

# A New Method and Equipment for Manufacturing New Adsorptive Materials with Active Carbon Content

## Abstract

*This paper presents a new method and equipment for manufacturing adsorptive materials. The new filter materials are designed for cleaning air from impurities in the form of strongly irritant aromatic or chemical substances. The adsorbent material adopted for the experimental part was a polypropylene fibrous filter material powder-sprayed with fine-granulated active carbon. The active carbon was permanently bonded with the filter material, being partly melted into the surface of its fibres. The adsorbent materials produced, based on carbon-powdered PP stitched nonwovens, were subjected to laboratory tests. The results of the tests showed that these materials were characterised by good end-use properties as a respiratory protective material to safeguard the user against harmful air-borne impurities. The composite adsorbent filter material which we developed can be used in many fields, including air-conditioning, ventilation, hospital equipment, respiratory protective equipment, etc.*

**Key words:** composite filters, active carbon, carbonised nonwoven, adsorbent materials.

## Introduction

The problem of filtering gas/gas and gas/solid mixtures is the subject of many research projects, and leads to ever newer practical solutions. One of the most frequent objectives is the filtration of air for the purposes of respiratory protection. The basic question here is how to ensure better filtration efficiency while at the same time minimising the airflow resistance of the filter devices. Additionally, the conventional filter materials do not remove strongly irritant chemical or aromatic substances, which included very small particles, sometimes in the dimensions of molecules. The latter can be dealt with by adsorption.

As shown by many authors [1, 3, 5, 6-12, 21] the most efficient adsorbent is active carbon. The porous structure of active carbon makes it capable of adsorbing many airborne impurities, especially the gaseous impurities. The air filters adsorbing gaseous impurities are particularly useful in respiratory protective half-masks and full masks, absorbers or industrial air filters. Filter materials with active carbon, which are designed for use in respiratory protective equipment, should have high filtration efficiency and

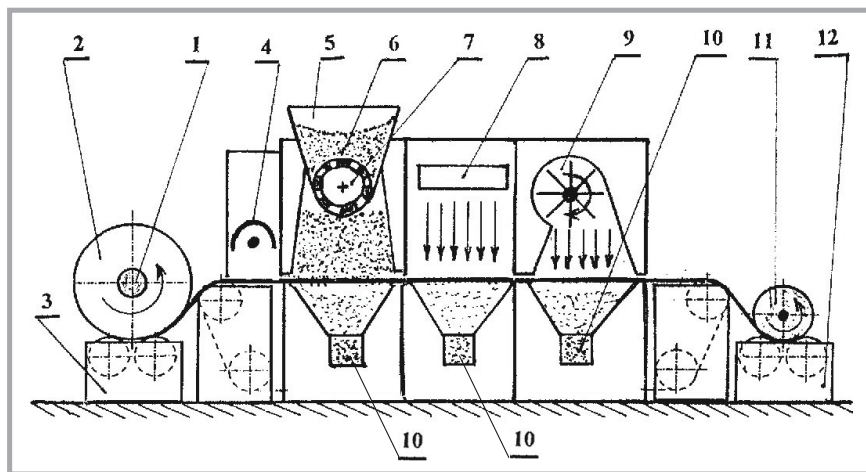
low airflow resistance. The bonding of the adsorbent with the substrate is also of great importance. This latter problem has still not yet been completely solved. Some notable advances in filtration have taken place in Japan, the UK and the USA [1 - 3]. German research institutes and manufacturers are the unquestioned leaders in this field [13 - 20].

Some new technologies for manufacturing filter materials have also been developed in Poland [4 - 12]. One of these is the original technology for manufacturing carbon-incorporating filter materials [5]. The product of this technology is a fibrous polypropylene filter material in which active carbon is embedded in the surface of the fibres. The carbon is thermally bonded with the filter material. The technology for manufacturing the carbon-incorporating filter materials and the test

results were presented in [10]. Further research in this field at the Institute of Natural Fibres, Poznań, has led to the development of an improved method for manufacturing carbon-incorporating filter materials [7]. The improvement consists in the input (unfinished) filter material being activated by means of a string electrode (the filter material is imparted with an electrostatic charge). This solution enables the deposition of a greater amount of active carbon on the filter material. Furthermore, by this method carbon can be incorporated in filter materials of higher unit weight.

## Experimental

In the experimental part, the materials selected for carbon powdering were polypropylene (PP) filter materials of an area weight ranging from 150 to 350 g/m<sup>2</sup>.



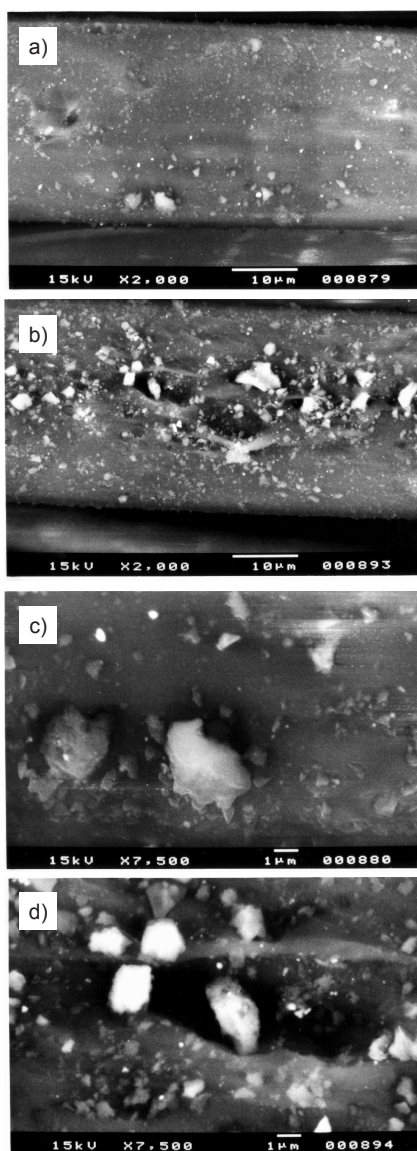
**Figure 1.** Device for manufacturing carbon-powdered nonwoven fabrics [7]; 1 – roller, 2 – nonwoven fabric, 3 – let-off drive, 4 – string electrode, 5 – container, 6 – active carbon, 7 – feeder, 8 – heating radiator, 9 – blower fan, 10 – chute, 11 – take-up roll, 12 – take-up drive.

The PP filter materials (not including the carbon content) were produced as a stitched nonwoven from thermoplastic fibres of a linear density of 18 dtex and a staple length of 50-60 mm.

The powdering operation, using SAR-P-type carbon (Gliwice, Poland) was carried out on a specially developed powdering device [7] shown in Figure 1 (see page 1). Microscopic photos of the PP fibres carbonised by powdering are presented in Figure 2 at two magnifications: 2000× and 7500×.

The powdering device consists of six zones:

- a feed zone with a roller, and a let-off device;



**Figure 2.** Microscopic pictures of PP fibres with constantly connected active carbon on their surface; a, b - magnification 2000× and c, d - 7500×.

- an activation zone with a string electrode of 24 kV activation voltage;
- a powdering zone with an active carbon container and feeder;
- a heating zone (heated by a radiator);
- a stabilising zone with a blower fan;
- a delivery zone with a rolling device with the take-up roll, and a take-up drive.

Imparting an electrostatic charge to the filter material before entering the powdering zone assisted the deposition of active carbon by adding electrostatic deposition (attraction) to the normal gravitational deposition. This dual deposition method offers the possibility of permanently bonding a greater amount of carbon with the filter material. The amount of active carbon fed to the powdering chamber is controlled by the feeder located in the carbon container. The carbon left unbound in the powdering, heating, and stabilising zones is collected in the chutes. The carbon accumulated in the chutes was fully reused for powdering the nonwoven.

The SAR-P active carbon used has the following parameters:

- Methyl number: 25 ml;
- Ash content: 8.7%;
- Water content: 3.8%;
- pH: 6.8;
- Grain-size: from 0.001 mm to 0.071 mm – 12%; below 0.001 mm – 88%.

The bonding of the active carbon is accomplished by its partial sinkage into the surfaces of the fibres. The black colour of the carbon particles causes them to be heated to a higher temperature than the white fibres, thanks to the heat radiator.

The amount of carbon that is permanently bonded with the fibres is 10-18% of the pure PP nonwoven mass, depending on the area weight of the filter material. The powdering efficiency of the thermoplastic PP fibres is mainly dependent on:

- the amount and type of the carbon powder (one type of carbon powder was used for our tests),
- the temperature in the heat radiator chamber (which can be set by the power of the heater),
- the rate of travel of the filter material (determined by the let-off and take-up drive), and
- the thickness (area weight) of the filter material (selected for the particular filter technology).

The four factors mentioned above are mutually related, and allow for various sets of parameters to be selected.

Generally, the thinner the nonwoven, the higher the percentage of carbon which bonds with the fibres. The increase in temperature also increases the carbon content, but the defined limitation is valid. The higher the area mass, the smaller is the content of bonded carbon, as in thicker nonwovens the carbon penetrates the nonwoven matter less efficiently. The filter-materials were designed as single-use packs, without any provision for regeneration. Their durability depends on the contamination of the air.

## ■ Laboratory tests

The adsorbent carbon-powdered materials were subjected to the following tests:

1. Test of static sorption capacity with respect to vapours of tertiary butyl benzene (TBB); performed in a closed vessel filled with a mixture of air with TBB vapours of a concentration near saturation, at room temperature. The mass increments were measured by an analytical balance.
2. Test of penetration of sodium chloride aerosol and aerodynamic resistance; in accordance with standards PN-2-02024 (for a), PN-EN-141 (for b), and PN-86-2-02010/10 (for c).
3. Test of dynamic sorption capacity with respect to a) trichloronitromethane (chloropicrin), b) carbon tetra-chloride, and c) tetrachlorobenzene; at samples of 28 cm<sup>2</sup> active surface, in accordance with standard PN-EN 143:1996.

The samples of adsorbent materials selected for testing varied in their area weight and the amount of carbon deposited. The results of the laboratory tests showed that the adsorbent materials had good values of practical performance from the viewpoint of respiratory protection against harmful airborne impurities. The detailed test results of selected filter materials are not a subject of this article, but may be found in other publications by the author, as well as in research reports from the Institute of Natural Fibres, Poznań, Poland and the VAMAC enterprise.

It was also confirmed that the materials tested had good adsorption capacity in relation to the test substances (trichloronitromethane (chloropicrin), benzene, carbon tetrachloride, tertiary butylbenzene) both under static and dynamic conditions of operation. The results of the tests of static saturation capacity of the adsorbent materials with respect to vapours of tertiary butylbenzene (TBB) are presented as an example in Table 1.

The high values of penetration of sodium chloride aerosol which we obtained are an indication of poor filtration properties. To improve the filtration properties, the adsorbent material needs to be combined with a material with good filtration properties. To extend the application of the carbon-incorporating materials to a wide range of filters meeting the requirements of various operating conditions, different composite adsorbent filter materials were developed (Figure 3).

The characteristics of the composite filter materials are presented in Table 2.

The selected filter materials presented in Table 2 were subjected to laboratory and practical performance tests carried out in the Military Institute of Chemistry and Radiometry, Warsaw, and the Central Institute of Working Protection (CIOP), Łódź.

The following composite materials with the particular area masses of the carbon-powdered layer were first manufactured and then tested:

- item 1: 150, 200, 250, 300, 350 g/m<sup>2</sup>,
- item 2: 150, 300 g/m<sup>2</sup>,
- item 3: 200, 250 g/m<sup>2</sup>,
- item 4: 200, 400, 2x200 g/m<sup>2</sup>.

For all these materials the following results were obtained:

- filtration efficiency – up to 99.6%;
- range of application – filtration of dust, molecules, odours;
- airflow resistance – maximum 200 Pa;
- filtration rate within the range of 1.5 dm<sup>3</sup>/m<sup>2</sup>s.

The filtration parameters are influenced by the structure and material composition of the filter. The most important are linear density of the fibres, type and granule size of the active carbon, the compactness of the fibre mass, the area weight of each component material, and the total area weight of the composite filter material.

**Table 1.** Static saturation capacity of adsorbent materials with respect to vapours of tertiary TBB [mg/g]. Increase in area weight with time of samples with active carbon SAR-P.

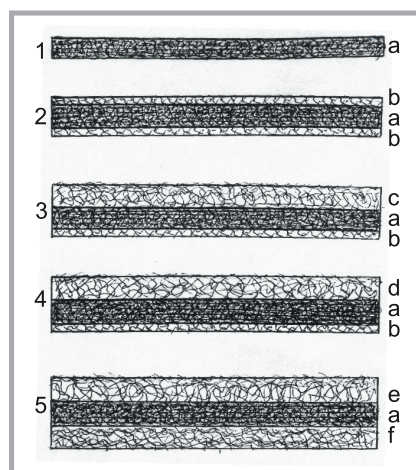
Time, h	Increase in area weight of sample in g/m <sup>2</sup> at the samples of following area weight in g/m <sup>2</sup>				
	150	200	250	300	350
0	0	0	0	0	0
2.2	48	60	71	78	84
4.0	54	64	86	89	100
6.0	60	68	98	110	123
22.5	110	125	151	162	178
46.5	123	141	168	177	183
70.5	120	140	166	181	188

**Table 2.** Characteristics of the composite filter materials.

Item	Type/ structure	Area weight, g/m <sup>2</sup>	Carbon content, %
1	One-layer (a)	150-350	18-10
	a) Carbon-powdered, calendered or non-calendered	150-350	
2	Three-layer (b-a-b)	210-410	18-10
	a) The interlayer carbon-powdered and calendered or non-calendered; b) The outer layers: melt-blown	150-350 2x30	
3	Three-layer (c-a-b)	430-580	16-12
	c) The upper layer: flame-retardant; a) The interlayer: carbon-powdered; b) The lower layer: melt-blown	200-300 200-250 30	
4	Three-layer (d-a-b)	430-730	16
	d) The upper layer: electret a) The interlayer: carbon-powdered; b) The lower layer: melt-blown	200-300 200-400 30	
5	Three-layered (e-a-f)	600-900	16
	e) The upper layer: electret or flame-retardant; a) The interlayer: carbon-powdered; f) The lower layer: needled and calendered	200-300 200-400 200	

## Summary

The results of the tests confirmed the high filtration efficiency of the carbon-incorporating filter materials. The method of surface bonding the active carbon with electrostatically activated filter material is a significant improvement of the technology. The dual powdering



**Figure 3.** Single-layer and three-layers composite adsorbent filter materials.

methods of the fibres with active carbon, gravitational and electrostatic, enabled the following:

- increase in the amount of carbon introduced to the structure of the filter material up to approximately 18%;
- increase in the area weight of the filter material up to 400 g/m<sup>2</sup> of a single carbon-powdered layer;
- increase in the sorption capacity of the carbon-incorporating filter material.

The fibre and carbon adsorbent materials produced by the new improved technology and the device constructed permit the development of highly efficient adsorbent filter composites with the following three-way performance:

- filtration (one component of the composite entraps particulate impurities);
- attraction (the electret component to attract and arrest dust particles, pollen, spores of mould & fungi, bacteria and viruses);
- adsorption (the component with active carbon adsorbs the odours and molecules of irritant chemicals).

The Institute of Natural Fibres, Poznań, has taken out patent No. 185702 for the method and device for manufacturing the carbon-incorporating filter materials.

## Conclusions

1. The process of producing carbon-incorporating filter materials was improved by altering the method of carbon-powdering the fibres in the powdering device.
2. The new gravitational/electrostatic method of powdering statically activated filter material with active carbon enables the deposition of a substantially higher amount of active carbon on the filter material.
3. The new method permits the area weight of the carbon-powdered filter material to be increased.
4. The adsorbent filter materials produced have good parameters of practical performance and protection against the vapours of harmful substances, and they are suitable for application in air-conditioning, ventilation, and respiratory protection.

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## 60 years of the Polish Textile Association



The celebration of the 60th anniversary of the Polish Textile Association (Stowarzyszenie Włókienników Polskich – SWP) was held during the SWP's special session on 11 December 2006 in Łódź. The session programme comprised:

- A lecture summarising the 60 years of the SWP's activity, by Professor Janusz Szosland, the honourable President of the Association;
- 'The history of the 60 years' activity of the Łódź branch, by Dr. Bogdan Ignasiak, the President of the Łódź Branch;
- 'The programme for the future', by Professor Witold Łucznyński, the current President of the Association;
- Congratulations by the Government & City of Łódź representatives and guests;
- A cocktail party.

The first professional organisations of textile engineers and technicians were already established in the 1920s and 1930s in Bielsko-Biała, Łódź and Warsaw. The Second World War disrupted this activity. Immediately after the battle-fields rolled west, the General Assembly of Engineers and Technicians founded the All-Polish Technical Association (OTT) in February 1945 in Łódź, with a predominant textile session; in April 1946 they founded the independent Association of Engineers and Technicians of the Textile Industry, the current Polish Textile Association. The first local branches were founded in Bielsko-Biała and Łódź, and at present the branches in Bielsko-Biała, Częstochowa, Łódź, Radom, and Wrocław are the most active. The seat of the Association has from the very beginning resided in Łódź.

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