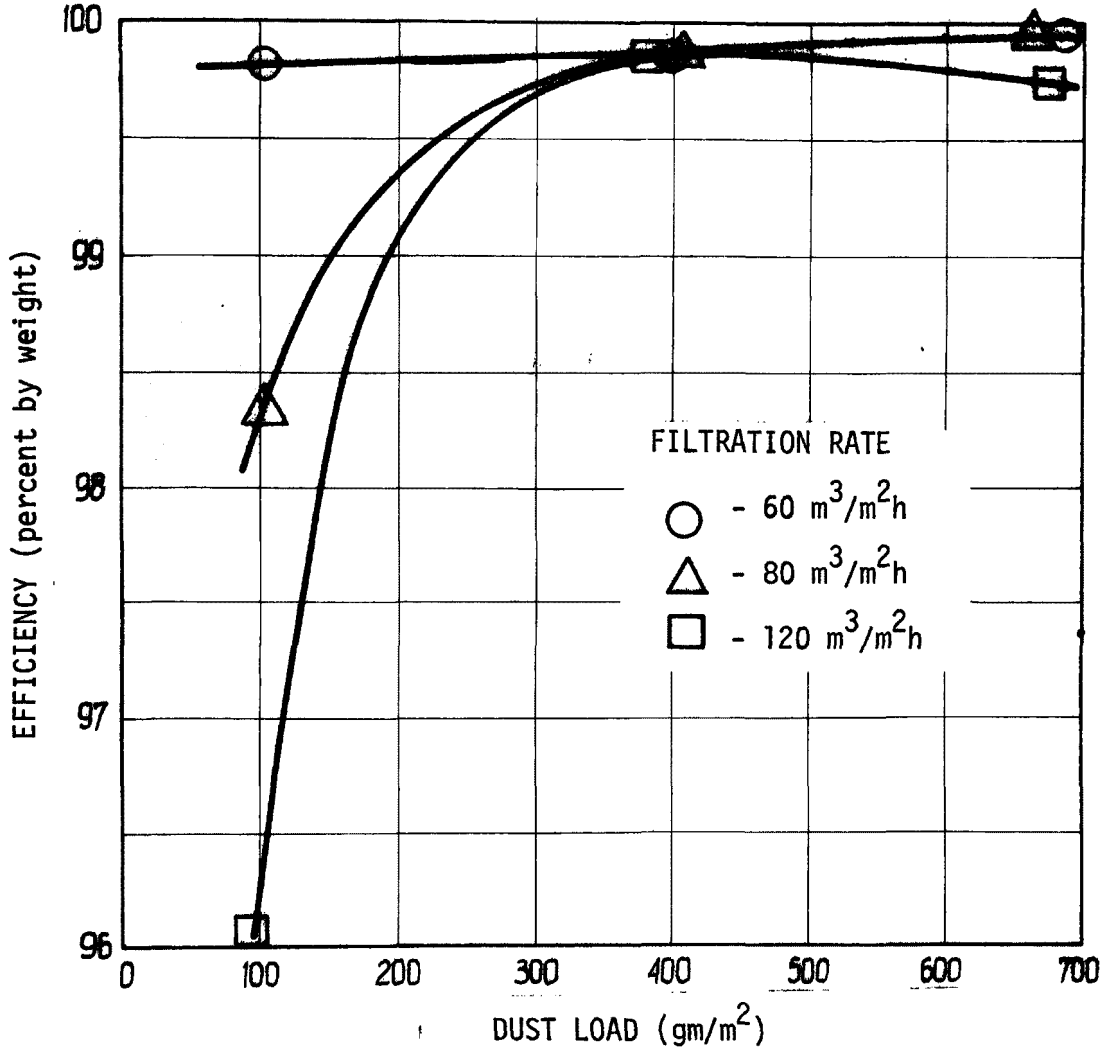


Figure A-55. Efficiency vs. Dust Load for Cement Dust and Fabric F-tor 5 (unseparated dust).

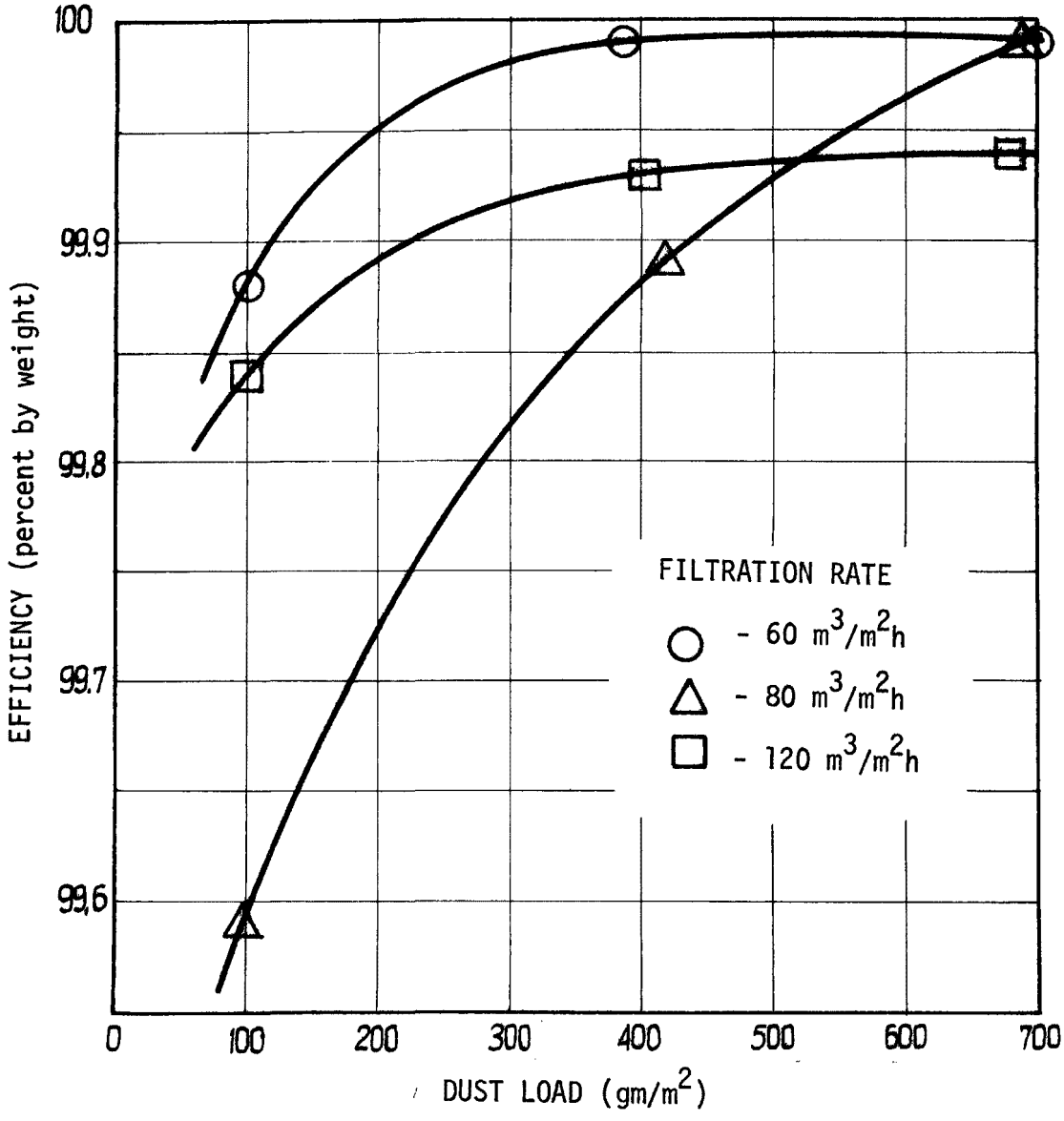


Figure A-56. Efficiency vs. Dust Load for Cement Dust and Fabric PT-15 (unseparated dust).

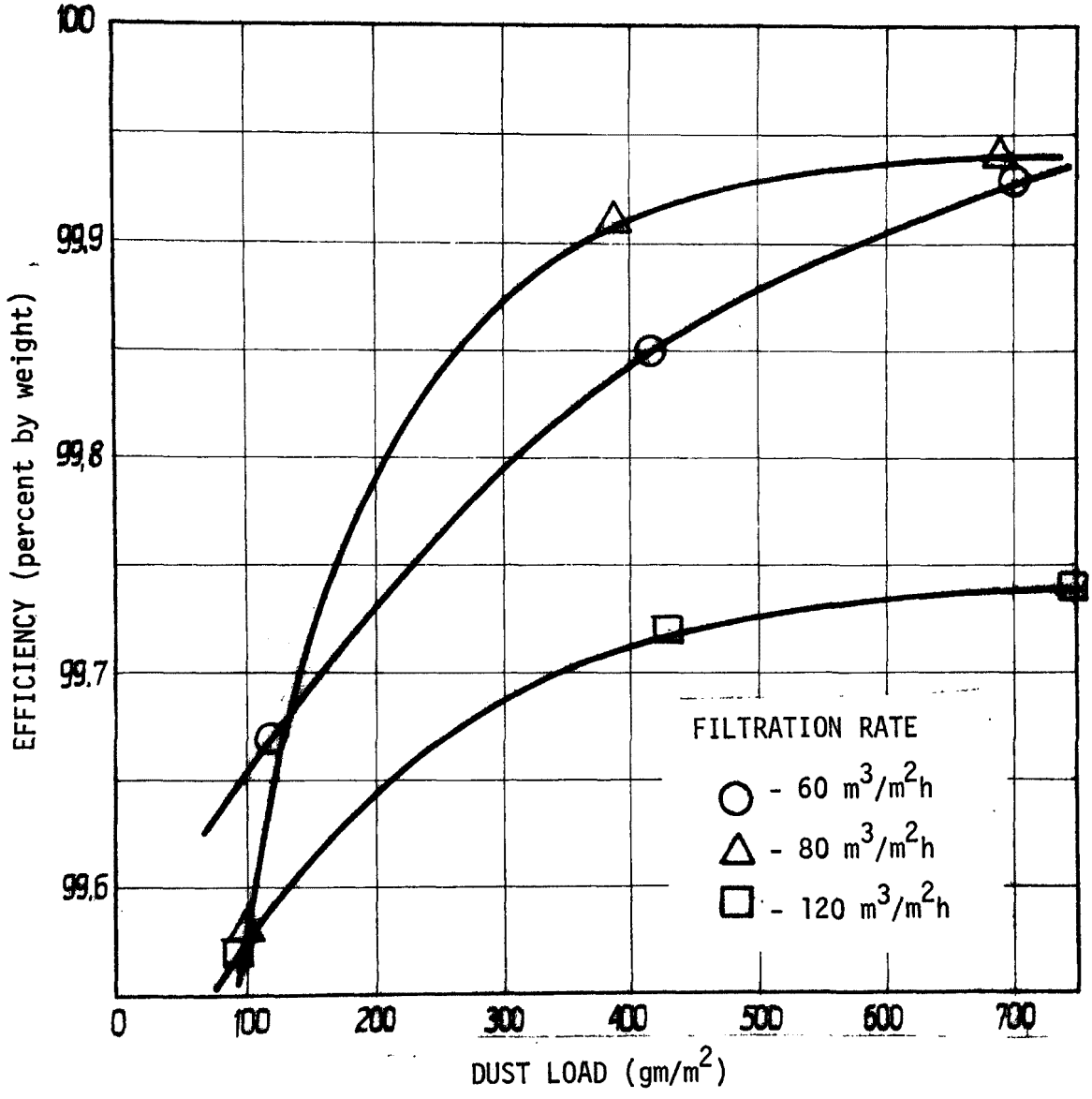


Figure A-57. Efficiency vs. Dust Load for Coal Dust and Fabric ET-4 (unseparated dust).

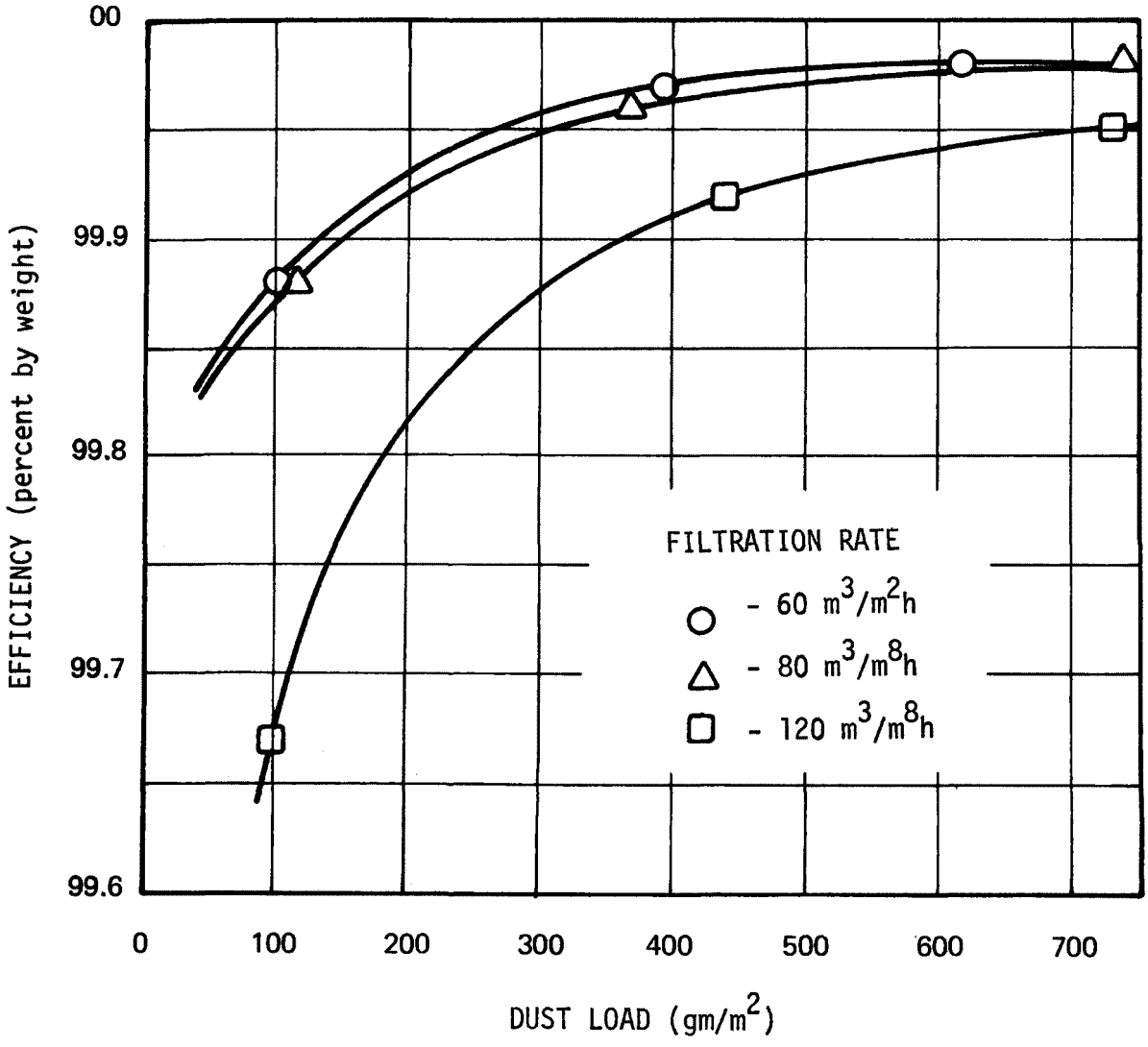
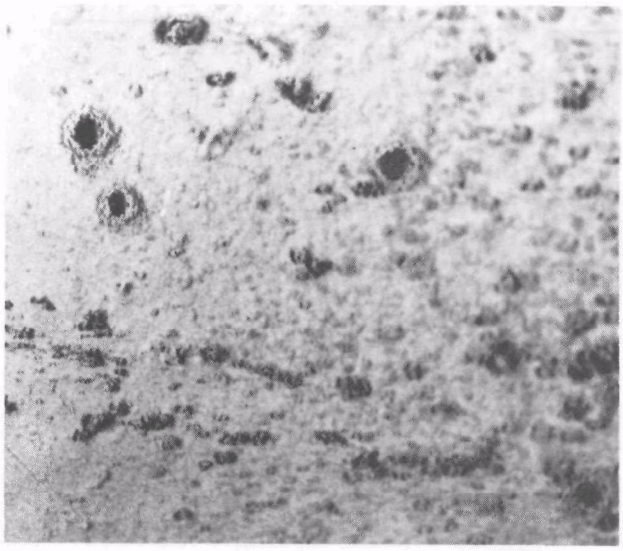
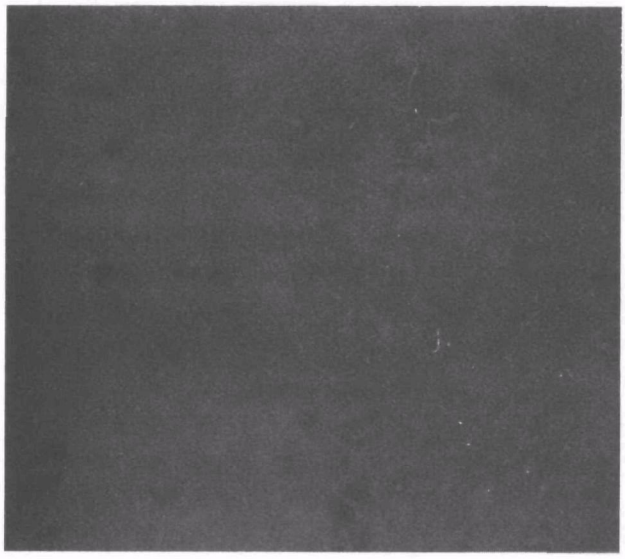


Figure A-58. Efficiency vs. Dust Load for Coal Dust and Fabric ET-30 (unseparated dust).



Cement dust



Coal dust

Figure A-59. Ducts/Canals in Coal and Cement Dust (3x magnification)
$q_o = 120\ m^3/m^2 \cdot min$, $L_o = 700\ g/m^3$.

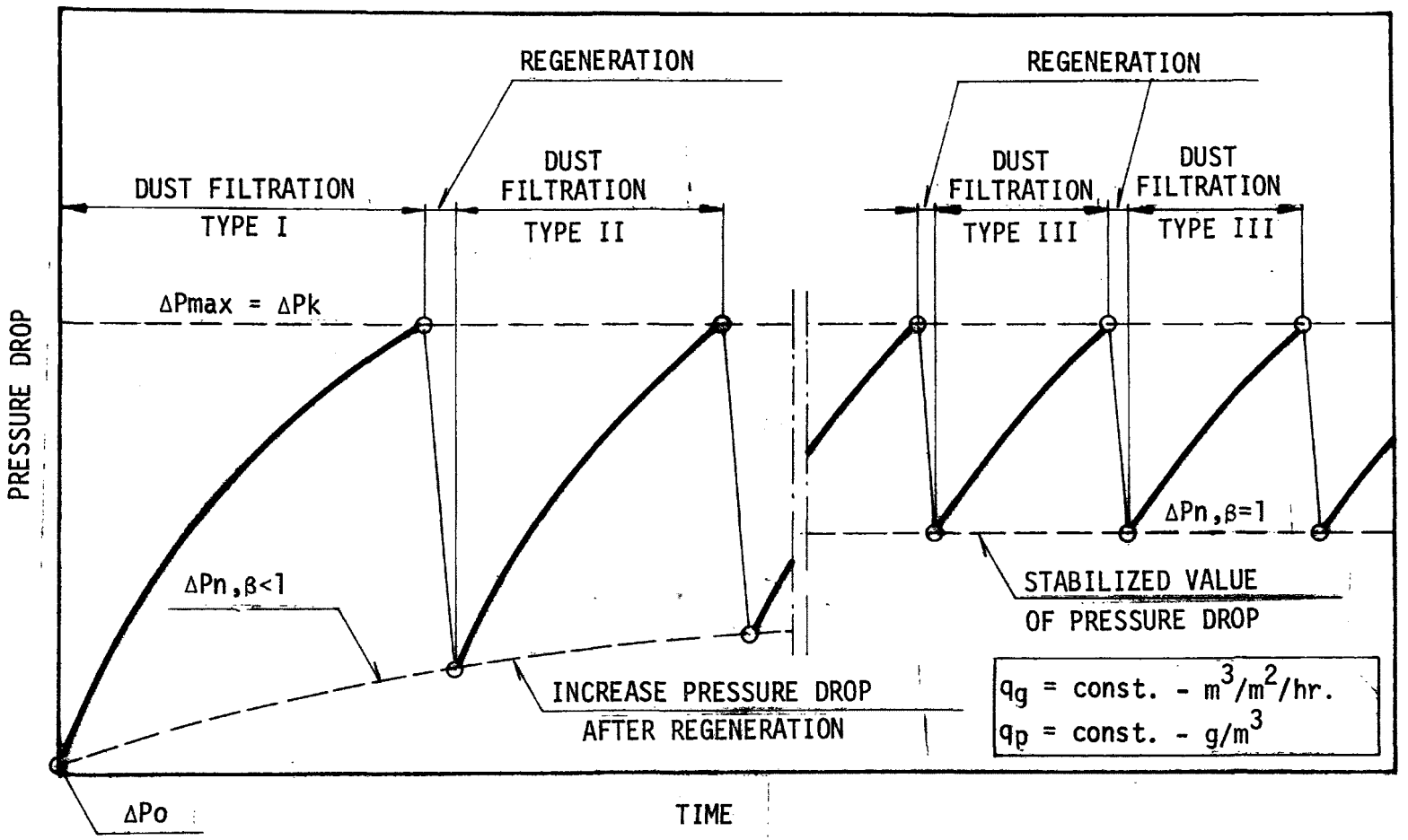
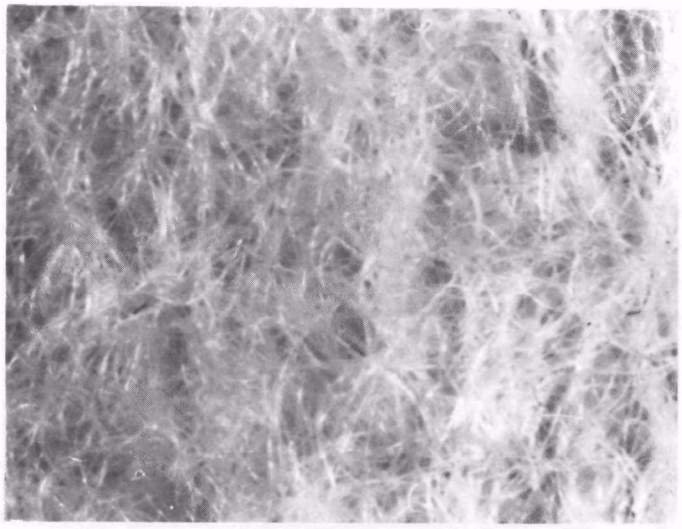
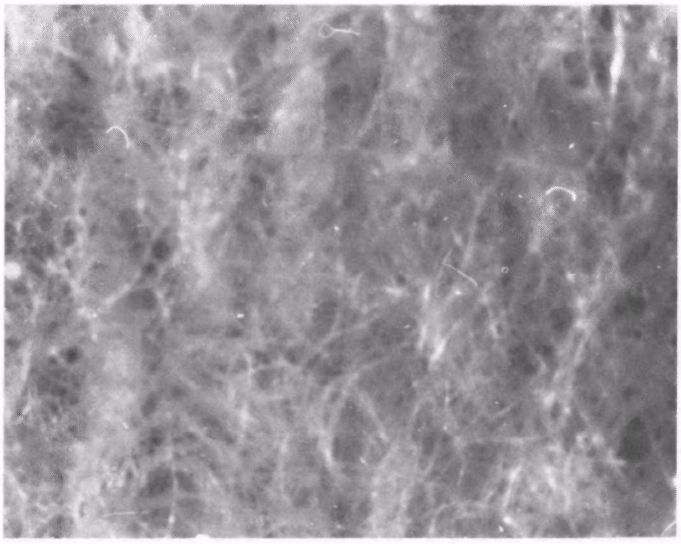


Figure A-60. Types of Dust Filtration.

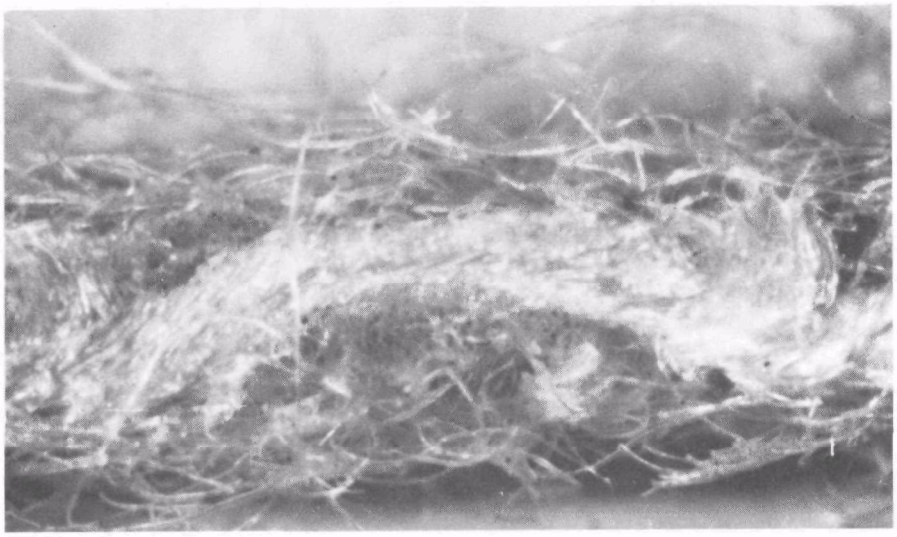


Inlet

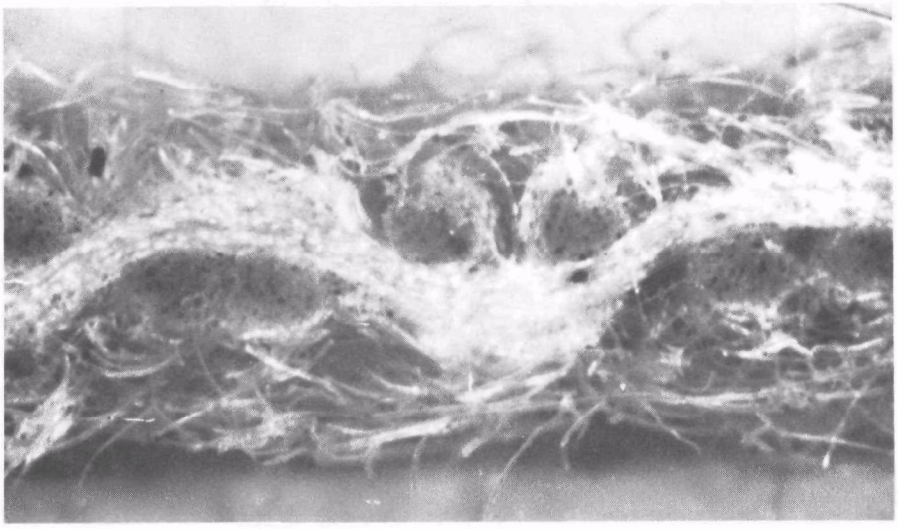


Outlet

Figure A-61. Surfaces of Clean Fabric WT-201 (wool fiber).



Across warp



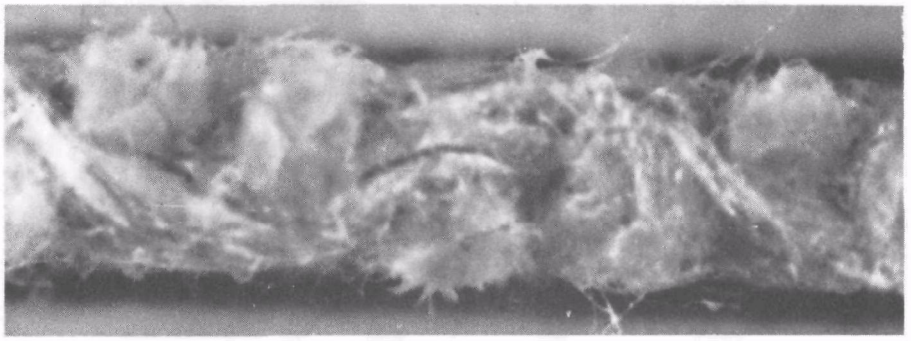
Across fill

Figure A-62. Clean Fabric WT-201.

Inlet

Outlet

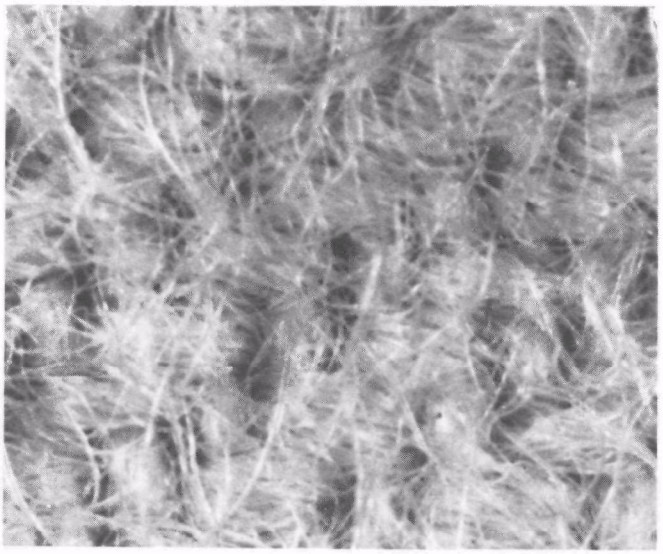
Figure A-63. Surfaces of Clean Fabric BT-57 (cotton fiber).



Across warp

Across fill

Figure A-64. Clean Fabric BT-57.



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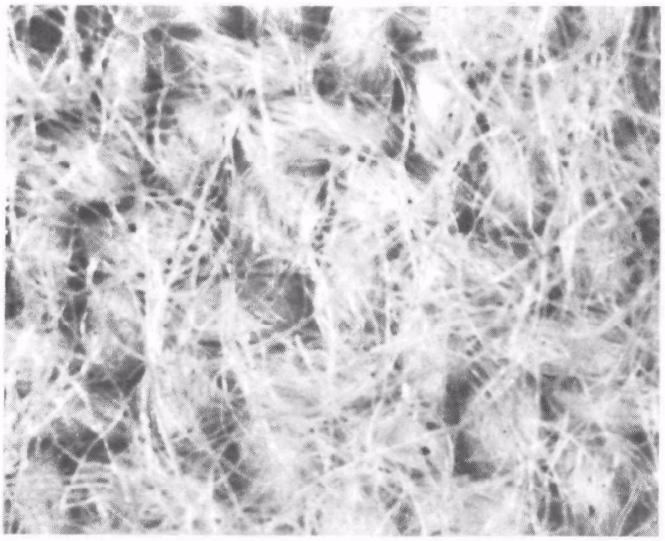
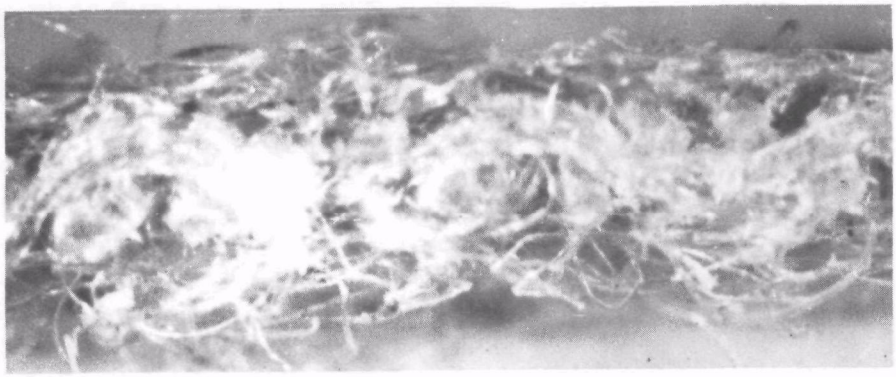
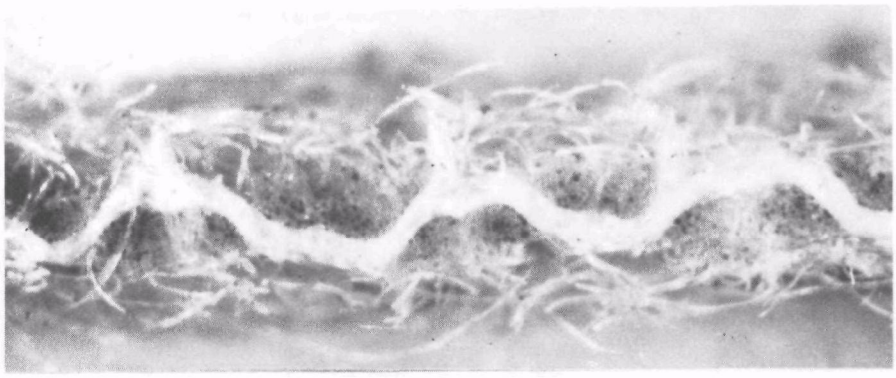


Outlet

Figure A-65. Surfaces of Clean Fabric WBT-210 (wool-cotton fiber).



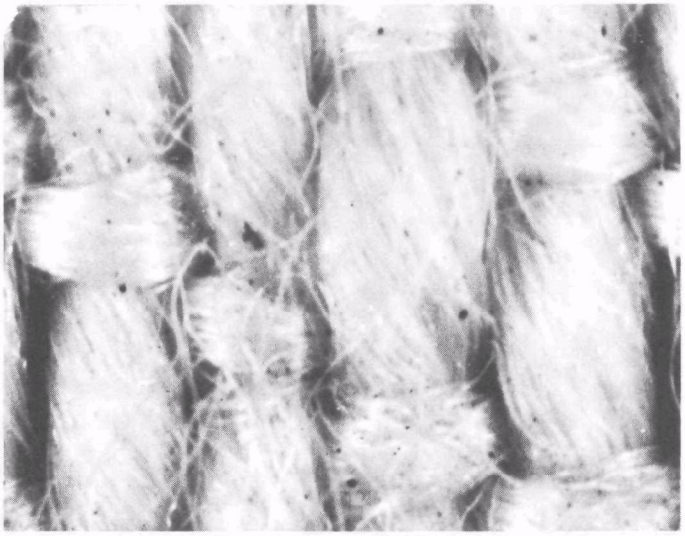
Across warp



Across fill

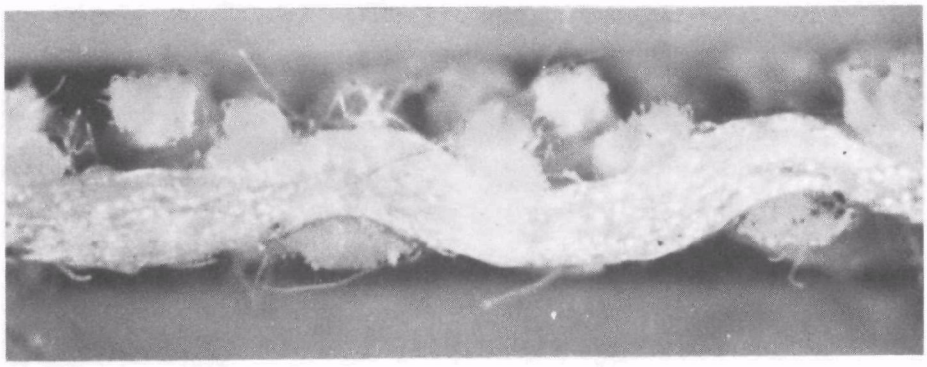
Figure A-66. Clean Fabric WBT-210.

Inlet

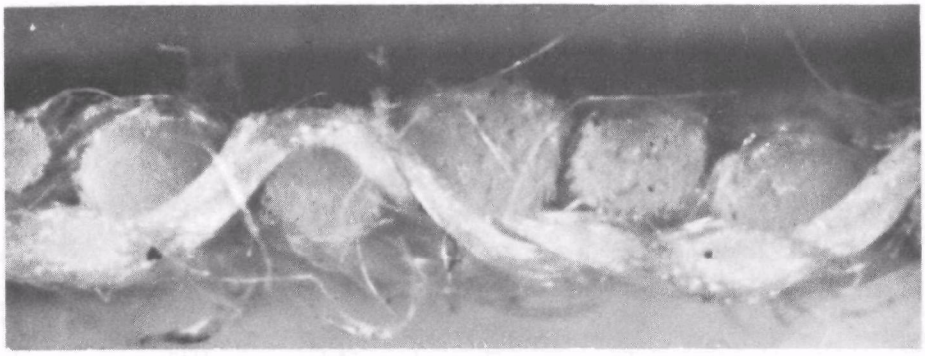


Outlet

Figure A-67. Surfaces of Clean Fabric ET-4 (polyester fiber).

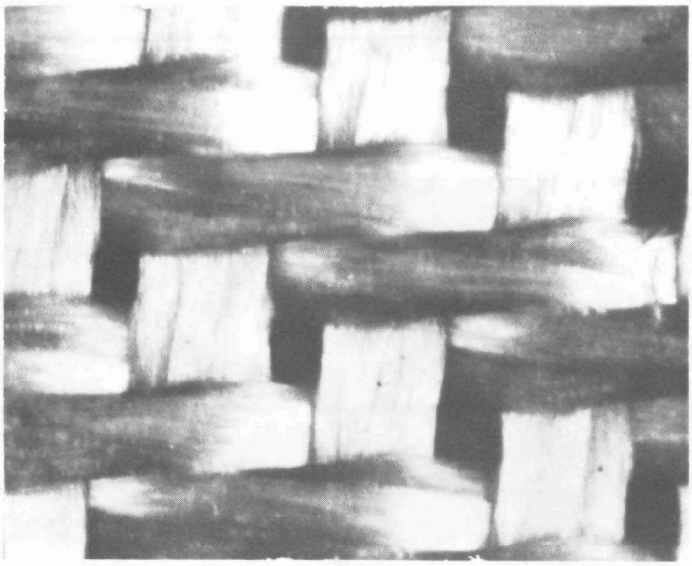


Across warp

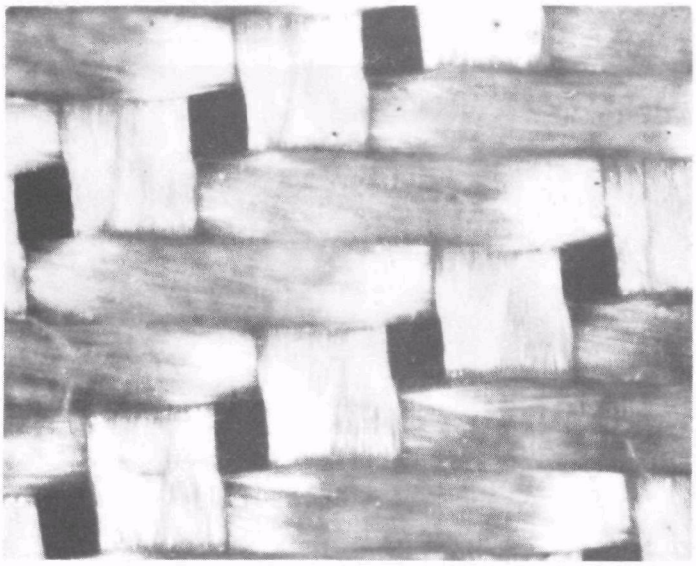


Across fill

Figure A-68. Clean Fabric ET-4.

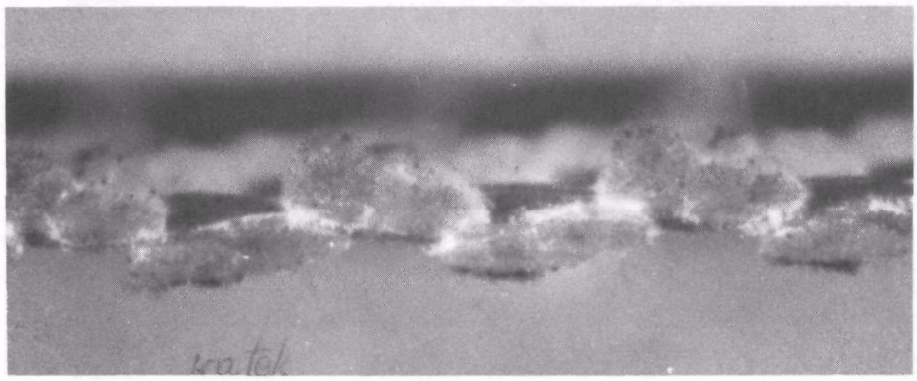


Inlet

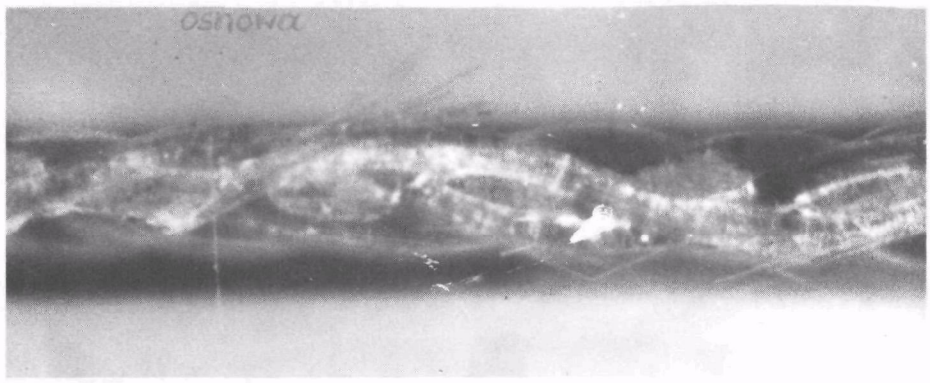


Outlet

Figure A-69. Surfaces of Clean Fabric ST-1 (glass fiber).



Across warp



Across fill

Figure A-70. Clean Fabric ST-1.

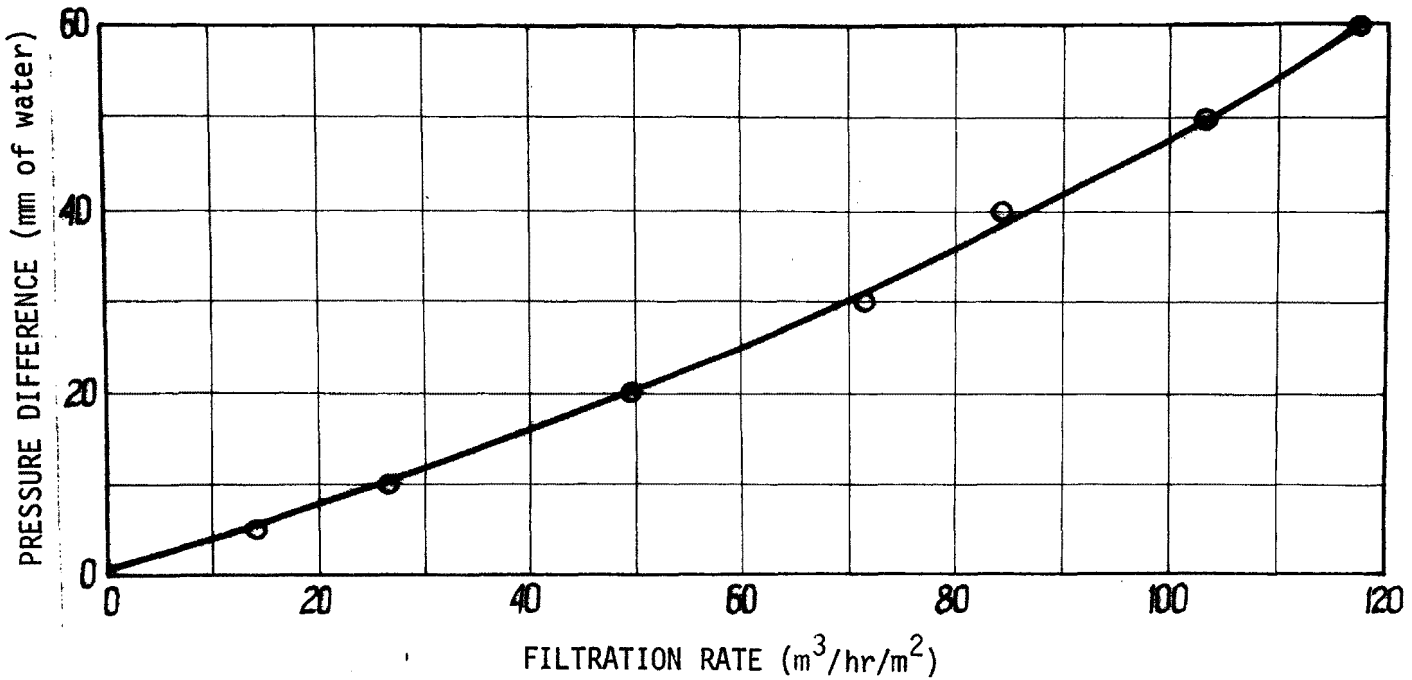


Figure A-71. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WT-201 (wool-high velocity).

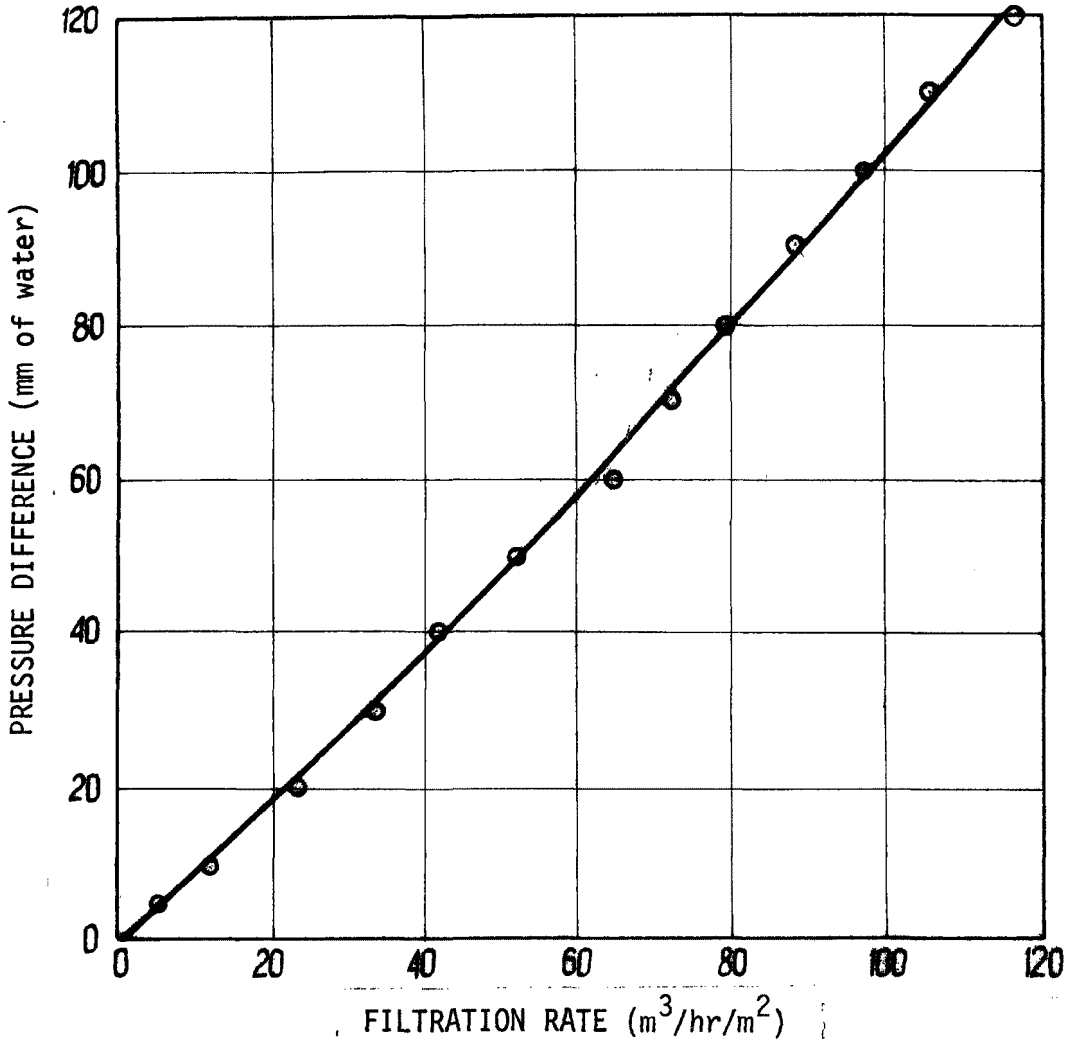


Figure A-72. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WT-202 (wool-high velocity).

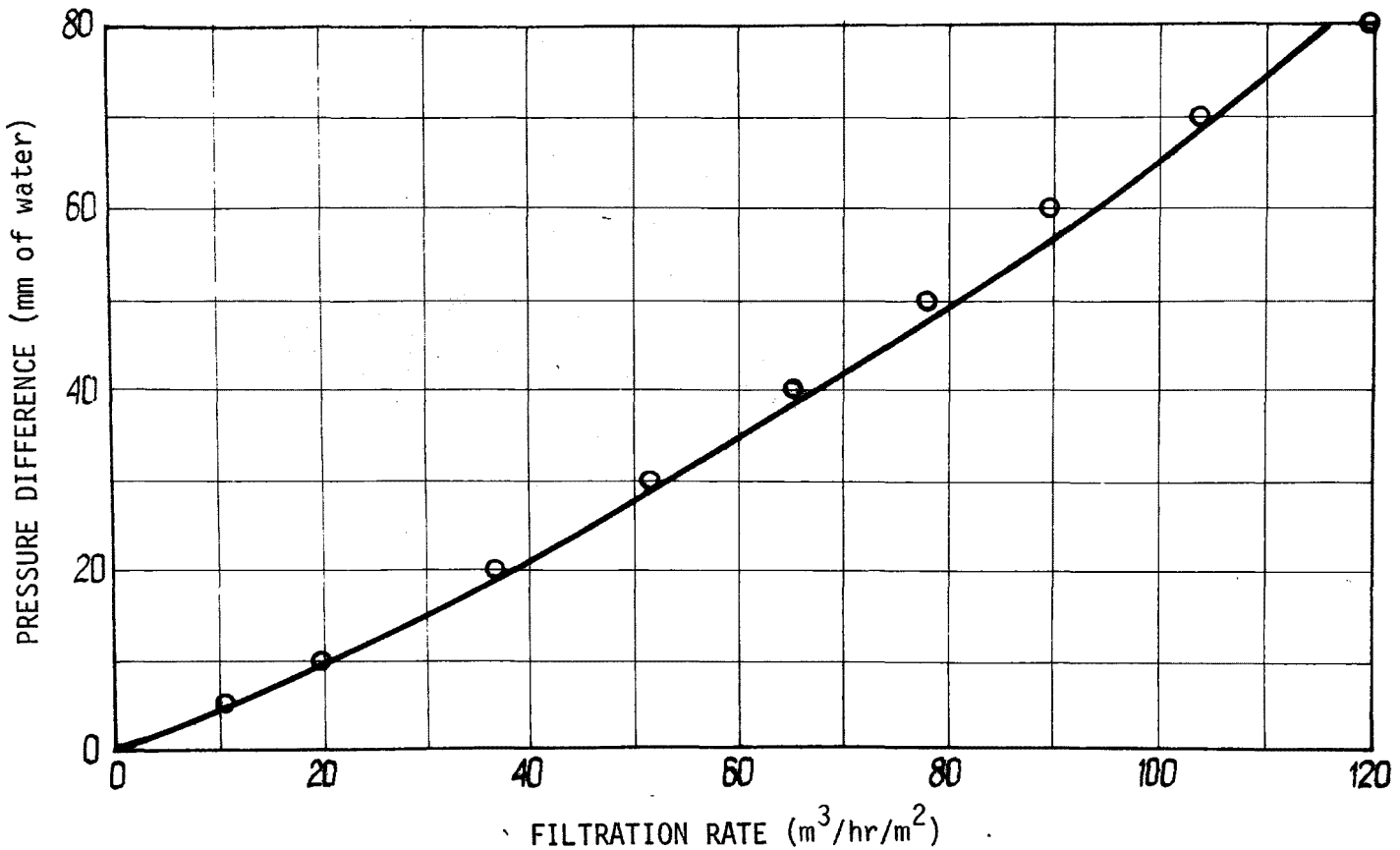


Figure A-73. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WT-203 (wool-high velocity).

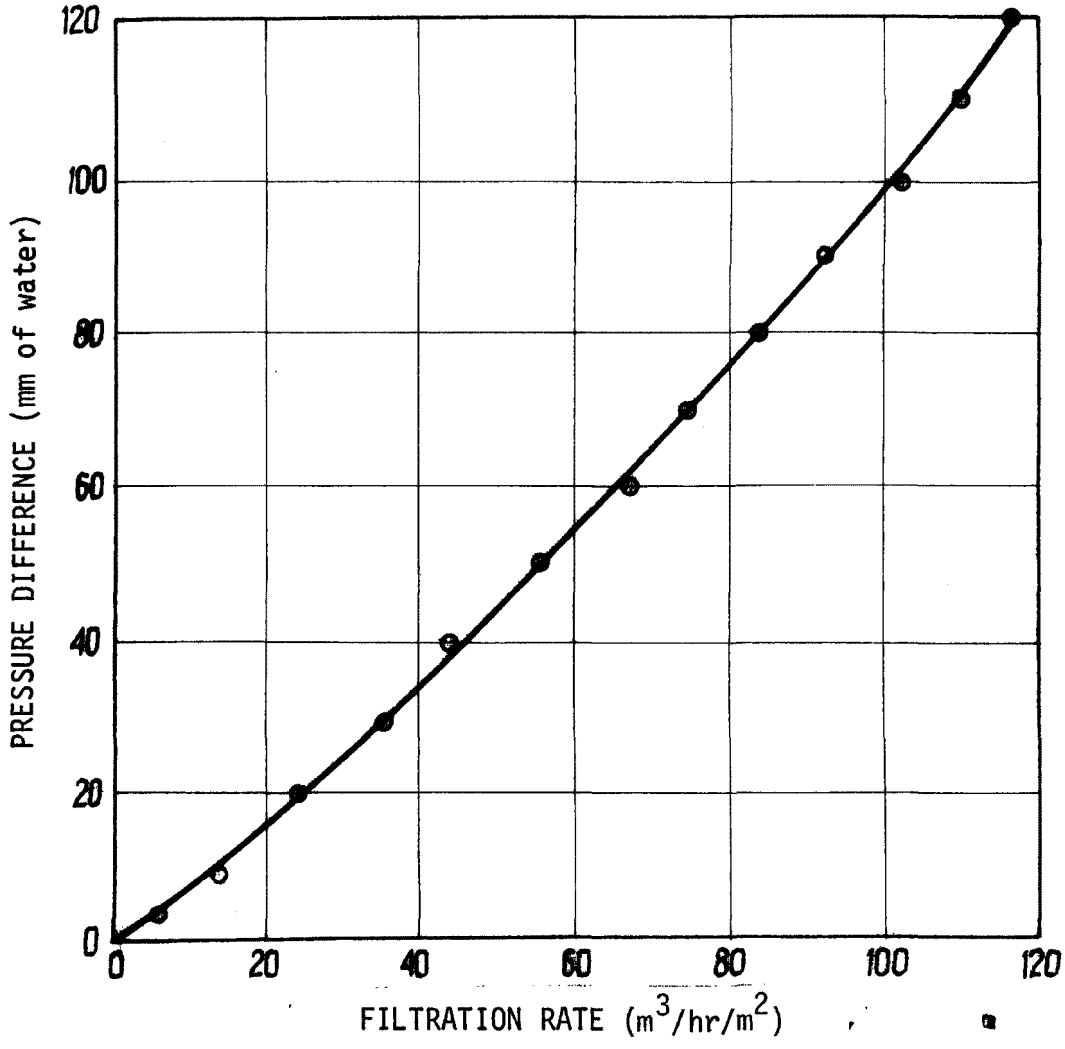


Figure A-74. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WT-207 (wool-high velocity).

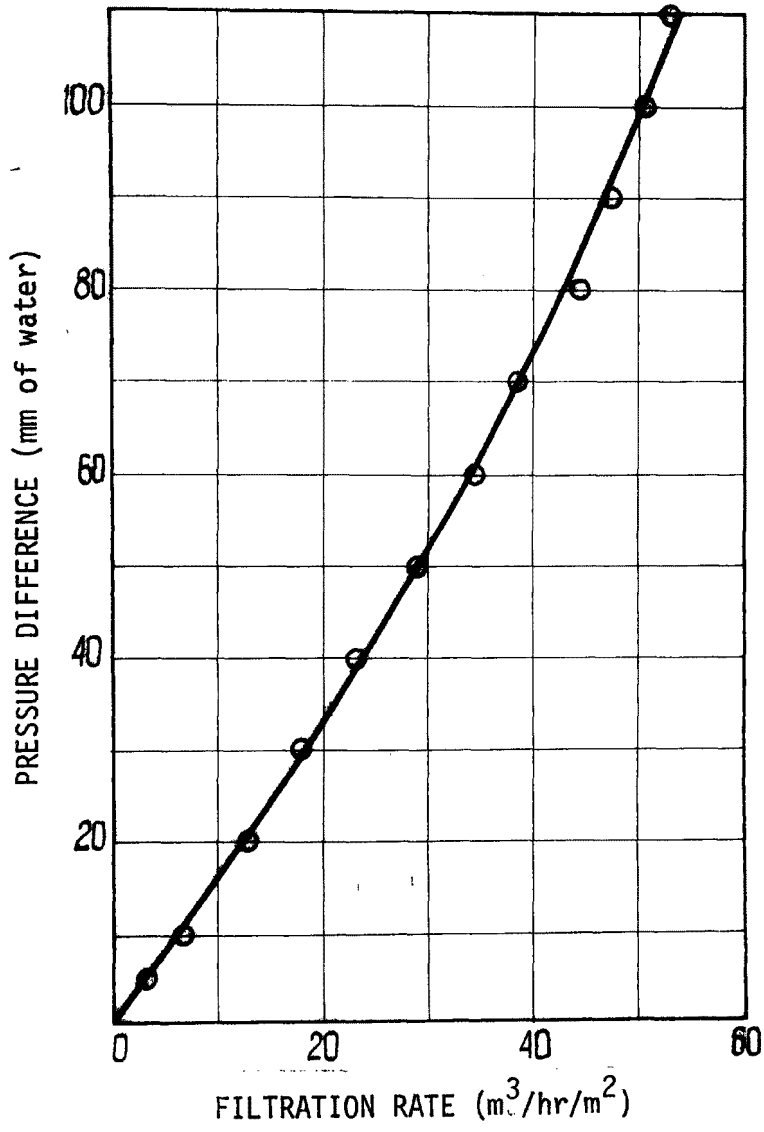


Figure A-75. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type BT-57 (cotton-high velocity).

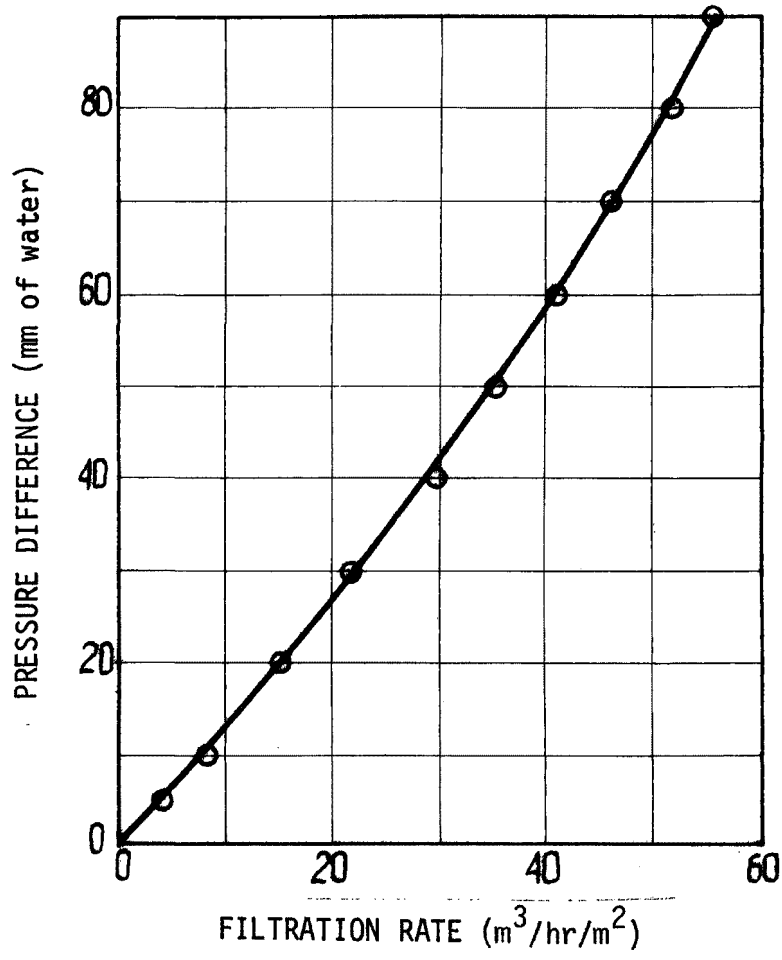


Figure A-76. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type BWA-1539 (cotton-high velocity).

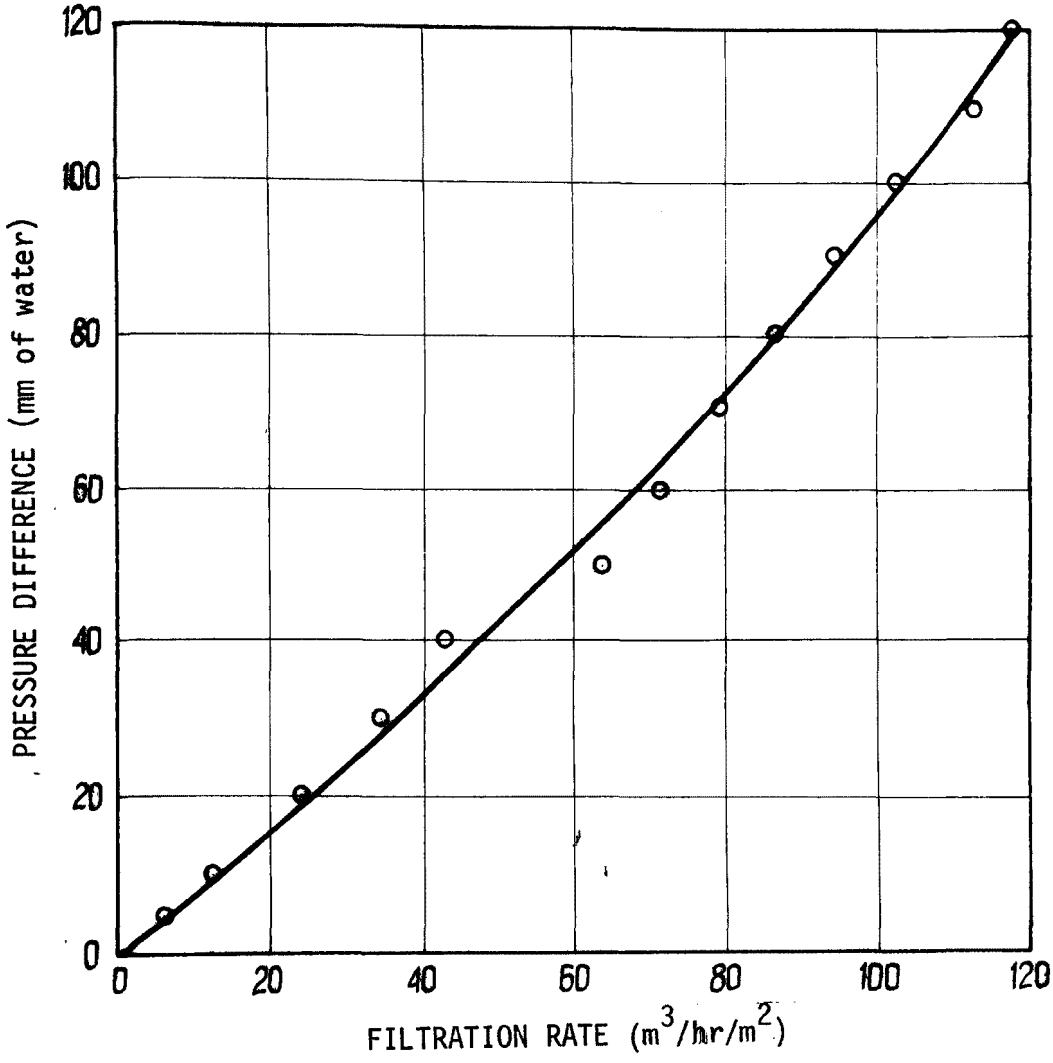


Figure A-77. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WBT-206 (wool/cotton-high velocity).

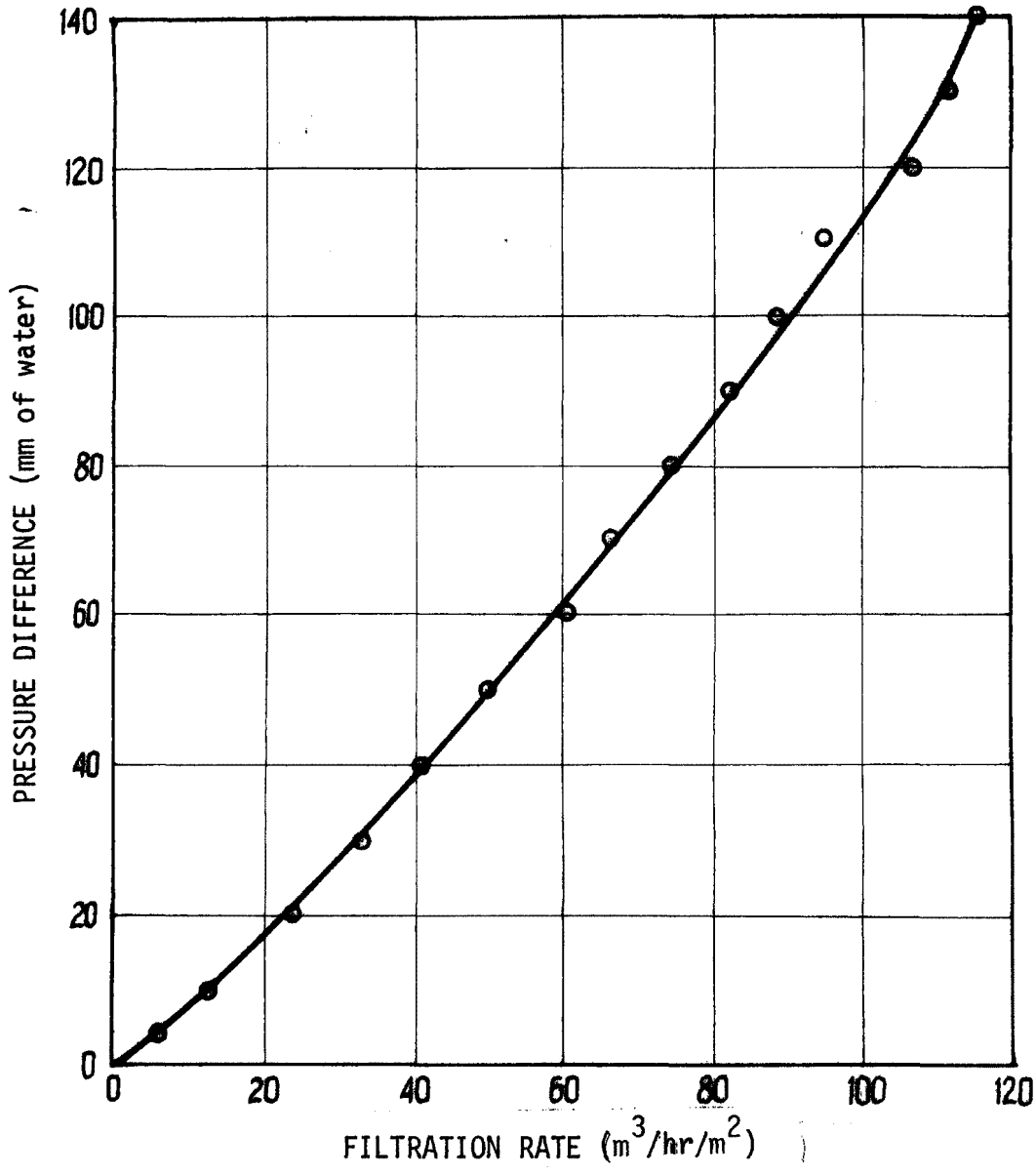


Figure A-78. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WBT-210 (wool/cotton-high velocity).

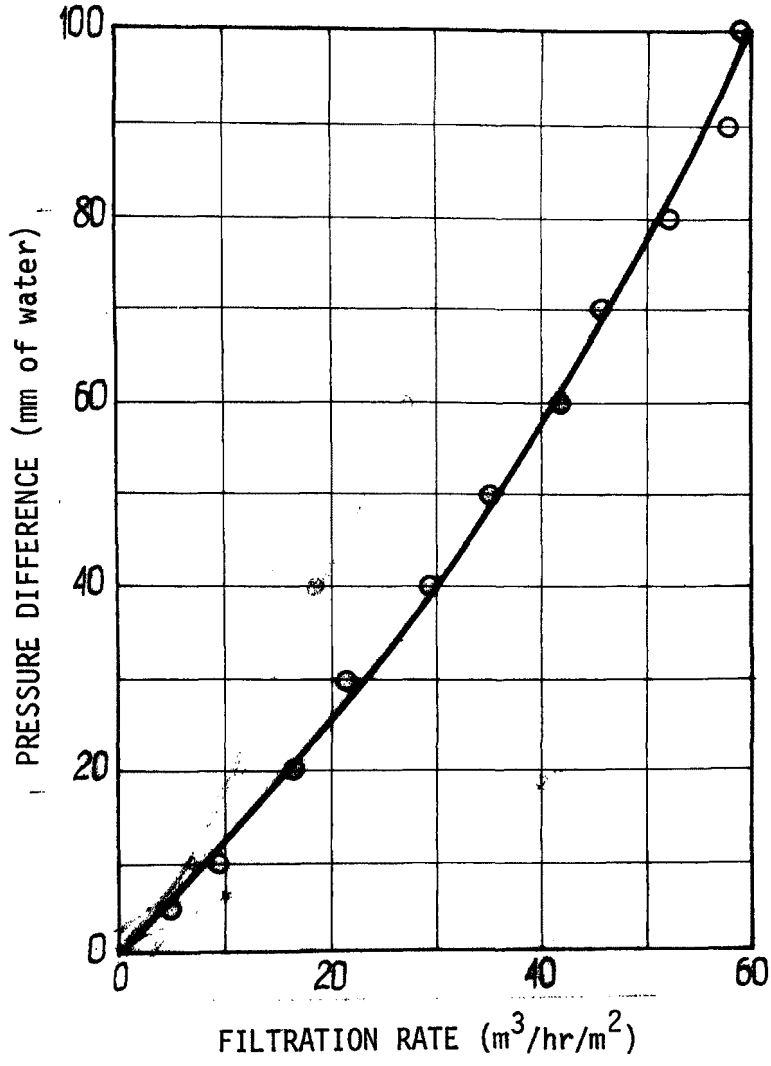


Figure A-79. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-1 (polyester-high velocity).

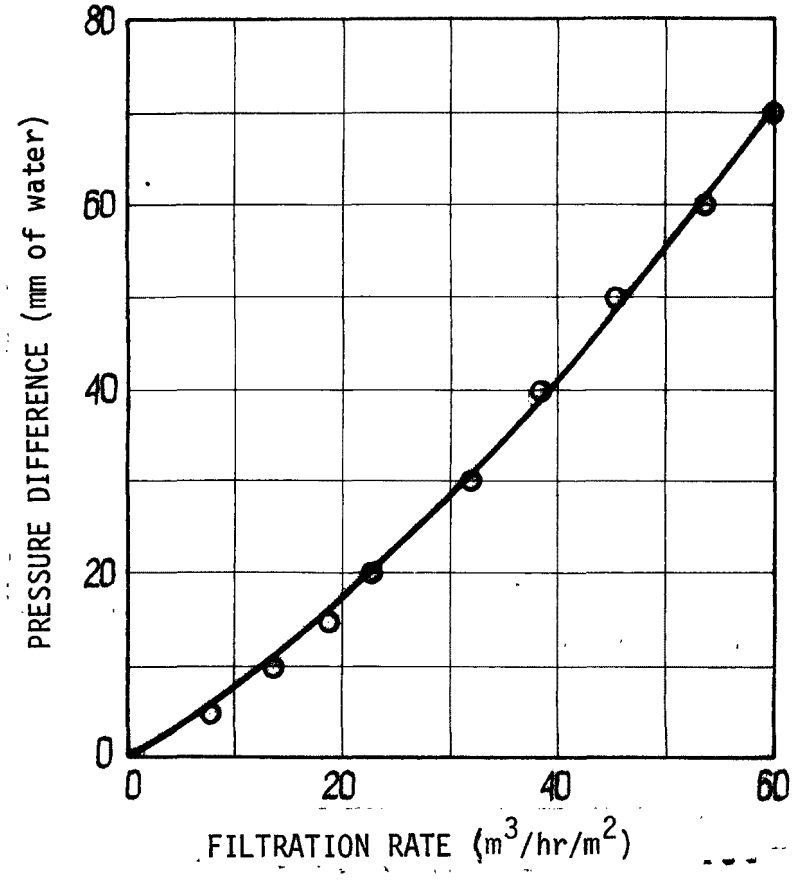


Figure A-80. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-2 (polyester-high velocity).

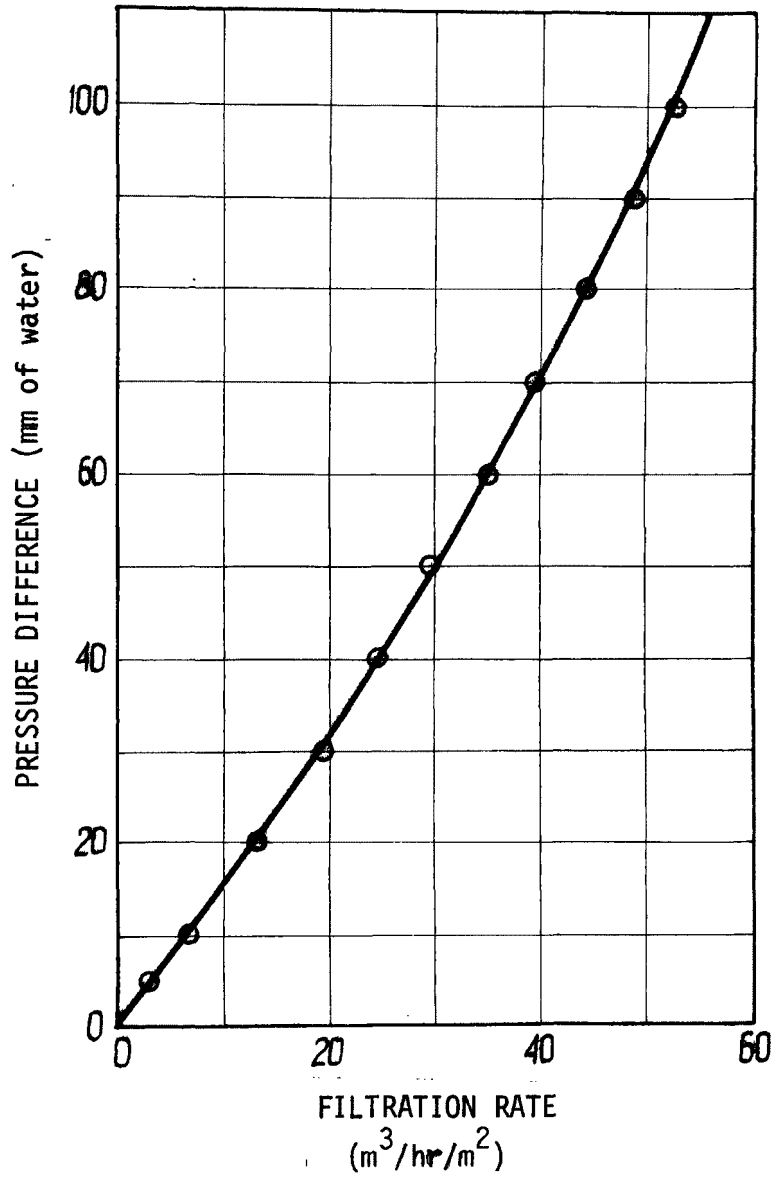


Figure A-81. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-3

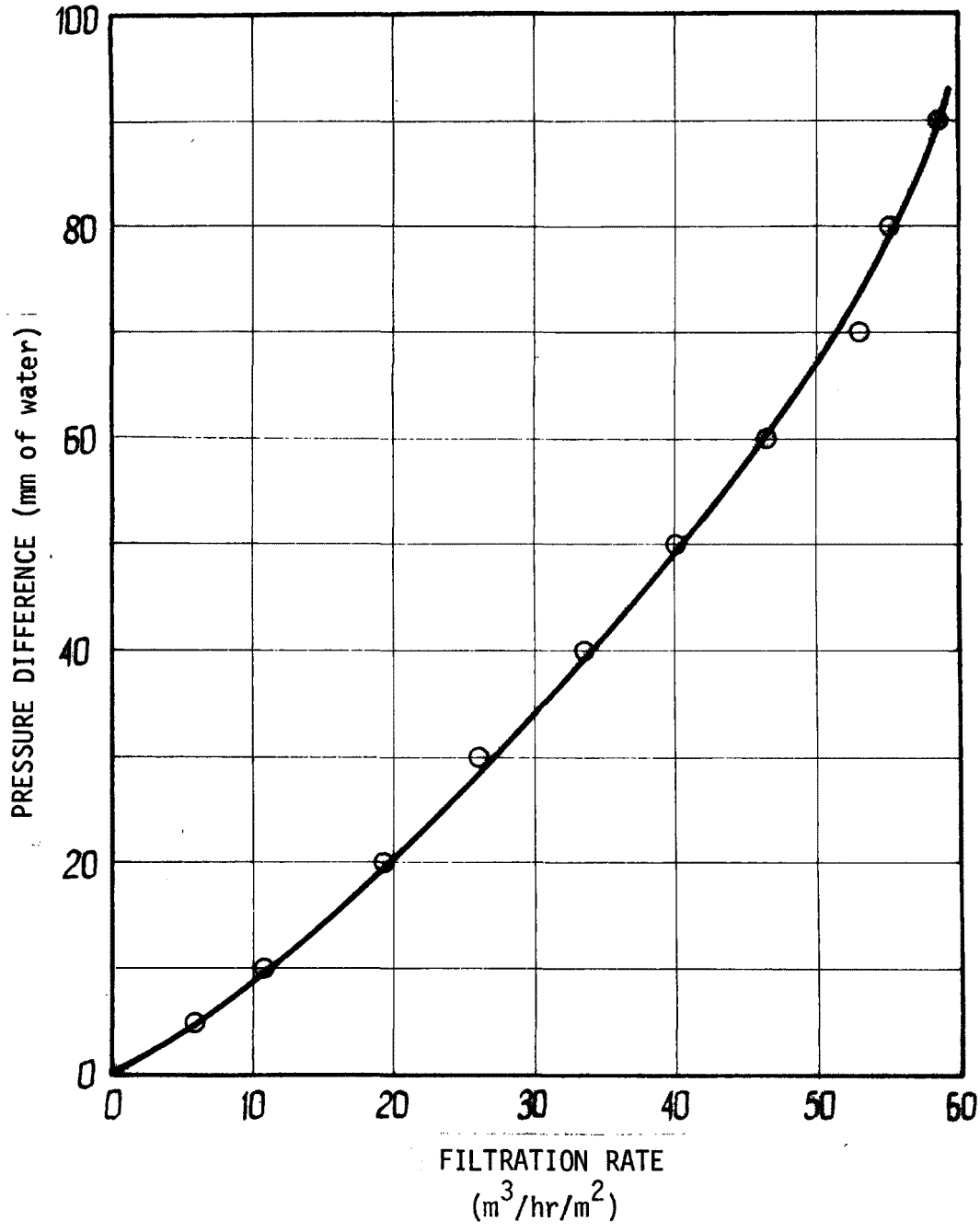


Figure A-82. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-4 (polyester-high velocity).

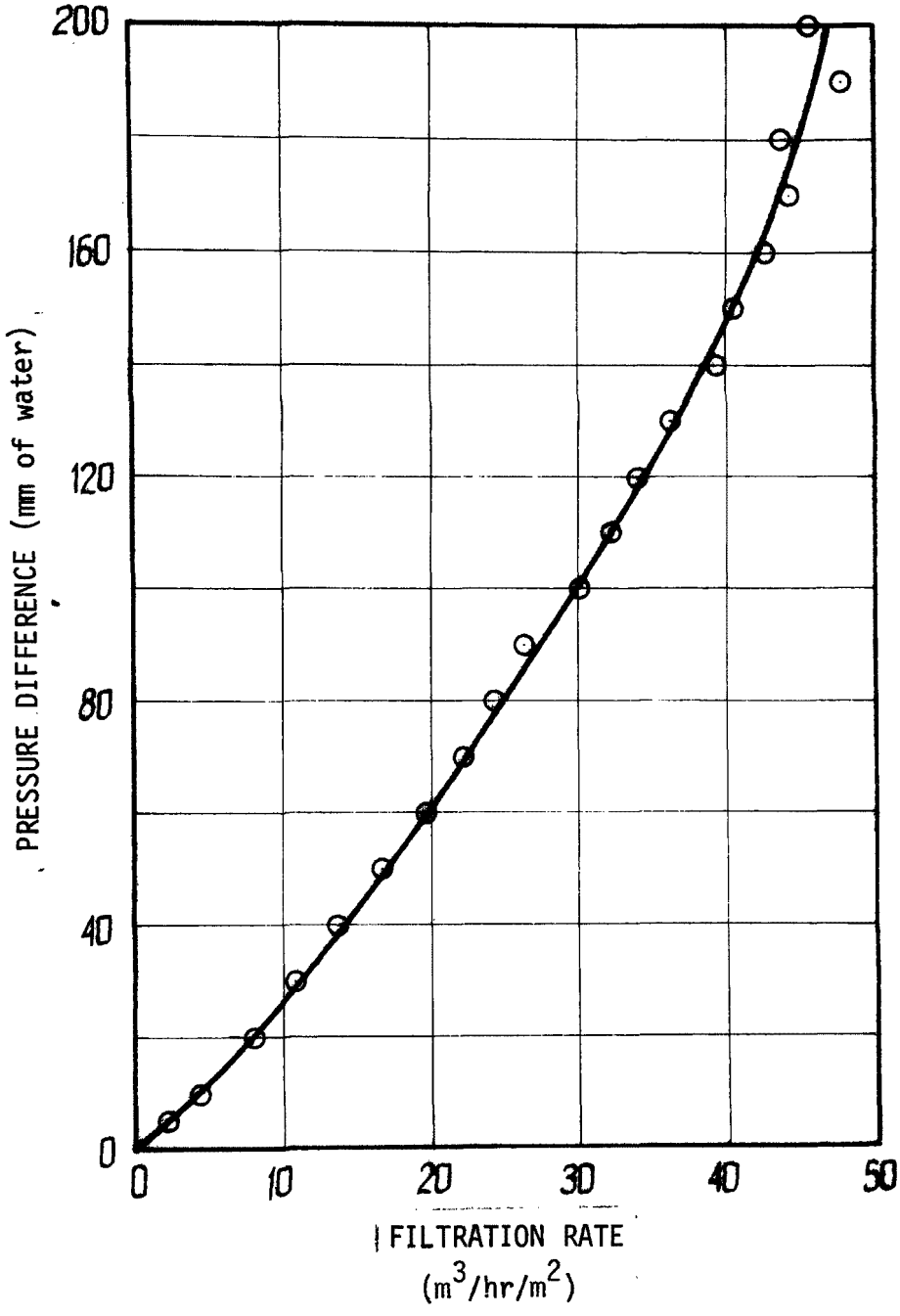


Figure A-83. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-30 (polyester-high velocity).

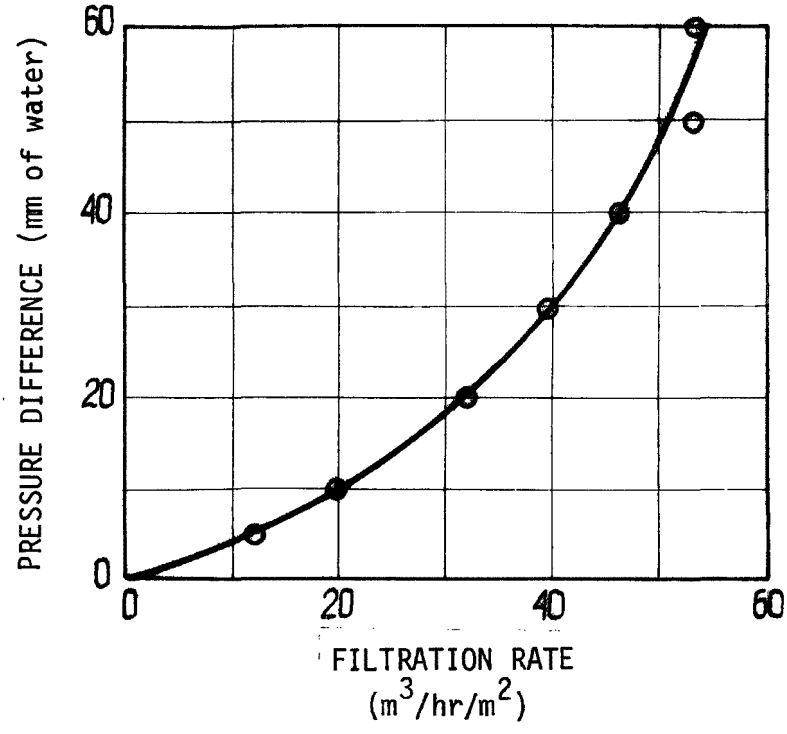


Figure A-84. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ST-1 (glass-high velocity).

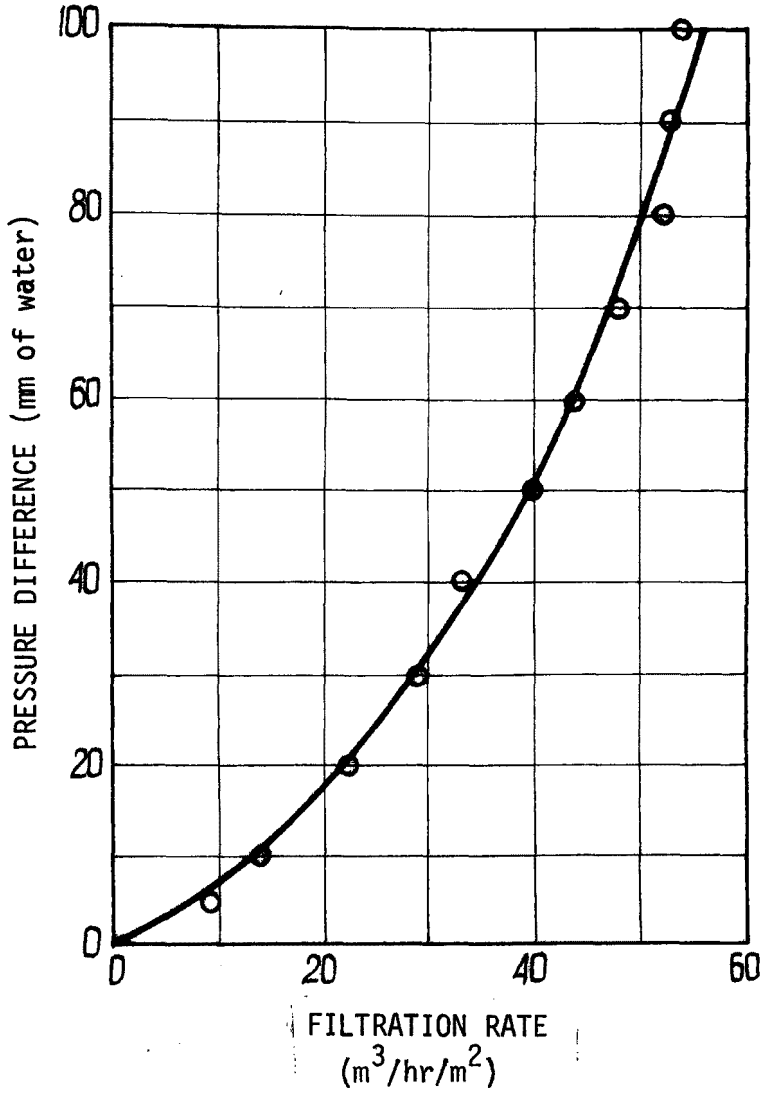


Figure A-85. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ST-13 (glass-high velocity).

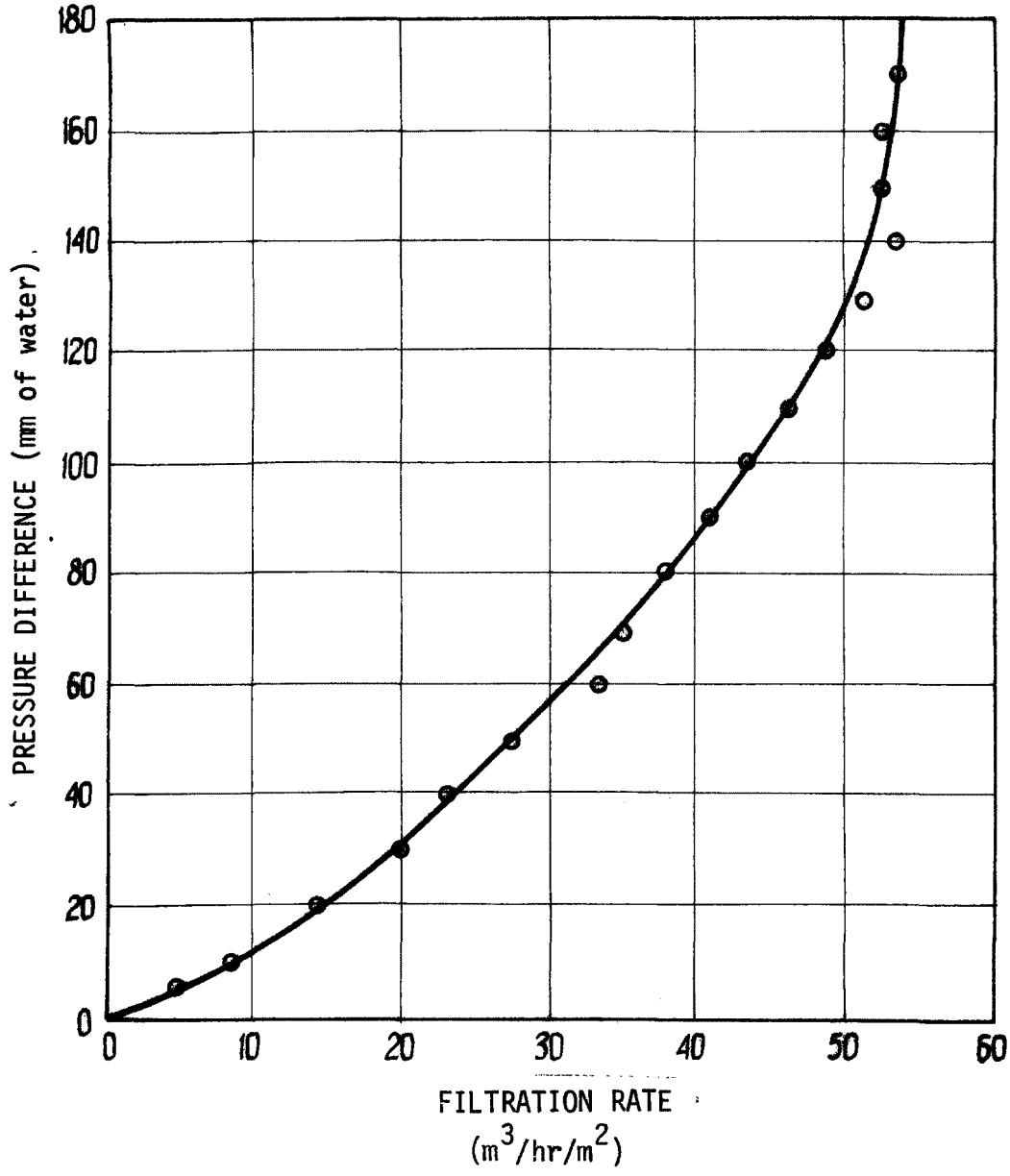


Figure A-86. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ST-41 (glass-high velocity).

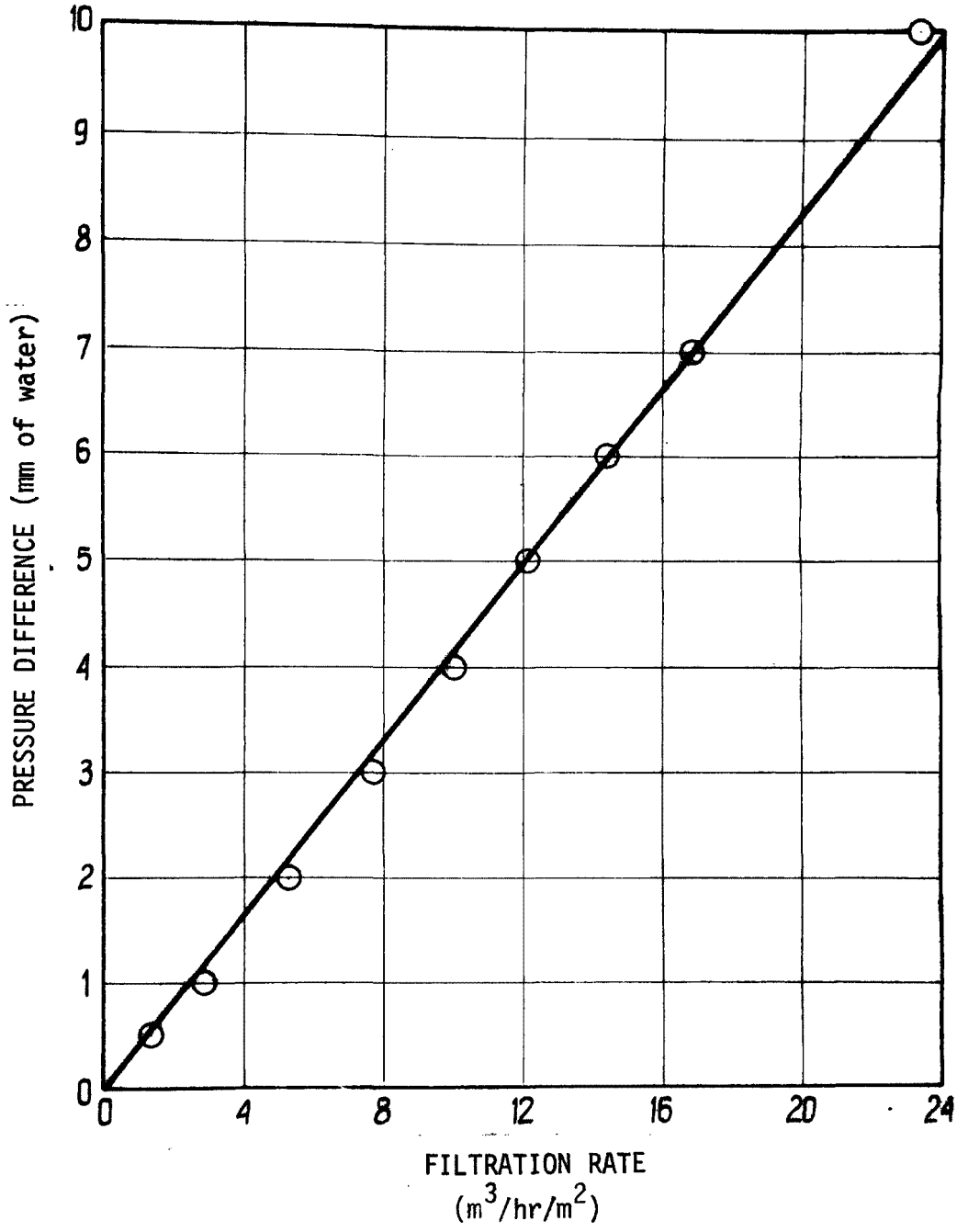


Figure A-87. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WT-201 (wool-low velocity).

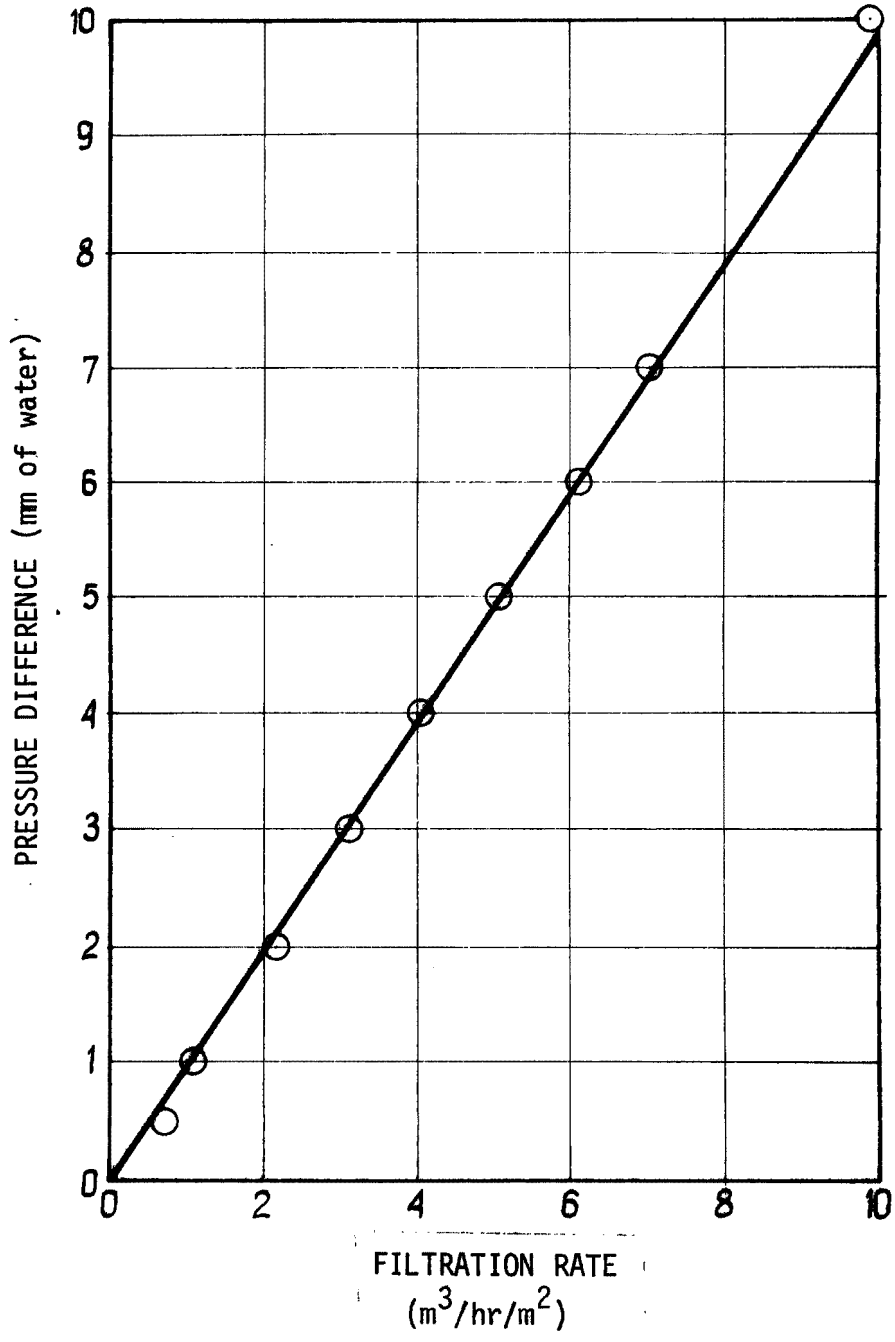


Figure A-88. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WT-202 (wool-low velocity).

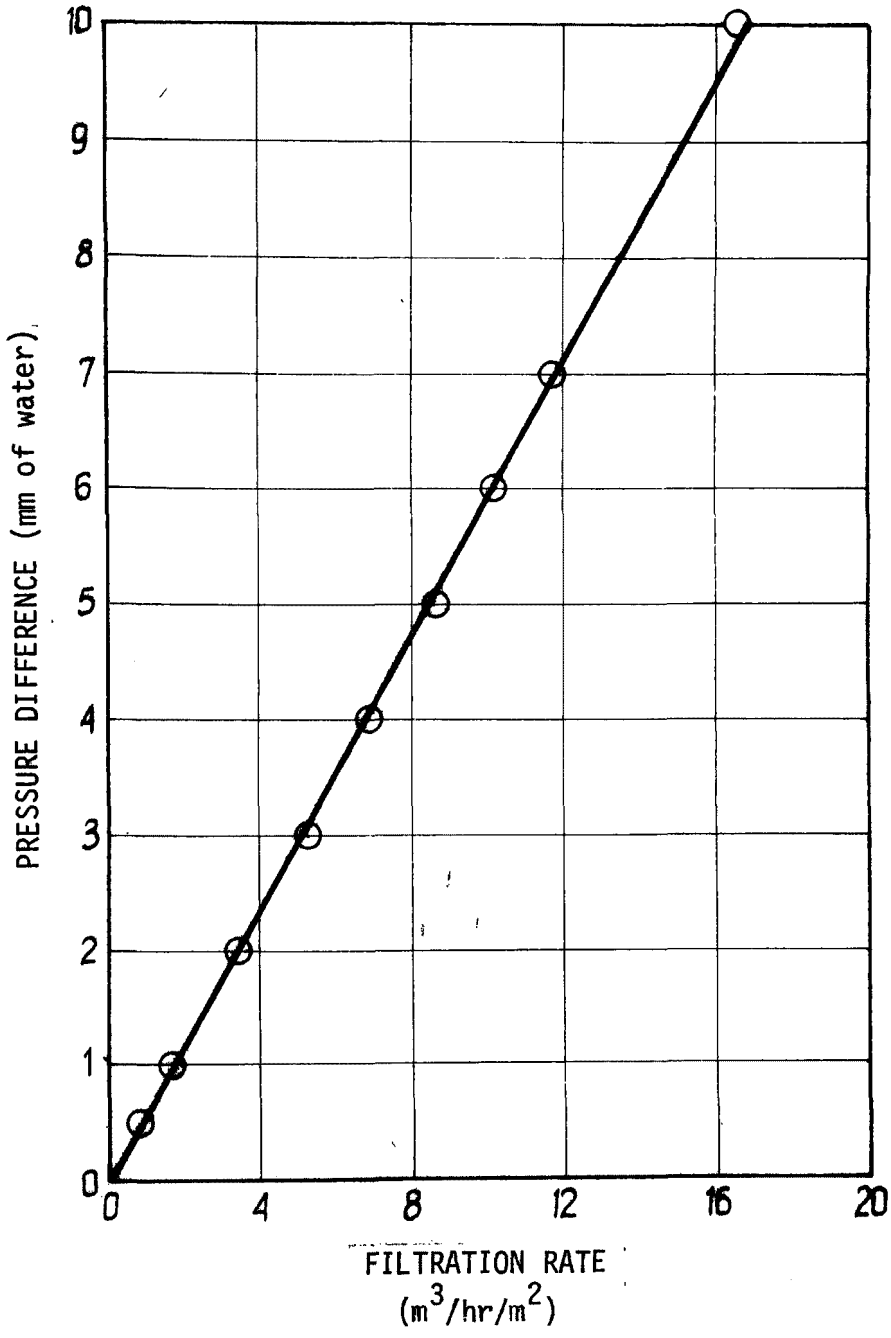


Figure A-89. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WT-203 (wool-low velocity).

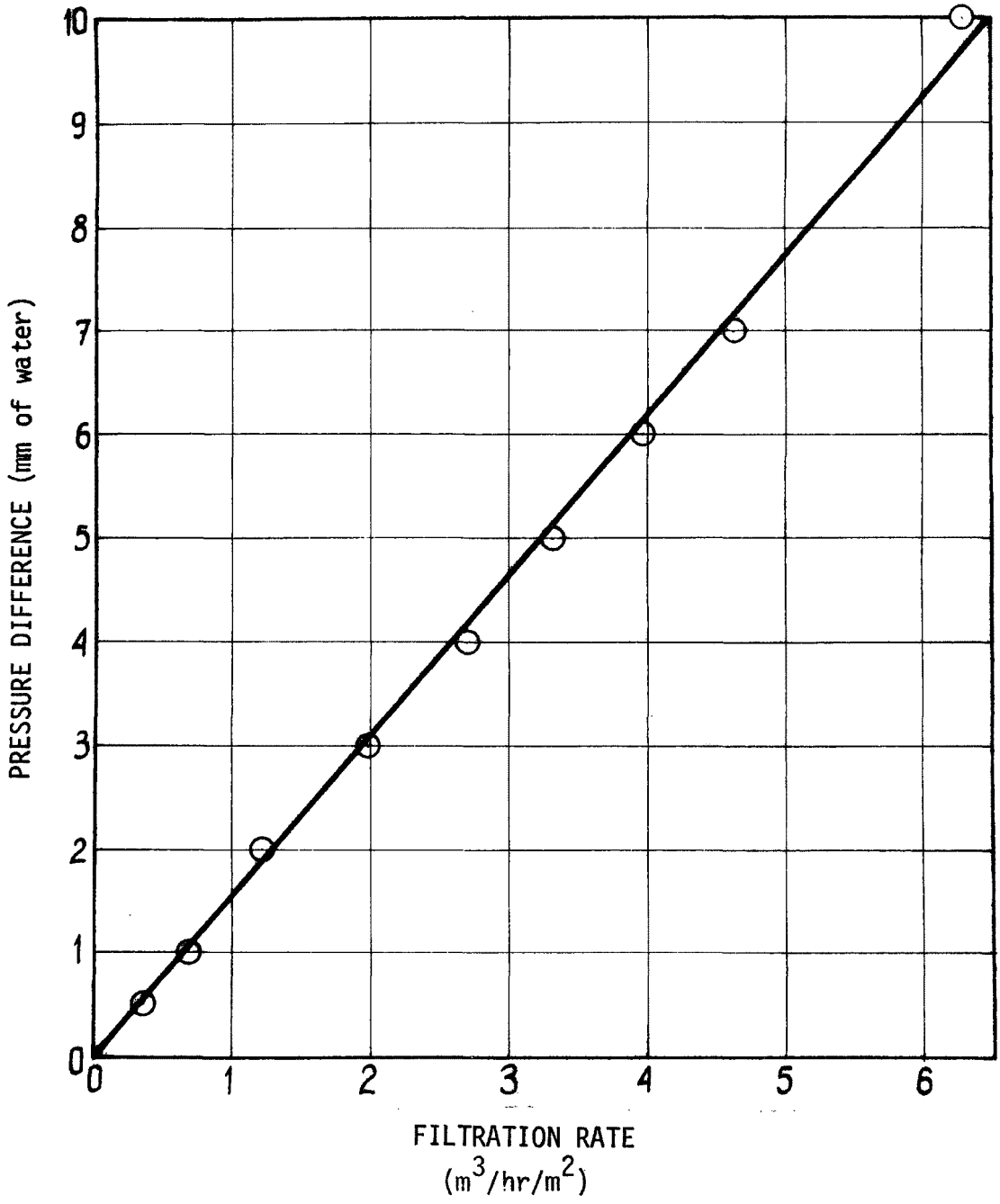


Figure A-90. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type BT-57 (cotton-low velocity).

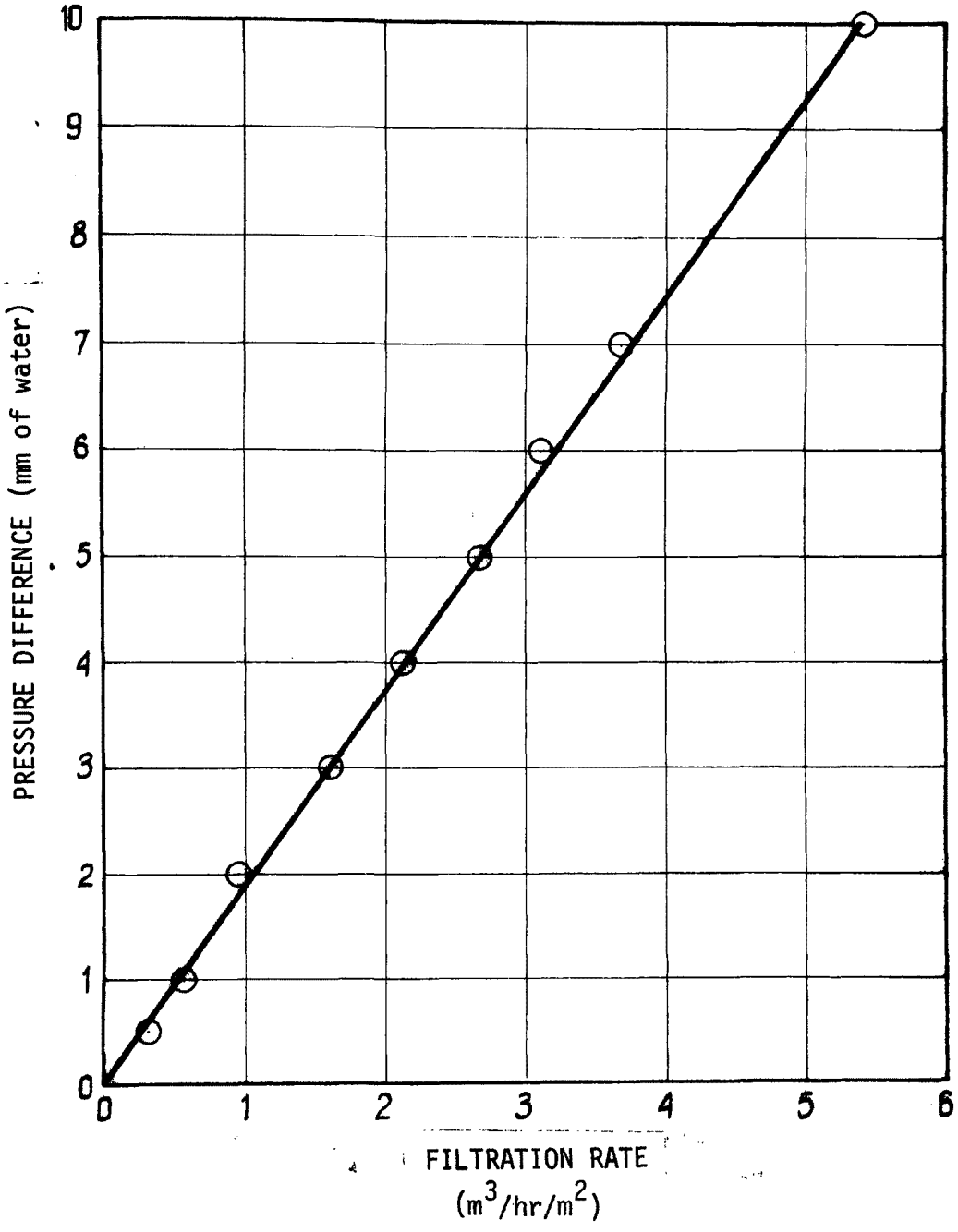


Figure A-91. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type BWA-1539 (cotton-low velocity).

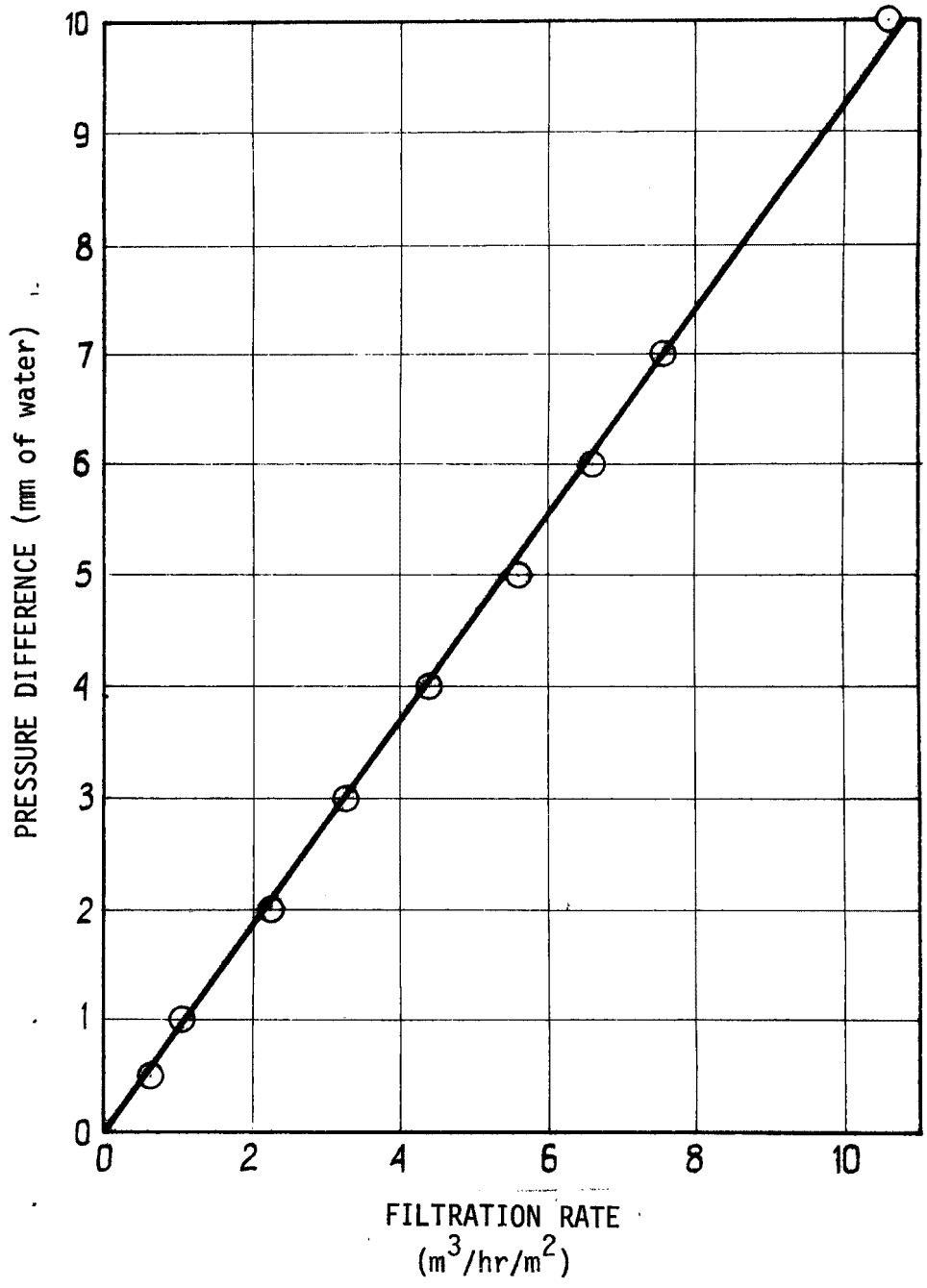


Figure A-92. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type WBT-210 (wool/cotton-low velocity).

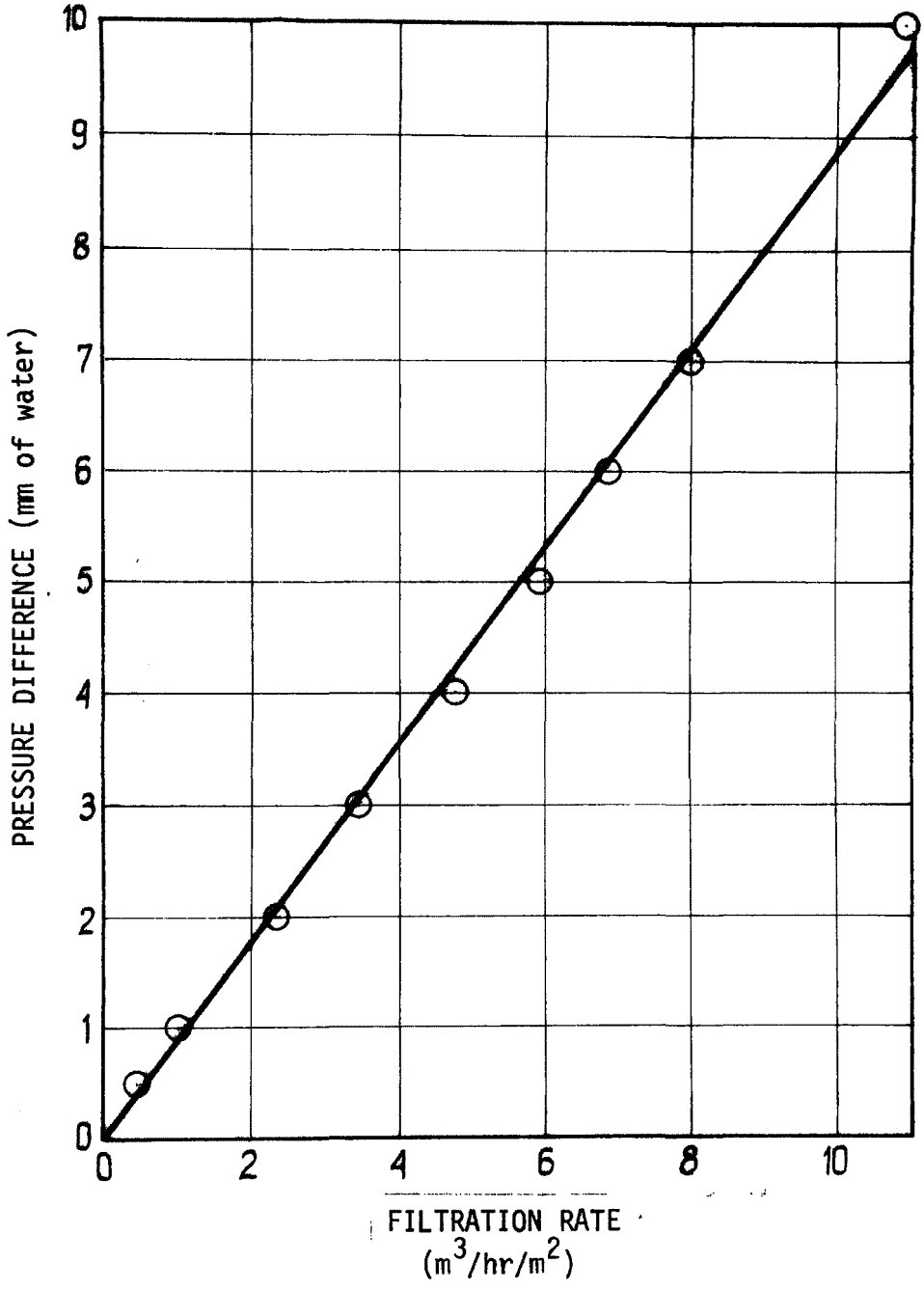


Figure A-93. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-1 (polyester-low velocity).

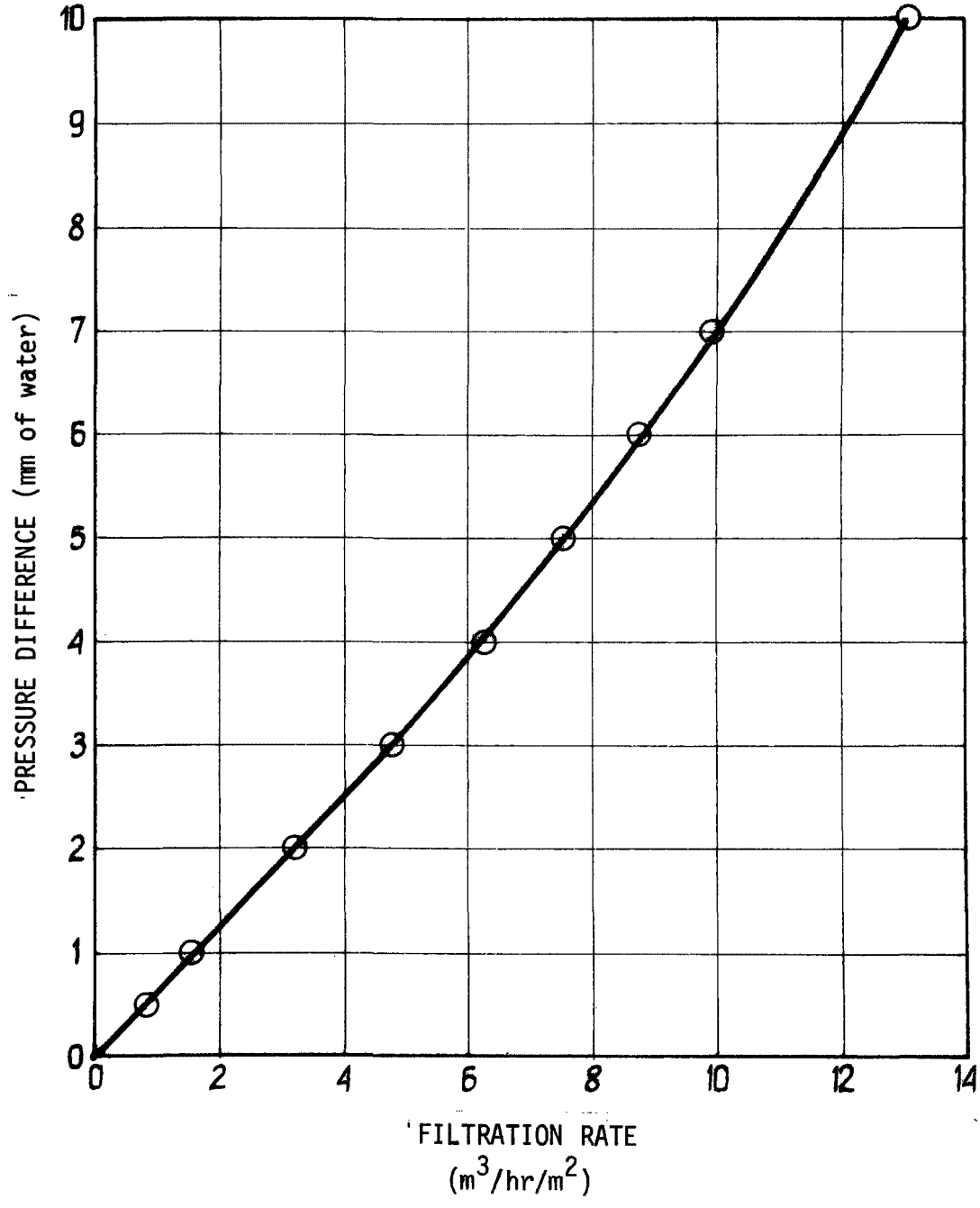


Figure A-94. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-2 (polyester-low velocity).

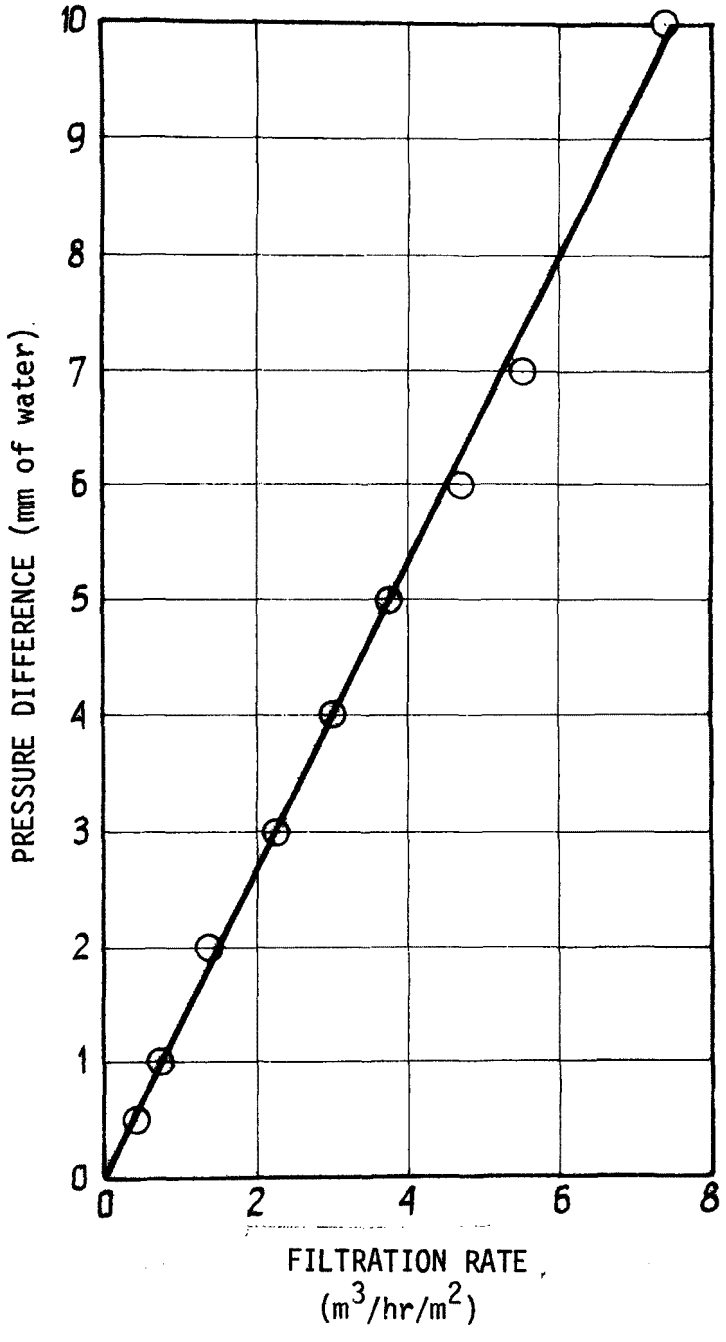


Figure A-95. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-3 (polyester-low velocity).

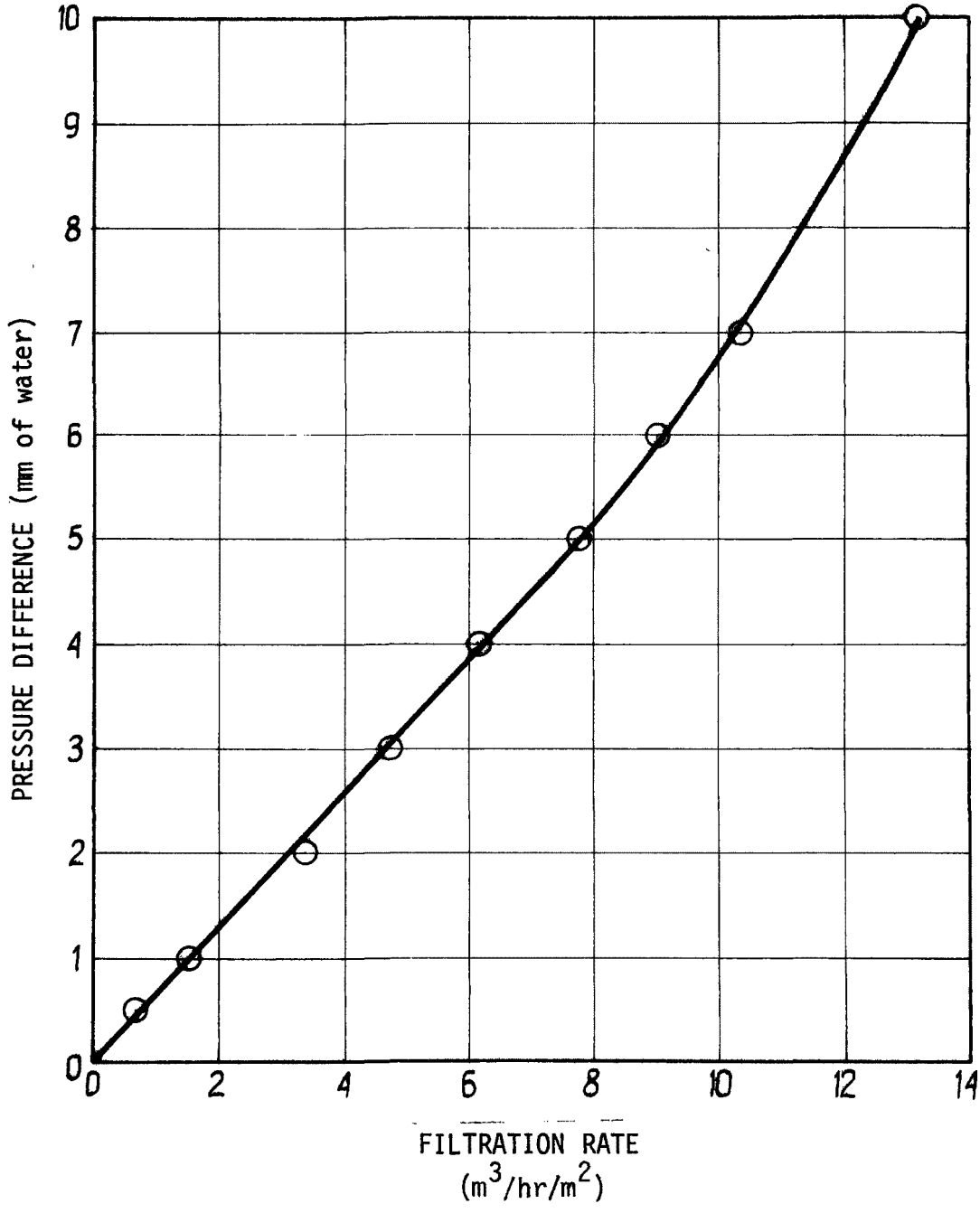


Figure A-96. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-4 (polyester-low velocity).

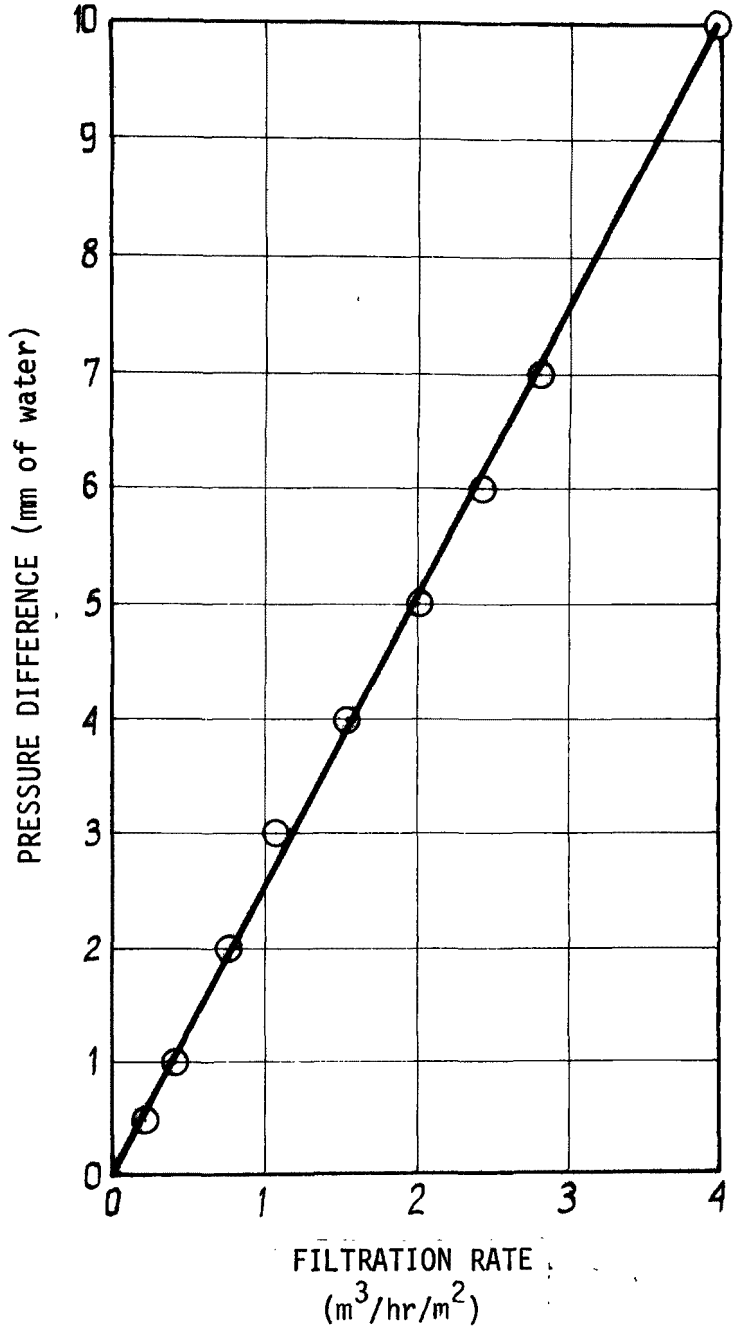


Figure A-97. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ET-30 (polyester-low velocity).

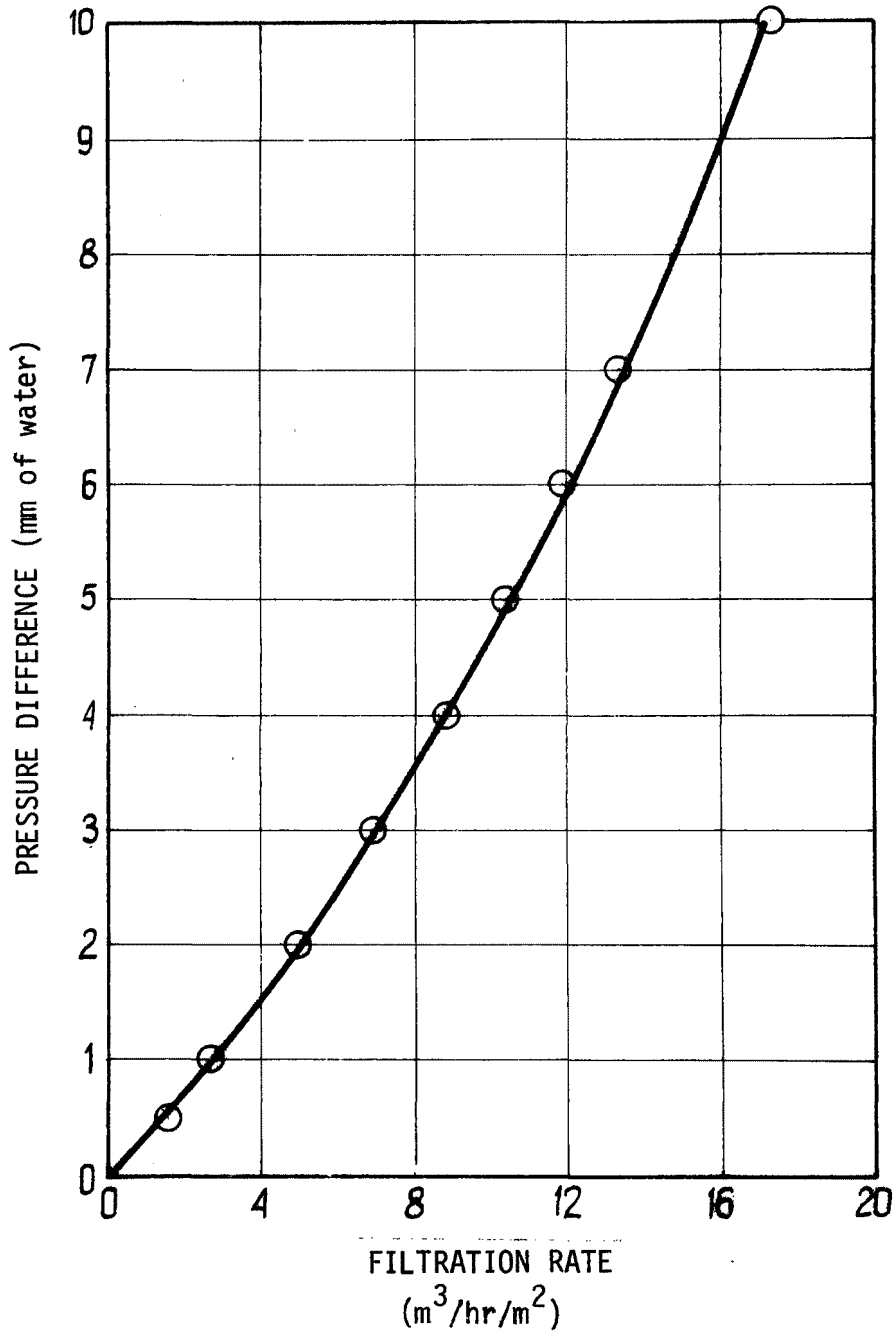


Figure A-98. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ST-1 (glass-low velocity).

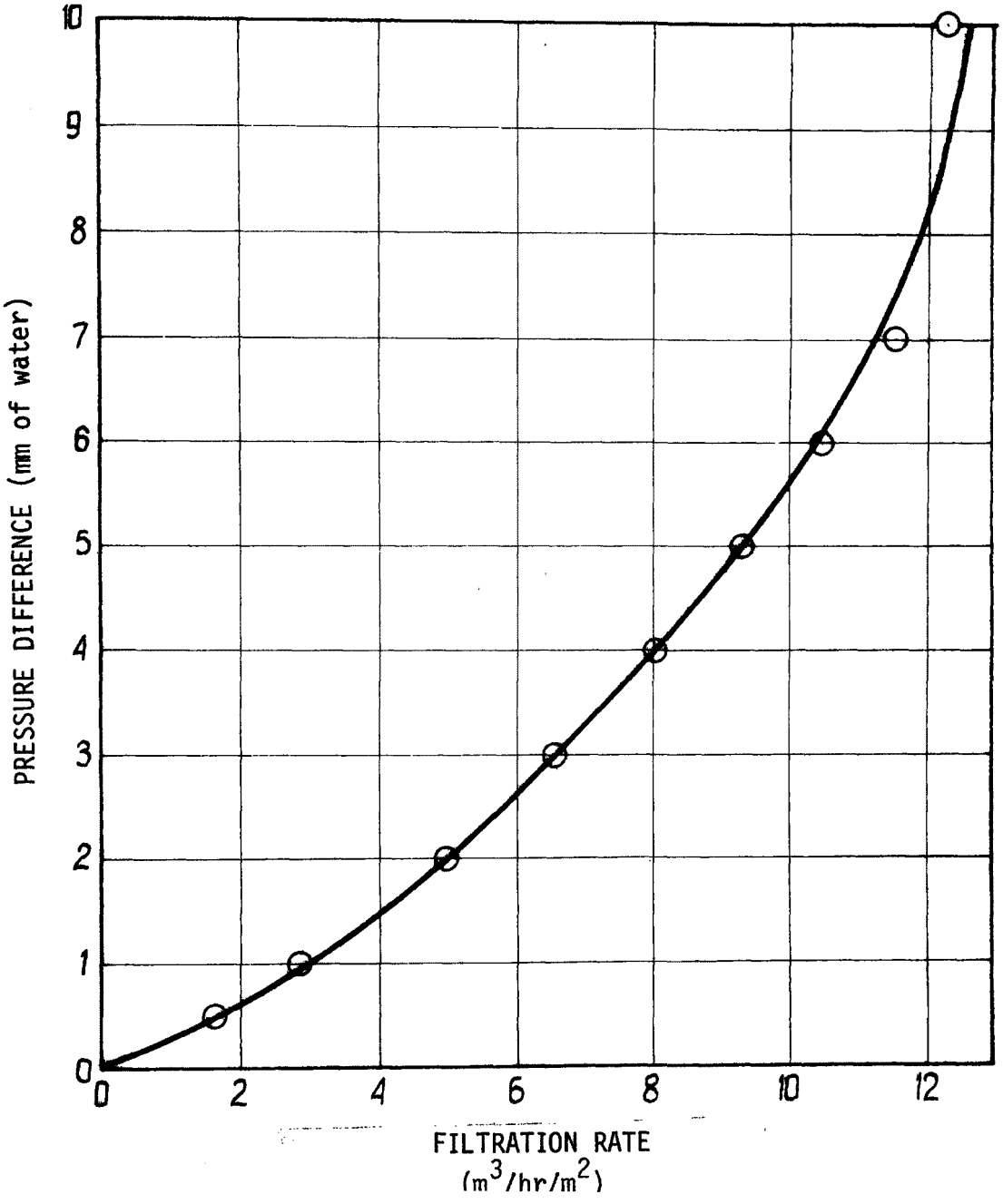


Figure A-99. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ST-13 (glass-low velocity).

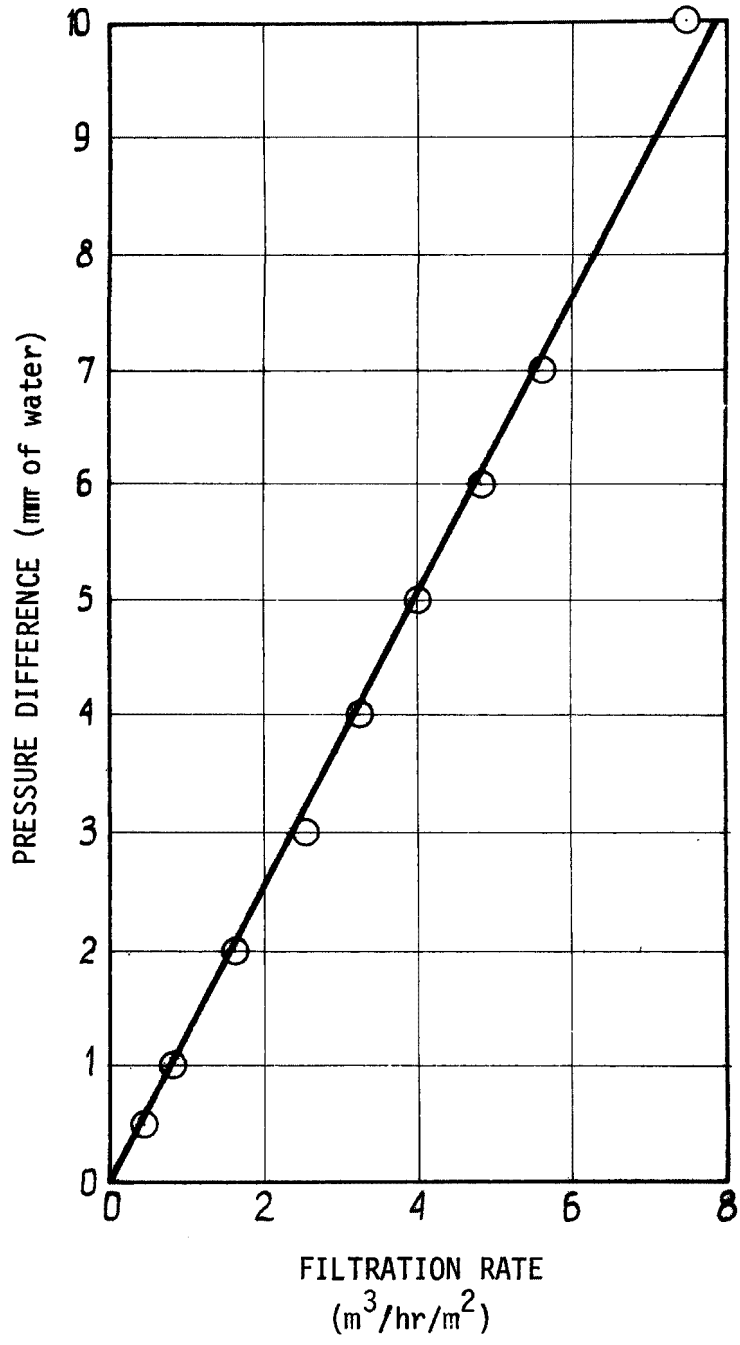


Figure A-100. Dependence of Pressure Drop vs. Filtration Rate for Pure Fabric Type ST-41 (glass-low velocity).

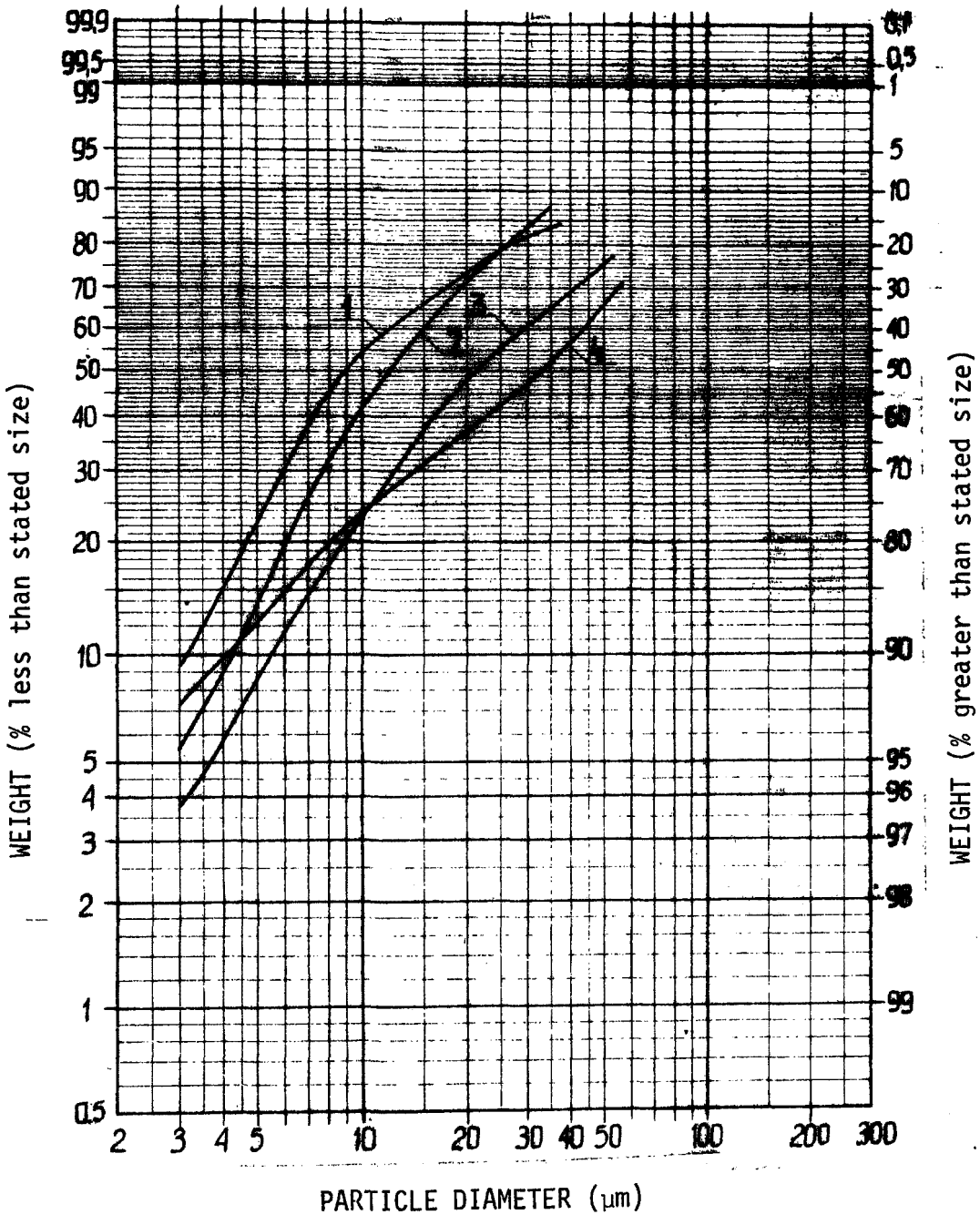


Figure 3. Particle Size Distribution of Tested Dusts (1 - hydrated lime, 2 - talc, 3 - coal, 4 - cement).

APPENDIX B

BAHCO CENTRIFUGAL MICROPARTICLE SEPARATOR (Establissements Neu Lille, France, Manufacturer)

Concept of Operation

The concept of operation of the BAHCO device is the separation of dry solid particulate matter into an eluriated or fine fraction, and a settled or coarse fraction, by subjecting particles to a centrifugal force opposed by air drag. A weighed sample is introduced into a spiral air current, of suitable tangential and radial velocities, created by vanes of a fan.

Depending on the size, density, and shape of the particles, a certain fraction of the sample (the settled, coarse particles) is accelerated by centrifugal force to the periphery, collected into a catch basin, and subsequently weighed. The fine fraction is carried out of the sifting chamber through the fan vanes; its weight is taken as the difference in weight of the coarse fraction measured before and after separation.

A sample of about 10 grams is required.

APPENDIX C

SARTORIUS SEDIMENTATION BALANCE (Sartorius-Werke Aktiengesellschaft, 34, Gottingen, West Germany, Manufacturer).

Application

This sedimentation balance operates according to Stokes Law. The test sample is mixed with an appropriate liquid. Settled or suspended dry matter can be used. The balance automatically records, during the test, the amount of sediment settling onto a specially shaped pan.

This balance is used to obtain the curve of tested particle distribution with a definition range of from 1 to 60 μm.

Under good conditions, the distribution of size particles up to 150 μm can be defined. By changing the distance of the particle fall (5, 10 or 20 cm), the duration of the test can be varied, depending on the range of the size particles. If the dust particles are not spherically shaped, only relative values are obtainable.

Concept of Operation

This device is equipped with a main balance bar. From the right hook is suspended a sedimentation pan or plate; from the left hook are suspended ring weight balances to equalize the displacement force of the sedimentation pan.

On the middle of the main balance bar, there is a mirror lighted through a lens. When the balance bar tilts, the light hits a photocell supplying power to a "JAG" motor. The motor twists a wire, causing the balance bar to return to the "0" point.

This cycle is repeated whenever the sedimentation pan or plate contains 2 mg of tested dust.

Each operation of the motor is recorded as a 0.08 cm horizontal displacement on the recording device.

APPENDIX D

MULTI-PLESC ALPINE SEPARATOR (Labor - Zickzacksichter 100 MZR: ALPINE Aktiengesellschaft Mashinfabrik und Eisengiesserei, Augsburg, West Germany, Manufacturer)

Technical Data

Separator:

Revolutions:	2400 - 20,000 rev/min.
Air flow:	15 - 53 Nm^3/hr

Blower:

Static vacuum:	About 1500 - 1600 mm of water
Air flow:	100 m^3/hr

Alpine Filter:

Filtration area:	1 square meter

Feeder:

Maximum capacity (ground limestone): About 10 kg/hr

Application

This device is used for the following

1. Definition of dust size distribution for dust samples over 50 grams.
2. Collection of several dust size fractions, within approximately 1 kg, in laboratory scale tests.
3. Separation of dry matter into two fractions, with quantities of a few kg/hr, in large-scale tests.

The range of separation for ground limestone is from 1 to 75 microns. In this range, separation can be adjusted to any desired value.

Operation

This separator operates by cross streams of air and dust. The concept is that of a zigzag tube, each section containing a lifting vortex. The separated material slides down and passes across the stream of air, then ascends and passes again through the air stream. Separation occurs during each crossing of the air stream. Several zigzag tubes are radially

mounted on a rotating disc, which permits sharpness of separation to a lower limit of 1 micron. The separated material is moved into the separator area by a screw feeder, and separated particles are removed by mixing with air in the cyclone, 125 GAZ.

APPENDIX E

AIR PERMEABILITY TESTING DEVICE, TYPE ALT-2/FF-1 (Metefem, Budapest, Hungary, Manufacturer)

Technical Data

Size of test area:	10, 20, 50, 100 cm^2
Range of manometer measurements:	0 - 30 mm of water 30 - 100 mm of water 100 - 200 mm of water
Range of tube rotameter measurements (tolerance of ± 5% of upper value of the range):	5 - 60 liters/hr 20 -200 liters/hr 150 - 750 liters/hr 500 - 3000 liters/hr 2500 - 12000 liters/hr
Maximum air flow through test fabric (by use of suction fan):	800 liters/hr

Principle of Operation

A suction fan draws air through the test area of fabric; a vertical manometer measures the air flow.

The manometer indicates the pressure differential between surfaces of the fabric. The rotameter indicates the quantity of air flowing through the fabric test area, with stabilized pressure differential.

From average measurements, an air permeability value is obtained, expressed as the quantity, in cubic meters, of air flowing through a square meter of test fabric each minute.

APPENDIX F

TENSIL TESTING MACHINE TYPE PMGw 500 (Serial 2170/R 18/68 (1968), FEB Thuringer Industriewerk, Ranestein, East Germany, Manufacturer)

Technical Data

Speed:	20 - 250 mm/min
Test sample length (excluding clamp areas)	100, 200, 300, 360, 400, 500 mm.
Elongation:	0 - 200 mm
Maximum force loading:	500 kp
Range of Measurement:	0 - 100 kp 0 - 250 kp 0 - 500 kp

The machine is equipped with a recording device.

Application

This machine is designed to test the elongation and tensil strength of fabrics, texrope belting, sailcloth, hardboard, etc.

Principle of Operation

A sample of fabric is held by a pair of clamps and is stretched, by moving the lower clamp, until it breaks. The amount of elongation is measured as the distance between the upper and lower clamps (excluding the fabric in the clamp) under a defined load.

To meet Polish standards, test specimens are cut along warp and weft of the fabric, with dimensions of:

Width: 50 $\pm$ 0.5 mm.

Length: About 150 mm longer than the distance between clamps.

For fabrics with elongation less than 150 percent, the distance between clamps should be set as 200 mm; for those with elongation greater then 150 percent, the distance should be set as 100 mm.

The duration of movement of the lower clamp is defined as the difference between when tension is applied and when the fabric breaks (equals 30 $\pm$ 10 sec).

The measurement of the strength of the sample is the maximum loading (which caused its breakage) with defined elongation (read from the scale of elongation).

APPENDIX G

LIST OF NOMENCLATURE

C = dust concentration

E_o = complete packing of yarn in fabric

G_c = weight of dust fed into testing chamber

G_o = weight of dust collected on control filter

G_z = weight of dust collected on the fabric

L = weight of dust/unit area of fabric

L_i = fabric filling at point i during dust filtration types I and II

L_N = fabric filling for a given regeneration cycle (Dust Filtration Type III)

L_N = characteristic value for fabric filled with dust but not having a dust cake

L_o = characteristic value of dust loading for a fabric filled with dust and a dust cake

L_o = dust loading

MMD = mean particle diameter

N_m = yarn count

N_{mo} = warp count of yarn

N_{mw} = fill count of yarn

$N_n{}^3/hr$ = normal cubic meter/hr; normal cubic meter is at pressure of 760 mmHg and temperature of 0°C

RH = relative humidity

Z_o = relative warp and fill packing

Z_t = superficial packing with yarn

Z_w = relative warp and fill packing

do = diameter of yarns

e = charge on electron; number of electrons

ko = length and width inside FA between threads

kp = kilopound force

ln = length of thread

lo = distances between axis of threads

m = mass of weighed threads

n = number of weighed threads in a fabric

no = number of threads

no/nw = yarn density

q = number of changes

q_g = gas loading

q_p = dust loading

v = average velocity of the air flow before reaching the filter structure

β_i = fabric filling parameter for cycle i

η = dust collection efficiency

σ = electrification parameter

ΔP = pressure drop for a static gas loading for q_g and no dust load

ΔP_K = pressure drop for a fully filled fabric with a dust cake

ΔP_N = pressure drop for a fully filled fabric without a dust cake

APPENDIX H

METRIC CONVERSIONS

Although EPA's policy is to use metric units for quantitative descriptions, this report uses certain non-metric units where it is felt that doing so will facilitate understanding by a majority of the readers of this report.

METRIC		NON-METRIC
1 newton/m^3	=	.0000099 atm
1 Kg(wt)/cm^2 = 9.8 x 10^4 N/m^2	=	.971 atm
1 liter	=	.0353 ft^3 = .00629 bbl
1 cal = 4.19 joule	=	.00397 BTU
1 joule	=	.000948 BTU
1 cm	=	.3937 in = .0328 ft
1 gram	=	15.43 grains
1 Kg	=	2.222 lbs = .0011 tons
1 $\mu m = 10^{-6} m$	=	.00003937 in
$\frac{9}{5}$°C + 32	=	°F
1 $\frac{\text{gram}}{\text{meter}^3}$	=	.437 grains/ft^3
1 $\frac{\text{gram}}{\text{meter}^2}$	=	1.433 $\frac{\text{grain}}{\text{ft}^2}$ = .029502 oz/$yard^2$
1 $m^3/m^2/hr$	=	3.28 $ft^3/ft^2/hr$
1 mm of H_2O pressure drop =		
98.06 dyne/cm^2 =		
.0735 mmHg =		
.0073 cmHg	=	.0029 in of Hg = .000097 atm

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(Please read Instructions on the reverse before completing)

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7. AUTHOR(S) Jan R. Kościanowski and Lidia Kościanowska		8. PERFORMING ORGANIZATION REPORT NO.
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15. SUPPLEMENTARY NOTES Project officer for this report is J. H. Turner, Mail Drop 61, Ext 2925.

16. ABSTRACT The report covers the first phase of research into the dependence of filtration efficiency on filtration parameters and fabrics. It gives results of laboratory tests of three types of polyester fabrics and one polyamid fabric in the filtration of cement and coal dusts with particles of mass median diameter of 7.5 micrometers. Noted during the tests were: the relationship between the type of dust and filtration process parameters; and the effect of electrostatic properties on the filtration process. The dust filtration process was classified into three filtration types. The structure of filtration fabrics was tested on the basis of air flow through 16 fabric samples in two ranges of air flow velocity. The stochastic character of air flow through the fabrics was verified. Structural parameters of the fabrics, as well as derivative parameters, were measured and observed phenomena were analyzed from an analytical viewpoint. The report also covers results of cement and coal dust electrification tests and fabric resistance measurements.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Air Pollution	Polyester Fibers	Air Pollution Control	13B	
Fabrics	Cements	Stationary Sources	11E	11B,13C
Dusts	Coal Dust	Fabric Filters	11G	21D
Filtration		Polyamid Fibers	07D	
Electrostatics		Fabric Resistance	20C	
Efficiency			14A	

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