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Deposition and Resuspension of Selected Aerosols Particles on Electrically Charged Filter Materials for Respiratory Protective Devices

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The primary aim of the study was to analyse the non-steady state of filtration for selected electrostatic filter materials designed for use in respiratory protective devices. The obtained results showed that the filtration process in electrostatic filters was dependent in the main on the following factors: type of the filter material, electrostatic field strength of the material, and the charge of the aerosol.

To a lesser degree the filtration process depended on the sign of the charge and the relative humidity of the air. A significant correlation was found between the increase in the penetration and the decrease in breathing resistance while the filter was being loaded.

The effect of resuspension (tearing off and re-deposition of dust agglomerates inside the filter) on the filtration process very significant. It was also observed that under certain conditions electrostatic filter materials lost their protection properties.

electrostatic filter materials   respiratory protective devices   deposition   penetration
filtration   aerosols   dust   aerosol electrostatic charge

1. INTRODUCTION

The filtering components of respiratory protective devices (RPD) are tested in laboratories using model aerosols. The basic parameter, penetration, which characterises filtration efficiency of these components, is determined for the total mass of the filter without accounting for fractional efficiency, i.e., the efficiency of entrapping various sizes of air-borne particles. Nor, in the standard tests, is allowance made for the electrostatic parameters of the aerosols or their effect on the electret filter materials generally used in RPD. That is why an empirical study was undertaken to determine the effect of the degree of electrification of dust particles on filtration efficiency of the electret filter materials with respect to a wide spectrum of particle size distribution. The results of the study enabled critical analysis of the protective efficiency of the electret filters against industrial polydisperse aerosols as determined by standard methods. The analysis led to conclusions that were a basis for the development of some guidelines for the selection and safe use of electret filters.

The process of filtration is characterised by a significant number of temporal changes in process parameters, such as aerosol concentration or local rate of airflow, and by the non-homogeneity of aerosol concentration or structure of the filter material. A further complication is added by the presence of the forces of electrostatic attraction between the electrified fibres and particles of the aerosol.

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The first relevant studies carried out in the 1980s [1, 2, 3] supplied empirical evidence that the electrically induced deposition of particles initially leads to deterioration of the filtration efficiency of the filter material, a phenomenon not observed in tests of filter materials that were not electrets. It was assumed at first that the phenomenon was a result of neutralisation of the charges accumulated on the fibres due to contact with charged particles of the aerosol. This conclusion was inferred from the results of an analysis of the distribution of charges on elementary fibres and the electrostatic properties of real aerosol particles [4].

However, further investigation into the phenomenon of electrically induced deposition made it necessary to revise the opinion that the reduction of filtration efficiency was the result of neutralisation of the particles. It was found that the reduction was only an effect of the phenomenon of "screening" [5]. This suggests that the degree of degradation of filtration efficiency is dependent on the conditions related to the rate at which particles are deposited on the fibres and the shape of the emerging dust structures (dendrites). This was confirmed by the results of research carried out in the 1990s [6], which showed that the smaller the transverse dimension of the aerosol particle and the higher the rate of airflow, the higher the loss of filtration efficiency with time. These findings were reflected in studies aimed at modelling the process of non-steady state filtration under conditions of electrostatic attraction.

Since the filtration efficiency of RPD is tested by a standard method which does not allow for a possible effect of the electrostatic properties of real aerosols, humidity of the air, or type of electrostatic activation of the filter material, there is the potential risk that the devices may be incapable of providing sufficient protection.

2. MATERIALS AND METHODS

2.1. Filtering Material

A melt-blown electret filter material was selected for this study. Filters made of this kind of material are characterised by high efficiency of filtration of submicron particles, owing to their structural parameters such as high packing density of the fibres (consistent with their fineness being in the order of 1–2 μm) and additional electrostatic effects.

The technology by which these fibres are produced consists in blowing melted polymer into fibres with streams of hot air and forming the blown fibres into a filter material on a take-up cylinder with a rotary and a reciprocating movement. To further improve its filtration efficiency the filter material is electrically charged by the corona discharge method.

In this method, ions of one sign are emitted by an electrode of a high potential to be attracted towards the collecting surface by an electrostatic field generated by an electrode of a lower potential. Corona charging can be applied to any filter material regardless of the method of its manufacture, but it is most frequently used in combination with the blowing of polymer melt [2, 4].

In the electrically charged melt-blown filter materials the mechanism of filtration is mainly based on the action of forces generated by the electrically charged fibres, wherefore the electrostatic effect is decidedly stronger than if the filter material is activated by other techniques [2, 4, 7, 8, 9] (compare, e.g., the triboelectric effect). The reason is that the efficiency of the electrically induced deposition is directly proportional to the intensity and density of the lines of the electrostatic field generated round the fine, densely packed fibres.

To determine the relationship between the efficiency of protective action of filter materials and the degree of their electrification, filter materials that were characterised by constant structural parameters and variable degree of electrification were analysed. Accordingly, variants of melt-blown polypropylene filter materials were produced using the following values of voltage of the charging electrode: 0.5, 15, and 25 kV.

The parameters of the analysed melt-blown filter materials were as follows:

- area weight—140 g/m^2;
- thickness—2.5 mm;
- mean fibre diameter—(1.6 ± 0.4) μm;

- dielectric constant of polypropylene—ε_{pp}= 2.2; initial NaCl penetration (according to Standard No. PN-EN 143 [10])—0.2–0.3% for filter materials activated with a voltage of 25 kV; 1.1–1.2% for activated with 15 kV; 11.0–12.0% for activated with 5 kV; 25–30% for non-activated filter materials (0 kV).

2.2. Aerosols

The process of filtration is essentially influenced by the physical and chemical properties of the aerosol. This particularly applies to the size distribution of the dispersed phase aerosol particles, concentration of the aerosol, density of the particles, and electrostatic charge accumulated on the particles.

In the natural environment, particles without an electrostatic charge are relatively rare. The charge of an aerosol depends on what material the particles are made of and on how it was generated [4]. The particles formed as a result of condensation have a low degree of electrification. The vapours condensing on nucleons to form aerosol particles neither generate nor remove charges. Therefore, the final charge of the particle is the same as the initial charge of the nucleon. On the other hand, a particle formed upon evaporation of the liquid has a significant charge because it takes over the total charge that the particle had before evaporation. A very high electrostatic charge may also be present on particles formed by fragmentation. The value of the charge is dependent, however, on the environmental conditions under which the aerosol is being formed.

When selecting a dust to be investigated the primary consideration was its electrostatic properties.

The following dusts were selected:

- metallurgic dust, composed mainly of iron particles, collected from a steel construction shop and representing the dust arising in the cutting, grinding and welding of plate steel;
- coal dust currently used in testing RPD;
- dolomite dust currently used in testing RPD;
- copper ore dust collected from the environment of belt conveyors in a copper mine.

The size distributions of the dusts made using a PALAS (Germany) particle counter PCS 2000 are presented in Figures 1, 2, 3, and 4. Table 1 presents the results for the density and electrical resistance of the dusts.

TABLE 1. Density and Specific Resistance of the Dusts

Type of Dust	Specific Resistance (Ωm)	Density (g/cm^3)
Dolomite	7.96×10^9	0.98
Coal	95.5×10^6	0.54
Metallurgic (steelworks)	294×10^3	2.41
Copper-mine (ore-conveyor dust)	58.9×10^6	1.19

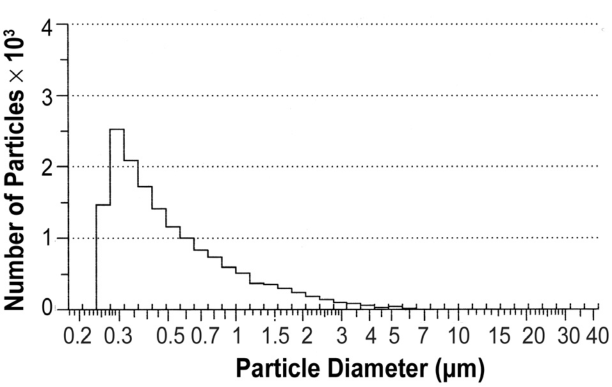

Figure 1. Particle size distribution of dolomite dust. *Notes.* Geometric mean diameter (µm) = 0.516, geometric standard deviation = 1.000.

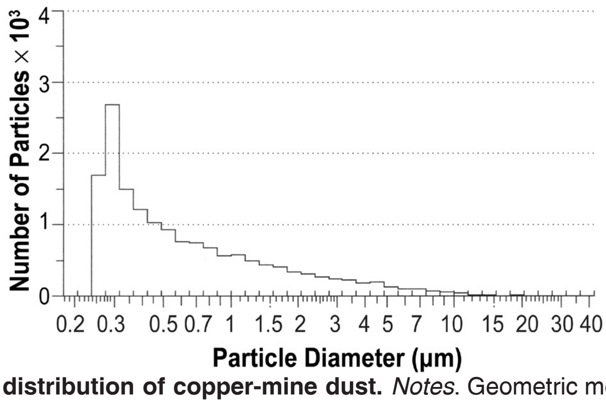

Figure 2. Particle size distribution of copper-mine dust. *Notes*. Geometric mean diameter (µm) = 0.636, geometric standard deviation = 2.409.

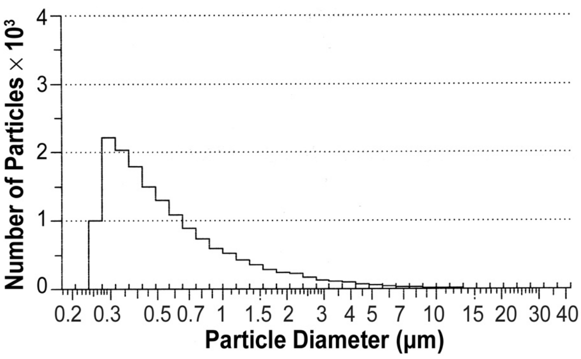

Figure 3. Particle size distribution of coal dust. *Notes*. Geometric mean diameter (µm) = 0.563, geometric standard deviation = 2.010.

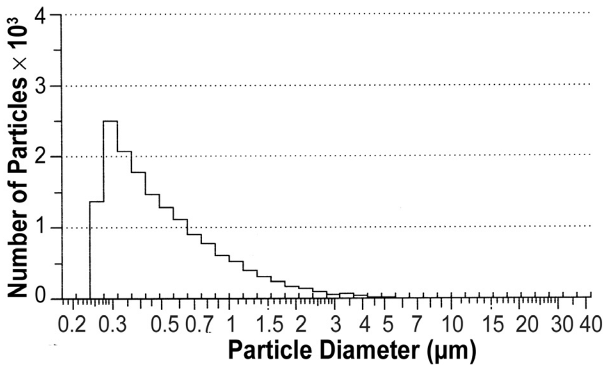

Figure 4. Particle size distribution of metallurgic dust. *Notes*. Geometric mean diameter (µm) = 0.504, geometric standard deviation = 1.797.

The tests were carried out on a test stand schematically presented in Figure 5. From the feeder disc the dust was sucked to the mixing chamber (5) where it was mixed with the diluting air to regulate the concentration of the aerosol being produced (2). The test stand was additionally supplied with compressed air (1), clean and dried (14), which was passed through the aerosol charge neutraliser (12). To ensure identical test conditions this air was also fed to the neutraliser when the latter was OFF while the "natural" dusts were being tested. After being mixed with an additional stream of clean air the aerosol was directed, via the neutraliser (12) and ioniser (6), to the tested filter (9). By suitable adjustment of ioniser voltage it was possible to up-charge, both positively and negatively, the particles of the aerosol. To determine the degree

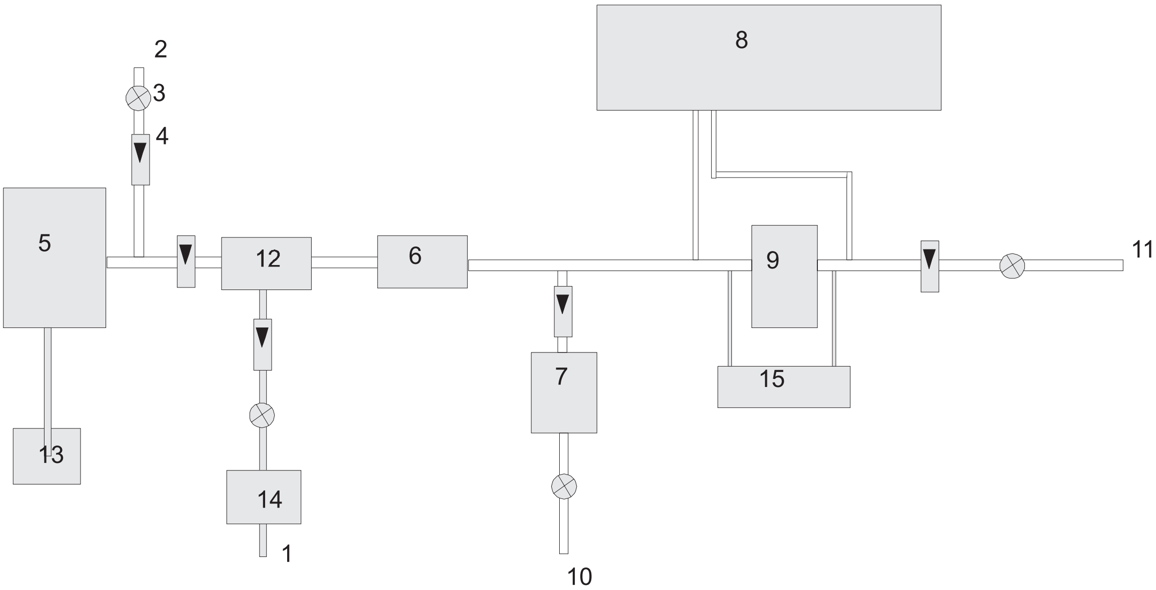

Figure 5. A schematic diagram of a test stand for testing the efficiency of electret filters against electrically charged aerosols. *Notes*. 1—inlet of compressed air, 2—inlet of clean diluting air, 3—control valve, 4—flowmeter, 5—dust feeder (disc type) and aerosol mixing chamber, 6—ioniser, 7—electrometer, 8—particle counter, 9—tested filter, 10—outlet to vacuum pump, 11—outlet to vacuum pump, 12—neutraliser, 13—ultrasonic humidifier, 14—filter set with reducing device, 15—digital differential micromanometer.

of its electrification, i.e., the mean charge, the aerosol was directed to the electrometer (7). The aerosol was sampled upstream and downstream of the filter for the particle counter (8) to determine filtration efficiency of the tested filter materials. The airflow resistance of the filters was determined using a micromanometer (15). An ultrasonic humidifier (13) was connected to the mixing chamber (5) to up-humidify the aerosol while testing at an increased level of humidity.

When testing the loading of the filter systems with real dust the changes in penetration with time were determined with the particle counter. The instrument in question was a PALAS (Germany) particle analyser PCS 2000 with the following parameters:

- particle size measuring range—0.25–40 µm;
- maximum test concentration—10^5 particles/cm^3;
- number of test channels—127;
- aerosol-sample flow intensity—3 L/min.

On the presented test stand the following series of tests were carried out:

- loading filter materials with real dust with a “natural” charge;
- loading filter materials with dust whose charge was previously neutralised;
- loading filter materials with dust charged negative and positive (every time before charging with the opposite sign the dust was neutralised);
- loading filter materials with natural dust, neutralised dust, and dust charged to allow for increased humidity of the air.

During the tests, filtration efficiency and resistance of aerosol flow through the layer tested were continuously recorded. The test procedure was continued until a decided increase in filtration efficiency was recorded, i.e., as long as the efficiency of aerosol particle deposition was mainly dependent on the mechanical factors.

The tests were carried out at a volumetric flow intensity through the test sample of 95 L/min, which corresponds to medium-high or high physical effort.

The loading of the filter materials with each selected dust was tested at an aerosol concentration of 10 ± 1 mg/m^3, i.e., at a concentration most frequent under the real conditions.

The tests were carried out at electrode voltage ±4 kV and ± 6 kV. If a higher voltage was selected, the recorded drop of penetration of the electrified aerosols through the tested filter material was too high.

TABLE 2. Results of Measurement of Excess Charge of the Test Aerosols

	Number of Aerosol Elementary Charges per 1 dm^3 ($\times 10^6$)					
Type of Dust	Real Aerosol	Neutralised Aerosol	Aerosol Charged +4 kV	Aerosol Charged –4 kV	Aerosol Charged +6 kV	Aerosol Charged –6 kV
Standard dolomite	+290	+80	+400	–1040	+600	–1530
Standard coal	–21	0	+350	–370	+500	–490
Metallurgic (steelworks)	+85	+12	+240	–270	+420	–350
Copper-mine	+42	0	+200	–230	+380	–340

In Table 2 are listed the aerosol particle charge electrometer values for each aerosol measured at a concentration of 10 ± 1 mg/m^3 and flow intensity of 95 L/min.

Due to the capacity of the measuring system regarding the amount of air that could be supplied to the mixing chamber and neutraliser it was possible to achieve relative humidity at a maximum level of 75%. Since the first series of tests was carried out at 25% relative humidity of the air, it was assumed that the obtainable maximum relative humidity of 75% would suffice for determination of the process character of the investigated phenomena.

3. RESULTS AND DISCUSSION

To assess the effect of the amount of charge in the aerosol particles on the variation of filtration efficiency of the electret filter materials, the following series of tests were carried out:

- Measurement of penetration changes with time for melt-blown filter materials:
  - material without imparted electrostatic charge,
  - material charged by corona discharge at charging electrode voltage of 5 kV,
  - material charged by corona discharge at charging electrode voltage of 15 kV,
  - material charged by corona discharge at charging electrode voltage of 25 kV;
- The above variants of filter material were loaded with:
  - natural aerosol as sampled at workplaces,
  - neutral aerosol,
  - aerosol ionised with a voltage of +4 kV,
  - aerosol ionised with a voltage of –4 kV,
  - aerosol ionised with a voltage of +6 kV,
  - aerosol ionised with a voltage of –6 kV.

Figures 6 and 7 graphically represent the relationships between the variations in penetration and time of loading with dust of the melt-blown filter material at various levels of activation for selected natural dust and dust subjected to the neutralising process. The results apply to filter materials without activation and materials activated at a voltage of 5, 15, or 25 kV.

An increase in the charging voltage always results in increased filtration efficiency of the filter material due to higher intensity of the electrostatic field generated by the electrified fibres. Tendencies similar to those shown in Figures 6 and 7 were observed in the case of the remaining dusts. It was observed in all cases that the value of penetration initially grew to slowly and irregularly fall due to clogging of the filter with dust. Increasing airflow resistance provided additional evidence that the filter was being clogged.

It is also worth noting that in the case of a melt-blown filter material with higher activation the process of the initial loss of efficiency is so rapid that within a short time the material reaches stabilisation of its filtration properties (increased efficiency), evidence of which is the curve of variation of penetration for filter materials activated with a voltage of 25 kV (Figures 6 and 7).

The curves presented in Figures 6 and 7 suggest one more important conclusion, namely that the process of changes in the filtration efficiency of the electret filter materials is dependent on the degree of neutralisation of the particles of the aerosol. An aerosol from which the electrostatic charges have been removed shows much stronger

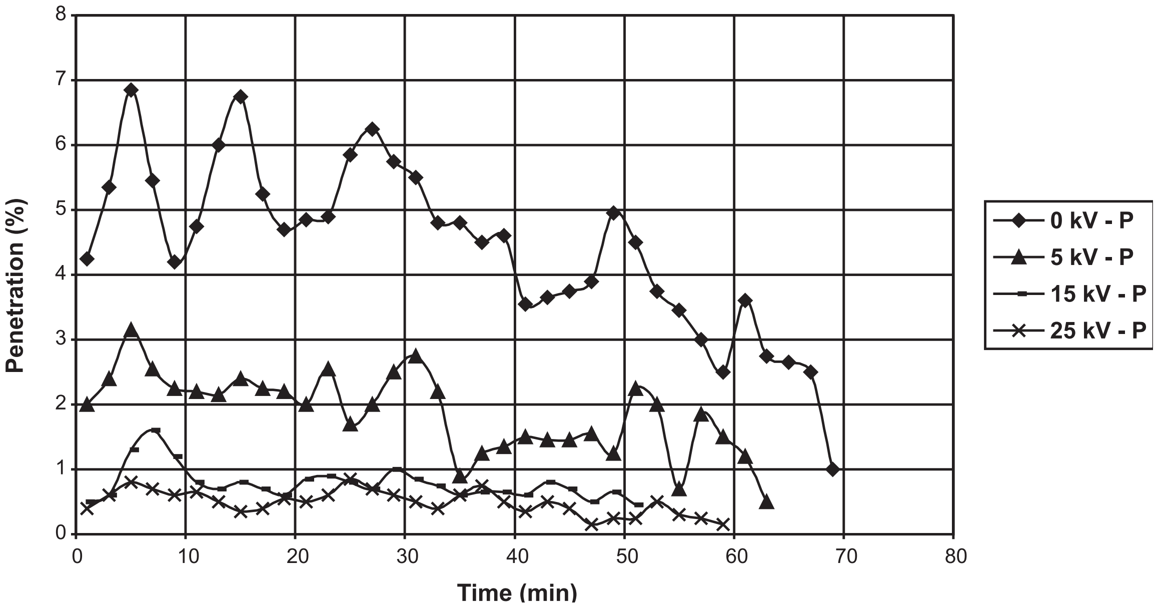

Figure 6. Changes in penetration with time of loading with copper-mine dust (P—as sampled) of melt-blown polypropylene filter material: without a charge; charged with a voltage of 5 kV; charged with a voltage of 15 kV; charged with a voltage of 25 kV.

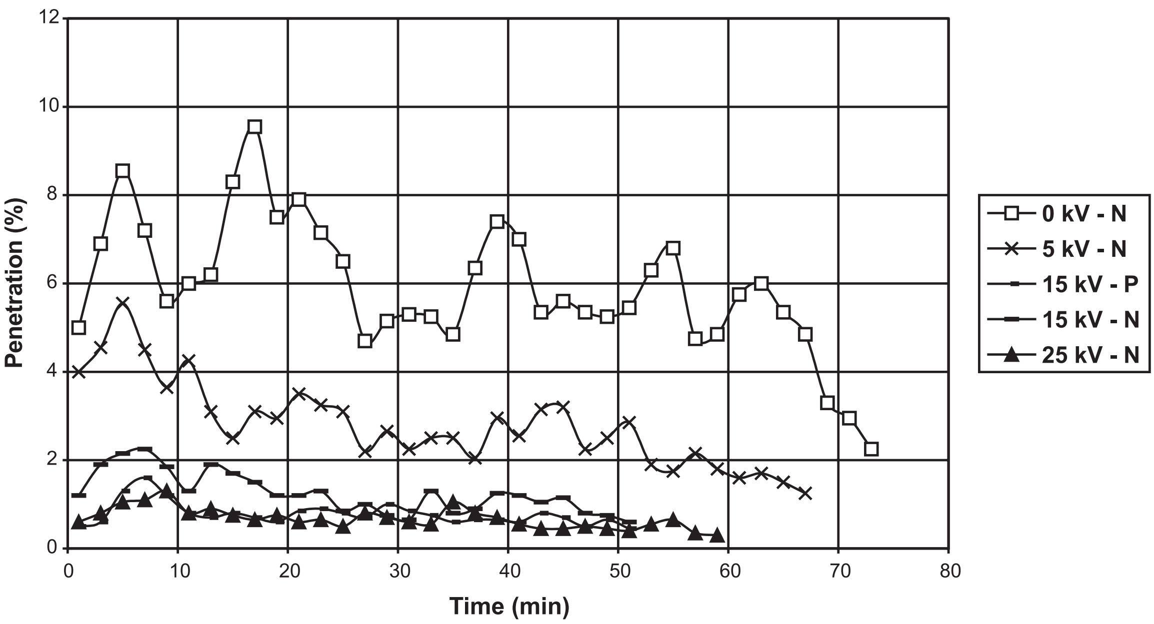

Figure 7. Changes in penetration with time of loading with copper-mine dust (N—after neutralising) of melt-blown polypropylene filter material: without a charge; charged with a voltage of 5 kV; charged with a voltage of 15 kV; charged with a voltage of 25 kV.

penetration through the electret materials than the same aerosol with a predominance of positive or negative charges. A possible explanation of the phenomenon is that there is a stronger interaction between a charged particle and a fibre than between the dipole induced in a neutral aerosol particle and the charged fibre.

The ionising of both a positive and negative aerosol resulted in significant differences in the process of nonsteady-state filtration. Here, the phenomena are similar to those observed when fibres with a high level of electrostatic activation are being loaded. Significantly shorter is the time of a reduction of filtration efficiency, which signifies a rapid process of particle deposition round the fibres. To illustrate this conclusion, an exemplary process of changes in the penetration of copper-mine dust, ionised positive and then negative, through a selected melt-blown filter material is presented in Figure 8. The curves of the changes had similar shapes in all test variants. This would suggest that the rate of deposition of dust particles is dependent on the predominance of positively- or negatively-charged aerosol particles and charges accumulated on fibres. Figure 8 clearly shows that the curves of changes in penetration for the same melt-blown filter material positively-charged with a voltage of 15 kV show significant differences if the aerosol is ionised with a plus or a minus sign. The particles, which carry negative ions, screen round the fibres much sooner with the result that the time in which the filter material loses its filtration efficiency is very short. This means that in the case of aerosol particles with an excess charge of a sign opposite to that of the electrically activated fibres, the process of degradation will take a short time before its filtration properties are stabilised (increased filtration efficiency). It is important to note that this conclusion applies to a case when filter materials are loaded with the same aerosol, which eliminates the effect of particle size on the filtration process and which means that the predominance of positive or negative charges is the only variable.

However, from the viewpoint of filtration efficiency of the filter materials used for respiratory protection the interesting question is how much filtration efficiency of the electret filter materials is dependent on the resultant charge of the real aerosol and how much on the sign of the charge. Relevant results are presented in Figures 8, 9, 10, 11, and 12 for a selected variant of activation of the melt-blown filter material.

Of the aerosols with a natural charge that showed the highest values of penetration were coal-mine dust, copper-mine dust and dust from the steelworks in Częstochowa, Poland. The resultant natural charge of these dusts varied as follows (given is the mean number of elementary charges in 1 dm^3 of aerosol):

- dust from the Częstochowa steelworks: $+42 \times 10^6$,
- copper-mine dust: $+85 \times 10^6$,
- coal dust: -21×10^6,
- dolomite dust: $+290 \times 10^6$.

After ionising, the first three aerosols showed a similar value of their electrostatic potential and

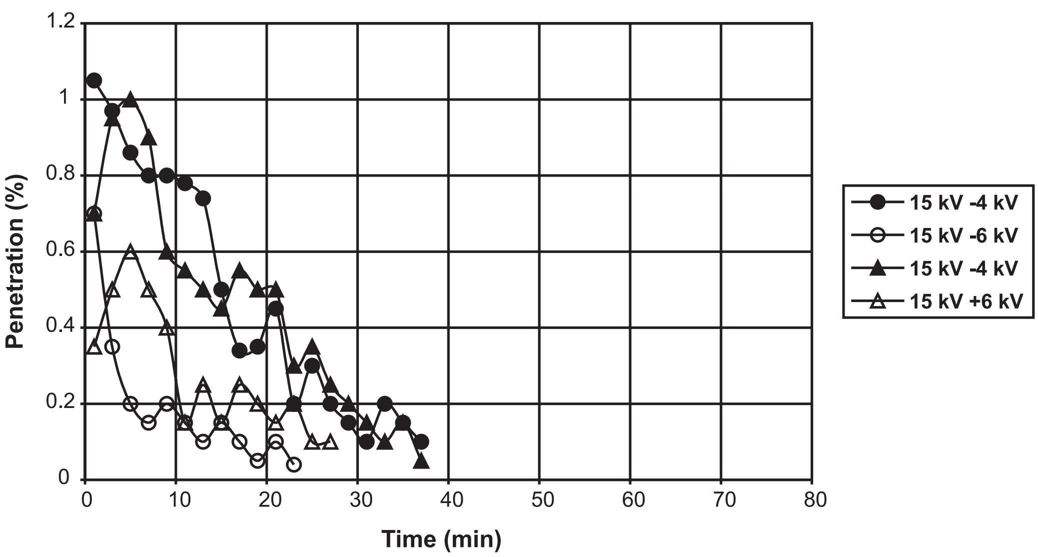

Figure 8. Changes in penetration with time of loading with copper-mine dust such as sampled—P, neutralised—N, ionised with a voltage of –4 kV and –6 kV and with a voltage of +4 kV and +6 kV for a melt-blown polypropylene filter material corona-charged at 15 kV.

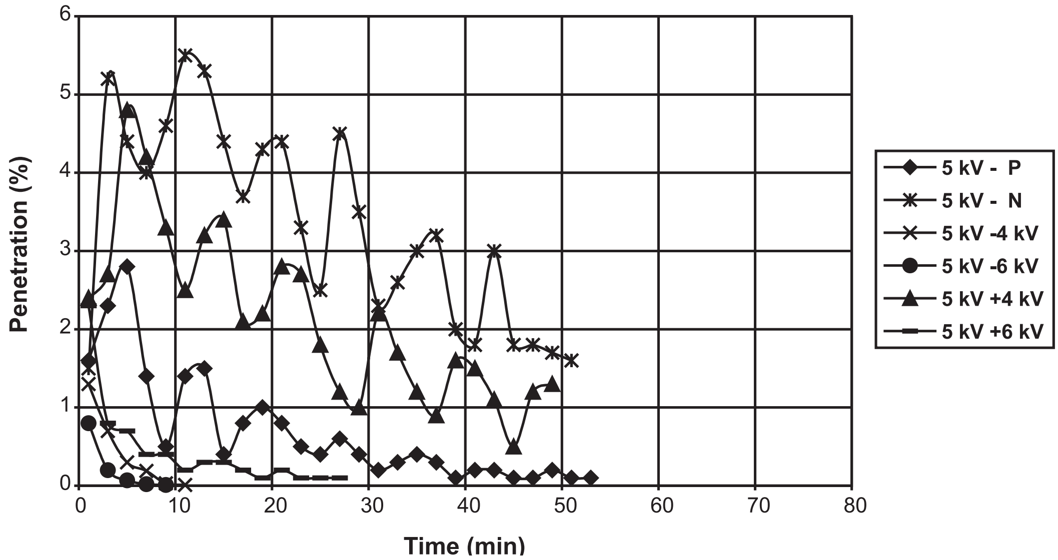

Figure 9. Changes in penetration with time of loading with coal dust (as specified by Standard No. PN-EN 143:2004 [10]) such as sampled—P, neutralised—N, ionised with a voltage of –4 kV and –6 kV and with a voltage of +3 kV and +6 kV for a melt-blown polypropylene filter material charged at 15 kV.

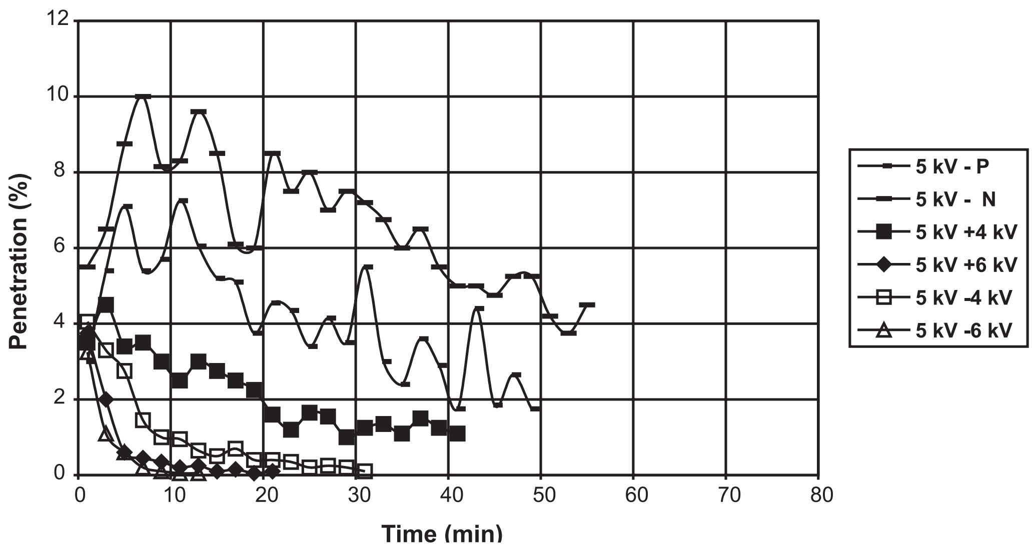

Figure 10. Changes in penetration with time of loading with dolomite dust (as specified by Standard No. PN-EN 143:2004 [10]) such as sampled—P, neutralised—N, ionised with a voltage of –4 kV and –6 kV and with a voltage of +4 kV and +6 kV for a melt-blown polypropylene filter material corona-charged at 5 kV.

it was independent of the ionising sign (Table 2). This was reflected in the result of the evaluation of the filtration efficiency of the tested melt-blown filter material. As shown in Figures 9, 10, 11, and 12 the filtration efficiency of the exemplified filter material was at worst from 4 to 7%, while if the same filter material was subjected to loading with dolomite dust, the result of its efficiency evaluation was decidedly better (2.5%). This was due to the fact that dolomite dust had the highest natural (positive) charge and, what is more, it charged 3 times stronger with negative ions at the same ionising voltage. It can be, therefore, concluded that the filtration efficiency of the electret filter materials is higher, the higher the resultant charge of the aerosol. To a lesser degree total filtration efficiency in use is dependent on the resultant sign of the aerosol charge. The sign, as it was shown

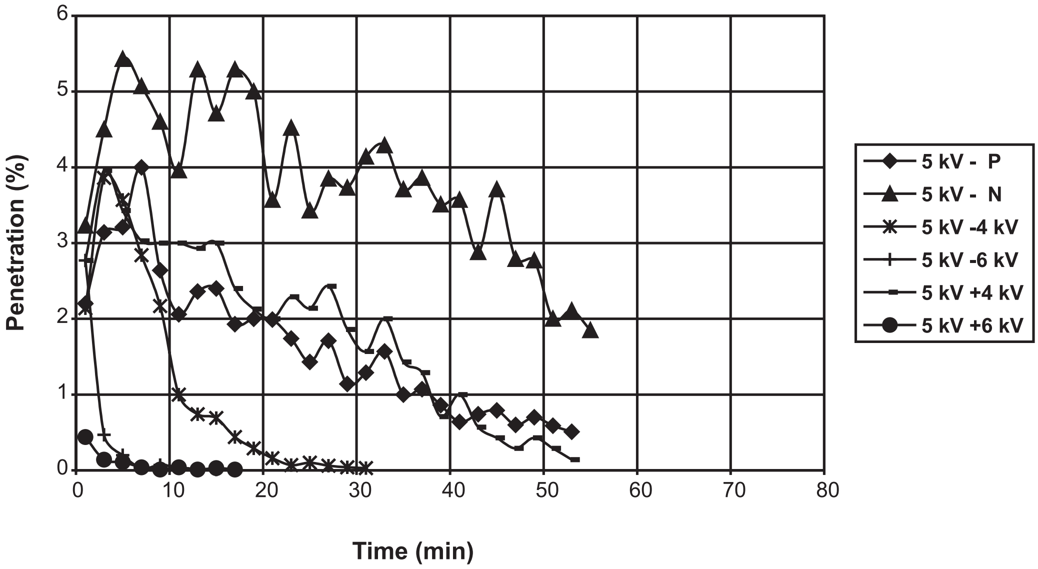

Figure 11. Changes in penetration with time of loading with coal dust (as specified by Standard No. PN-EN 143:2004 [10]) such as sampled—P, neutralised—N, ionised with a voltage of –4 kV and –6 kV and with a voltage of +4 kV and +6 kV for a melt-blown polypropylene filter material corona-charged at 5 kV.

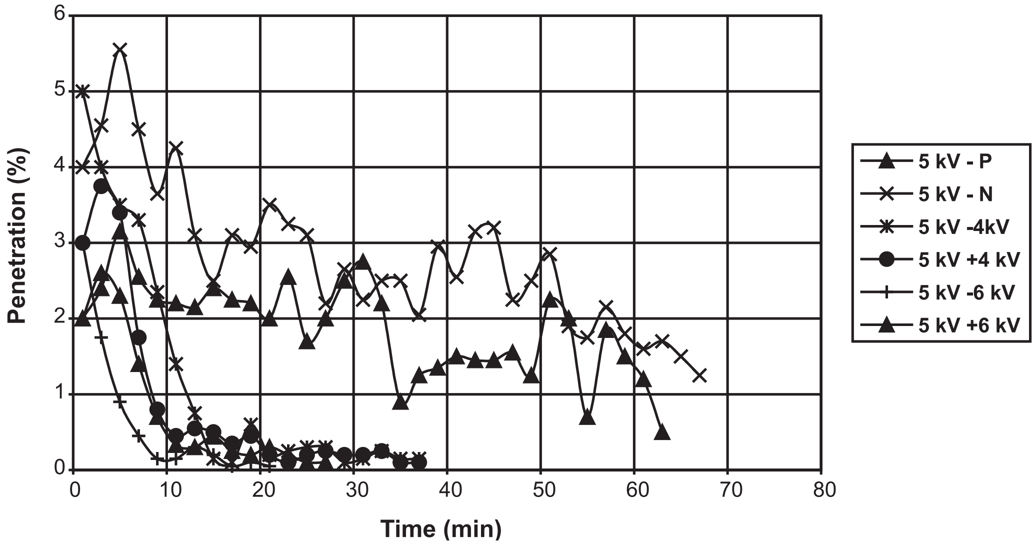

Figure 12. Changes in penetration with time of loading with dust from Steelworks, Częstochowa, Poland, such as sampled—P, neutralised—N, ionised with a voltage of –4 kV and –6 kV and with a voltage of +4 kV and +6 kV for a melt-blown polypropylene filter material corona-charged at 5 kV.

before, has a direct influence on the screening time of the charges accumulated on the fibres, and it can be a factor affecting filtration efficiency only if a real aerosol has small electrostatic potential. It seems, therefore, that at a higher resultant charge of the aerosol the difference between the efficiency of deposition of the negative and of the positive particles is obliterated.

In all cases, the test results confirmed the conclusion that the aerosols that showed the strongest penetration through the tested filter materials were the aerosols subjected to the neutralising process.

The dusts selected for the tests, starting from dielectric to conducting, were characterised by varied resistivity. However, no relationship was found between their conductance and penetration or changes in penetration with time. This suggests there is no transfer of charges from fibre to fibre, which is in agreement with the published data cited earlier.

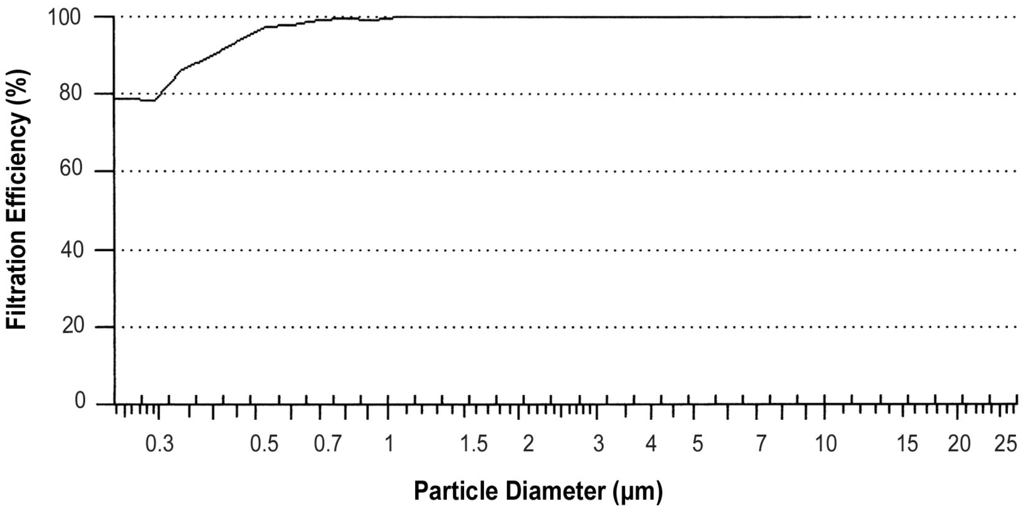

Figure 13 Relationship between filtration efficiency (vertical axis) and aerosol particle diameter (horizontal axis) for melt-blown polypropylene filter material, electrified at 5 kV, and steelworks dust.

From the viewpoint of protective performance of filter materials some extremely important observations were made when analysing filtration efficiency in the individual ranges of particle size. This is of essential importance as far as standard laboratory tests are concerned, in which the protection class of a filter material is determined by its mass efficiency against particles of the sodium chloride aerosol. Consider the case where the total penetration in terms of all particles that penetrated through the test filter was 4%. A detailed analysis showed that the value of penetration for particles of up to 1 μm, i.e., the fraction regarded as the most harmful for the respiratory system, was in excess of 20%. Such a case involving melt-blown filter material, i.e., the one most frequently used in RPD, is presented in Figure 13. Admittedly, a filter made of such material would satisfy the requirements of the relevant standards, but it would not provide sufficient protection against aerosols of very fine particles.

To verify the validity of the foregoing conclusions under conditions of increased humidity, tests were made for all of the aerosols and both types of filter material. For a better illustration of the phenomenon, the results of the tests are presented against results obtained at 25% RH (relative humidity) in Figures 14 and 15.

In all tests carried out under conditions of increased humidity (75%) increased filtration efficiency of the filter materials tested was observed for all variants of loading and of aerosols. The associated phenomena are mainly the results of adhesion between the particles of the aerosols, while no association with the electrostatic properties of the particles was found. Furthermore, when comparing the curves of penetration changes with time it is observed that the aerosols strongest penetrating through the electret filter materials were those with the highest hygroscopicity. If this conclusion is added to the observation that the neutrally-charged aerosols show decidedly higher values of penetration, it is likely that in the course of loading at the presence of substantial humidity, dissipation of the charges of the particles through conduction may be taking place.

Dust structures, as they grow with time, begin to interact and co-operate in the filtration process. The result is a change in the porosity of the filter material and a consequent change in the velocity of the gas inside the filter. If gas velocity exceeds locally a certain critical value, some particles of the dust deposited in the filter in the form of dendrites are detached and carried away by the flowing gas. This phenomenon, resuspension, always accompanies nonsteady-state filtration,

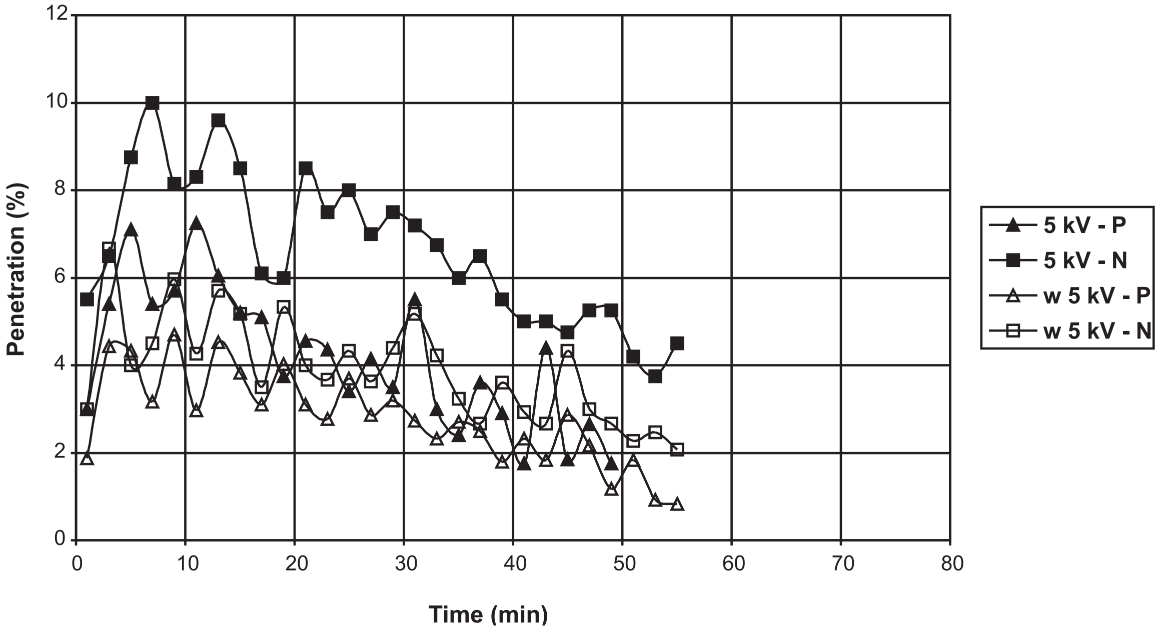

Figure 14. Changes in penetration during loading with coal dust [10] such as sampled—P and neutralised—N of polypropylene melt-blown filter material corona-charged at 5 kV and relative humidity of 25 and 75% (marked "w" in description).

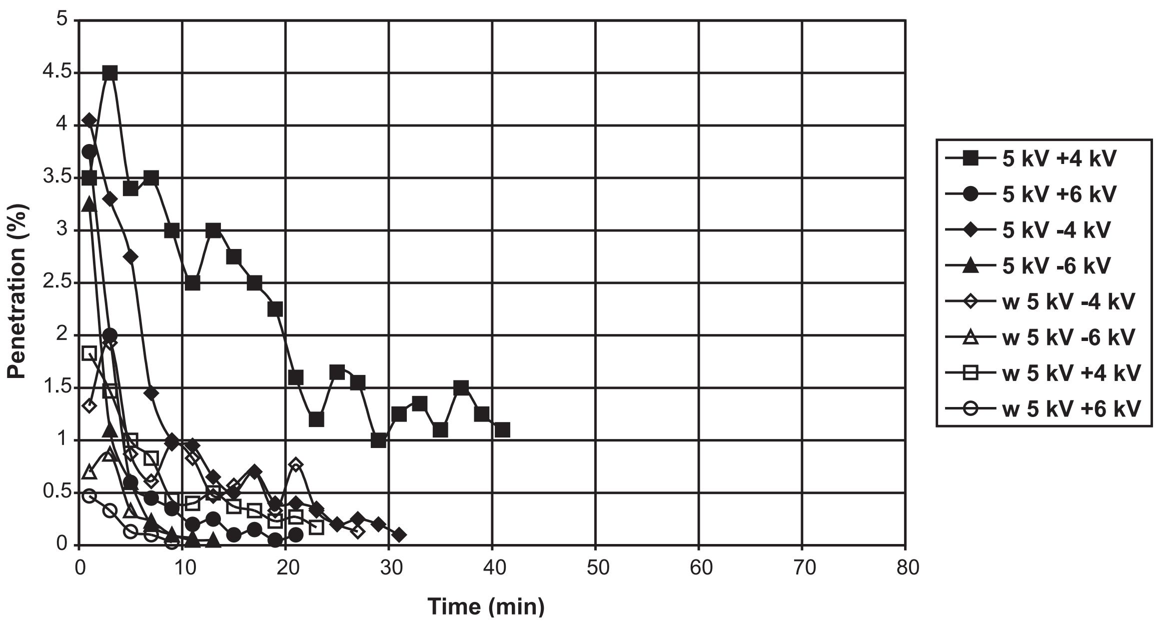

Figure 15. Changes in penetration during loading with coal dust [10], ionised at –4 kV and –6 kV and at +4 kV and +6 kV, of polypropylene melt-blown filter material corona-charged at 5 kV and relative humidity of 25 and 75% (marked "w" in description).

influencing the shape of the arising dust structures and, thereby, affecting efficiency of the filtration.

A confirmation of the occurrence of this phenomenon was provided by the discussed tests in which decreasing resistance of airflow through the tested filter was observed in all cases. It is always accompanied, with minimum anticipation, by a momentary increase of penetration. The described effect is illustrated in Figure 16 for copper-mine dust and melt-blown polypropylene filter material.

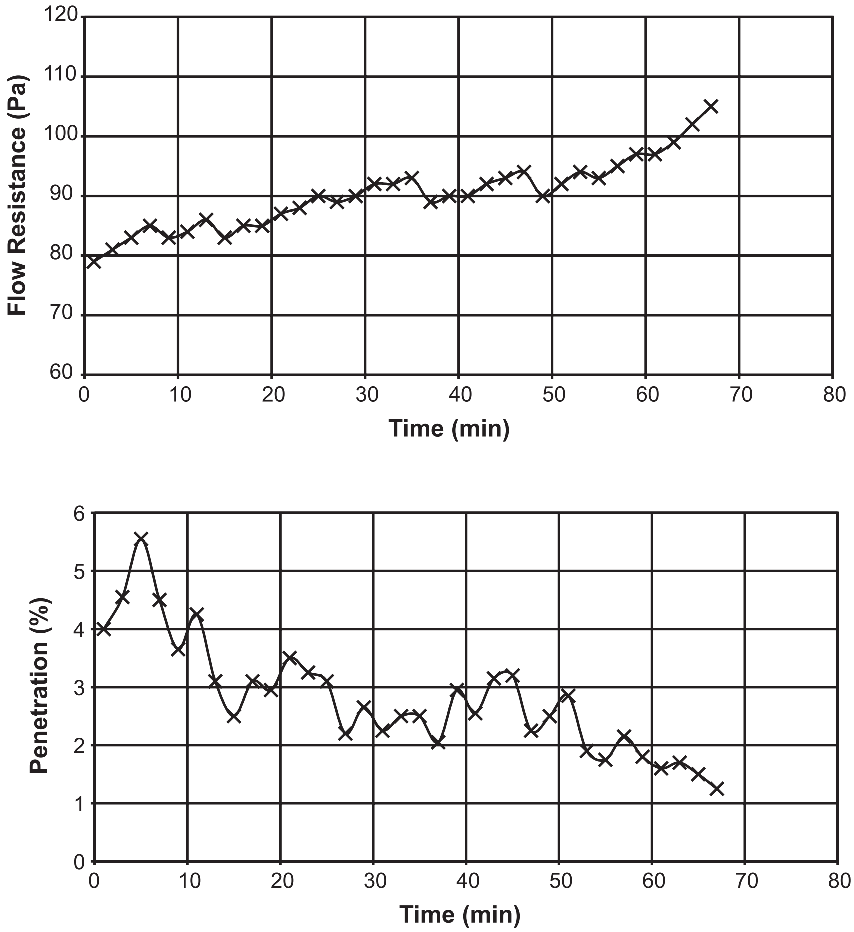

Figure 16. Changes in the airflow resistance and penetration of copper-mine dust through melt-blown filter material.

4. CONCLUSIONS

- With the assumption that dispersed particles had a uniform distribution, the aerosols strongest penetrating through the electret filter materials would be those with neutralised charge. The aerosols of which the resultant charge is close to zero show better penetration through electret filter materials. The particles of such aerosols charge with both positive and negative ions in a like manner.
- In the filtration of aerosols endowed with a high resultant electrostatic charge the efficiency of the electret filter materials is only weakly dependent on the sign of the charge. However, if in the filtration process an aerosol with a low resultant potential is involved, the filtration efficiency of the electret filter material depends on the type of the electret and the sign of the charge of the aerosol particles.
- No relationship was found between conductivity of the aerosol and the value of penetration and its changes with time. This suggests there is no migration of charges between the fibres and the deposited particles.
- If the object of filtration is fine-grained aerosol (of particle diameter up to 1 μm) with a neutral charge, filters meeting the requirements of Standards No. EN 143:2004 [10] or EN 149:2004 [11] may actually be incapable of providing sufficient protection for the respiratory system.
- A higher degree of electrification of the filter material always goes together with improved filtration efficiency throughout the full size range of the filtered particles (provided the structural parameters of the filter material remain unchanged), which results in a reduction of the time in which there is a drop of filtration

efficiency due to a screening of the charges accumulated on the fibres.
- Improved filtration efficiency is observed if the filter is operated under conditions of increased humidity. This phenomenon was observed in all tests of the filter materials and aerosols in all variants of their electrification.
- The aerosols with hygroscopic properties were stronger penetrating and they reduced the filtration efficiency of the tested filter materials to a higher degree.

The conditions of storage of RPD may affect their performance. This particularly applies to the highly efficient respiratory protections (Class P3, P2) which may lose their protective efficiency with time (of storage).

Also in use, there is the possibility of loss of filtration efficiency when dust particles accumulate in the filter material. This applies to electret filter materials. Loss of efficiency is promoted by low dust concentration and the presence of fine-grained dust (especially sub-micron fractions). If equipment Class P3 is used for protection against a particularly hazardous dust, it would be well advised to check up the selected equipment in a test simulating long-term exposure to sub-micron dusts.

If there are particularly dangerous (e.g., carcinogenic) aerosols without an electrostatic charge, then to prevent the decrease and loss of filtration efficiency it is recommended to use filters made, for instance, from glass fibres suitably protected against detaching. Glass-fibre filter materials have no charge and, therefore, there will be no reduction of filtration efficiency with time.

If there are aerosols with a predominance of one of the charges, then to achieve maximum filtration efficiency and to prevent its reduction it is recommended to use filters made from electret filter materials with a sizeable resultant charge of a sign opposite to that of the aerosol.

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