THE EFFECT OF MEDIA AREA ON THE DUST HOLDING CAPACITY OF DEEP PLEAT HEPA FILTERS

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ABSTRACT

The high potential cost of storage, treatment and disposal of radioactive wastes places a premium on the longevity of installed HEPA filters in situations in radioactive processing facilities where dust capacity is a life determining factor.

Previous work investigated the dust holding capacity v pressure drop characteristics of different designs of HEPA filter and also the effect of using graded density papers.

This paper records an investigation of the effect of media area variation on the dust holding capacity of the "deep-pleat" design of HEPA filter. As in the previously reported work two test dusts (carbon black and sub micron sodium chloride in the range (0.15 - 0.4μm) were used. Media area adjustment was effected by varying the number of separators within the range 60 - 90.

Results with the coarser dust allowed an optimum media area to be identified. Media areas greater or smaller than this optimum retained less dust than the optimum for the same terminal pressure drop. Conversely with the finer sodium chloride aerosol the dust holding capacity continued to increase up to the maximum area investigated.

INTRODUCTION

The prime concerns of facility operators (and regulators) in the nuclear industry in respect of HEPA filter systems are their efficiency (DF) and reliability in accident conditions.

Considerations of economy in conjunction with the high potential cost of storage, treatment and disposal of radioactive wastes mean that the longevity of installed HEPA filters (in situations where dust capacity is a life determining factor) is also an important consideration.

Earlier investigations[1,2] looked at the influence of filter design viz deep-pleat vs minipleat and the use of graded papers[3] on dust holding capacity.

This paper describes an investigation into the effect of variable media area on the dust holding capacity of a particular design (the 1000cfm deep-pleat design) of HEPA filter. The media area was varied by varying the number of pleats/separators.

SCOPE OF WORK

Dust holding capacity of filter units is influenced by a number of factors, related to the nature of the airborne dust and its mode of deposition within the filter structure.
An ideal study procedure would freeze all parameters other than the one under investigation. Resource limitations constrained the present work to a limited practical investigation of real filters; procurement logistics dictated the use of filters from 3 different sources employing 2 different papers (of equivalent grade) in their construction.

In real operating situations HEPA filters encounter a whole range of conditions where they can be subject to widely varying dust burdens, both in terms of concentration and size distribution.

As in the graded media investigation[3] reported at the previous (23rd) Air Cleaning Conference, this work was carried out using two test dusts, one a fine thermally generated condensation aerosol of sodium chloride and the other a carbon black aerosol generated by dispersion of powder using a standard ASHRAE dispenser.

These two aerosols were selected partly on the basis of technology availability as established test dusts and partly on the basis of simulating widely differing operational conditions.

This approach utilised available technology to carry out a viable programme capable of producing an indicative if not a totally rigorous and comprehensive answer to the question of HEPA filter optimal dust holding capacity.

TEST EQUIPMENT AND FILTERS

Test Rig

The test rig consisted of circular ductwork with an open inlet to enable dust to be dispensed into the airstream, a filter housing and downstream ductwork connected to an extract fan. Volume flowrate was measured by BS orifice plate and controlled by adjustable damper. Filter resistance was measured using a micromanometer. The rig was identical with the one described in the graded paper work[3].

Test Filters

The deep-pleat filters were supplied by 3 manufacturers and conformed to the requirements of the British Nuclear Industry Specification[4] with media area varying from 18.8 m^2 up to 28 m^2. All filters were rated and tested at 1700m^3/h (1000 cfm) and had a minimum efficiency of 99.95% when tested by the sodium flame test[5]. They were all manufactured using either Hollingsworth and Vose Grade F39ZAE/R ("HV" in data) or Lydall grade L3255 ("L" in data). (Grades of paper currently in use in the UK nuclear industry).

Test Aerosols

The test aerosols used to load the filters were:-

(a) Sodium chloride with a MMD of 0.14μm[6]. A thermal generator was used in this work producing a condensation aerosol by vaporisation of sticks of solid sodium chloride in an oxy-propane flame; this equipment is capable of generating particulate material at rates between 0.32 and 6.7 g/min.

(b) Carbon black, acetylene, 50% compressed, with a nominal MMD of 0.6μm. Measurements carried out with an Anderson Mk III impactor[7] on airborne material dispersed with the standard ASHRAE dispenser gave an aerodynamic MMD of 2μm (35% below 1μm). These measurements are in accordance with the view that dispersion of this material by this method is far from complete. The standard ASHRAE dispenser is suitable for dispersing carbon black aerosols at rates between 0.3 and 2.4 g/min.

Test Procedure

All filters were tested at their rated flow of 1700 m^3/hr (1000 cfm). The mini-pleat filter although rated at 3000 m^3/hr (1760 cfm) was tested at 1700 m^3/hr (1000 cfm).

Dust holding capacity determinations were carried out with each filter mounted in the appropriate housing and subjected to a dust challenge at a uniform feed rate. For carbon black aerosol the feed rate to the deep-pleat filters was 2.4 g/min and to the mini-pleat unit, 1.2 g/min. For sodium chloride aerosol the feed rate was 3.6 g/min. The filter resistance was recorded against the known quantity of dust.

For purposes of comparison it is assumed that filters are changed out at a terminal resistance of 4"wg (1000 Pa), although operating practice may vary depending on other installation parameters.

CARBON BLACK LOADING RESULTS

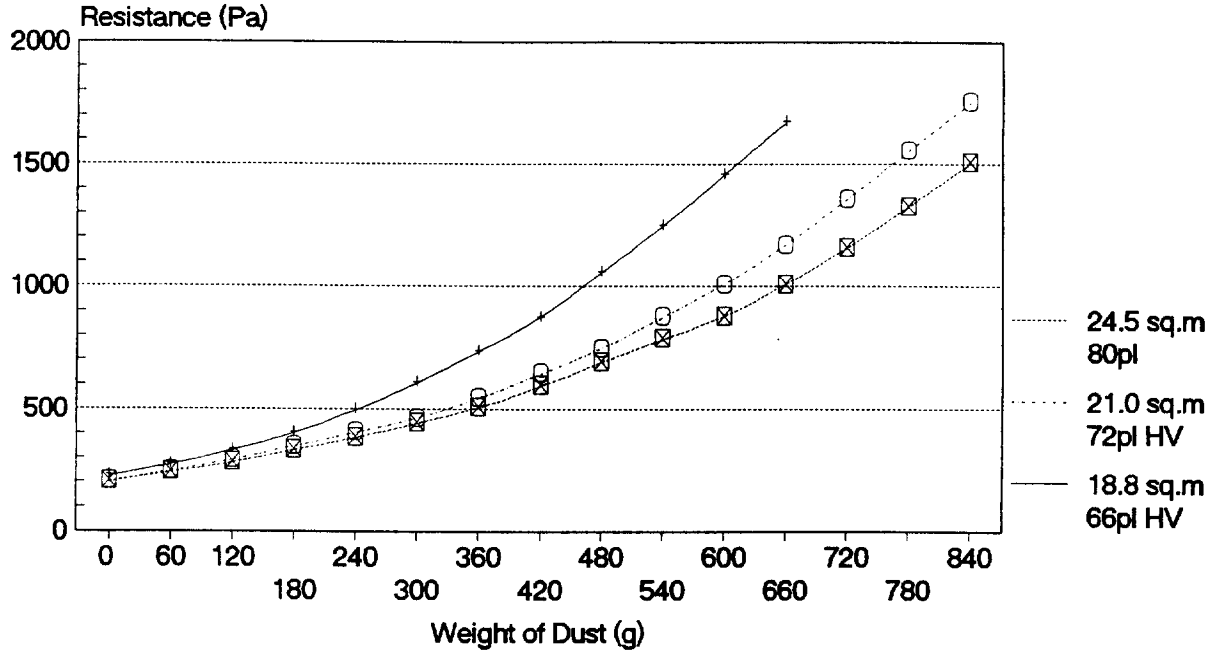
Deep-pleat Filters

The results, (Figures 1 & 2), indicate the extent to which the carbon black dust holding capacity of this design varies with varying media area.

The current standard deep-pleat filter which has an average media area of 19 m^2 and approximately 66 media pleats (132 single sheets of media) can absorb some 470 g of carbon black before its resistance increases to 4"wg (1000Pa).

As the number of pleats increased from 66 to 80 the weight of carbon black absorbed rose to approximately 660 g for the same final resistance. Further increases in the number of pleats to

FIGURE 1 - DUST LOAD v RESISTANCE
(DEEP PLEAT FILTERS)
Carbon Black Loading



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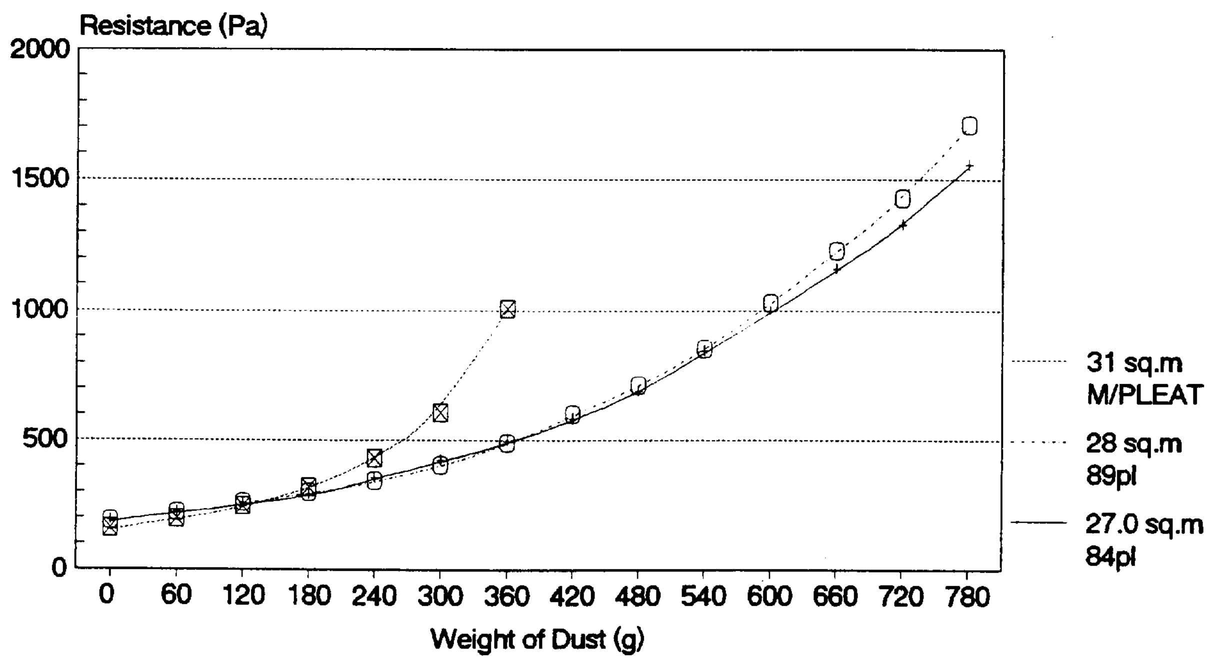
DUST1

FIGURE 2 - DUST LOAD v RESISTANCE
(DEEP-PLEAT & MINIPLEAT UNITS)
Carbon Black Loading



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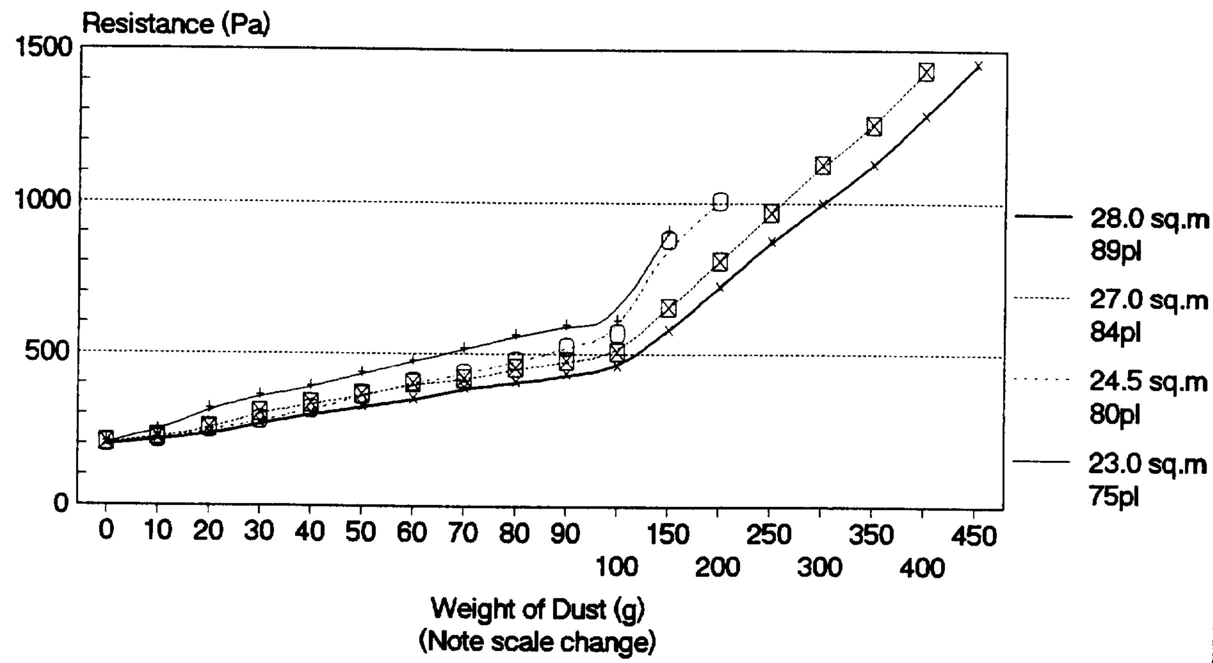
DUST2

FIGURE 3 – DUST LOAD v RESISTANCE
(DEEP–PLEAT UNITS)
Sodium Chloride Loading



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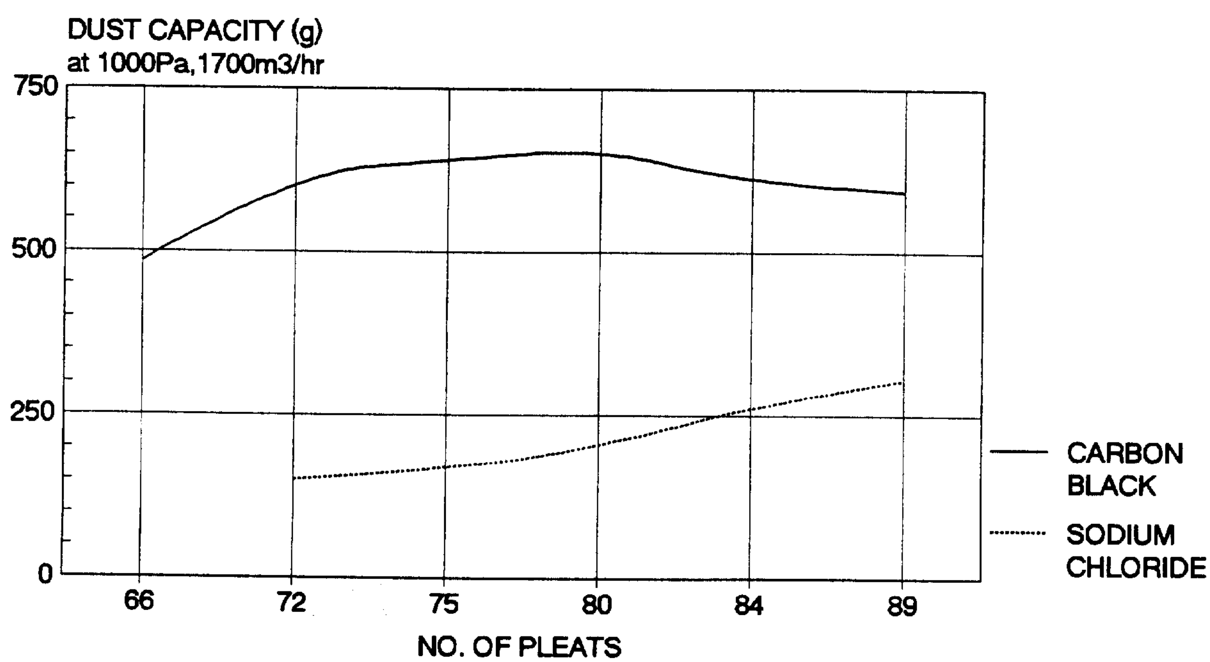
DUST3

FIGURE 4 – DUST CAPACITY v No OF PLEATS
(DEEP–PLEAT UNITS)
Sodium Chloride and Carbon Black



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DUST4

84 and 89 pleats resulted in a (small) apparent reduction in carbon black capacity.

Discussion of Results

As the number of pleats varies, different mechanisms interact to affect the filter resistance. Channel cross-sectional areas will decrease both individually and overall, so that the increased air velocity at the channel entrance will cause increased pressure losses.

The increased velocity may also in the latter stages of loading encourage a build-up of dust at the channel entrance thus further reducing the entrance cross sectional area.

It appears these effects are cumulative and more than counterbalance the advantages of the larger media area as may be seen in the results for 84 and 89 pleats, where the dust capacity of the unit is less than for 80 pleats.

This result suggests that HEPA filters having a paper area of 24-25m^2 will have an optimum capacity for dust having properties equivalent to those of carbon black.

Deep-Pleat v Minipleat Capacity (Carbon Black) at 1700 m^3/h

Figure 2 shows carbon black dust loading results obtained with a minipleat filter having some 31 m^2 of media. Although its initial resistance was well below those of all of the deep-pleat units, it rose to the terminal value, (1000Pa), with a dust load of only 360 g, approximately 55% of that obtainable (660g) with the 80 pleat deep-pleat unit. This result, which was for comparative purposes only was in line with the results of earlier tests[2] carried out on minipleat filters at a higher flowrate.

SODIUM CHLORIDE LOADING RESULTS

The results of loading the range of deep-pleat filters with the sub-micron sodium chloride aerosol are shown in Figure 3. The capacities are lower (in terms of weight) than those obtained using carbon black by a factor of about 3. As the basic particle density is similar it may be deduced that the difference relates to the greater drag engendered by the finer particle deposits.

The sodium chloride dust holding capacity of the range of deep-pleat filters increased steeply with increase in media area, in line approximately with (number of pleats)$^{3.5}$; considering that the average thickness of a continuous the dust layer would be in the region of only 5-10μm, it is apparent that a "cake" filtration regime will not have been established; thus the changes in resistance will be accounted for by a combination of increase in fibre drag from the adhering particles on the one hand and on the other by increased local velocities where the flow passages between the surface fibres are restricted.

DISCUSSION OF RESULTS

Results obtained for the two dusts vary significantly but do not necessarily represent the extremes of the whole range of operational situations.

It will be seen that the advantages of larger area HEPAs in terms of dust holding capacity are realisable principally when "fine" aerosols are involved. For aerosols having properties equivalent to carbon black there is a significant advantage in an increased area up to say 24 m^2. Increasing the area further can be counter productive.

Should a dust be coarser and even more cohesive than carbon black then the chances of covering the channel entrances become greater. The optimum HEPA design in such a case would be likely to shift towards fewer (and wider) channel entrances.

Such observations fit with the thesis that HEPA filters are far from ideal as economic collectors for significant quantities of dusts, particularly coarse and/or "sticky" dusts. They perform best as "final polishers", or the ultimate guarantee of the effective removal of airborne particulate material, when the residual airborne concentrations involved are very low.

When filter disposal costs become a major operating cost as may be the case with radioactive processing facilities it is relevant to note that the weights of dust collected (of the order 150 - 600g in the present work) are a small percentage fraction (say ~1-2%) of the total weight (20 - 30 kg) of a typical HEPA element.

Economic use of HEPAs where significant concentrations of airborne particulates are involved requires that consideration be given to the use of renewable (eg cleanable) devices to remove coarse cohesive material and thus minimise the number of HEPA changouts during the life of a system.

Enhancement of HEPA life by using increased areas of filter media within the same envelope is therefore most effective when fine well dispersed aerosols are involved; this is also reflected in the findings for graded papers[3] when optimum enhancement was obtained in the collection of the finer aerosol.

CONCLUSIONS

1 For operational situations/conditions where the challenge is predominantly a "fine" aerosol which is collected evenly throughout the whole effective media area and where there is a premium on disposal costs there would appear to be significant potential advantage in using filters with larger areas of filter media. Such conditions also favour the use of filters having "graded" paper media, and the dust characteristics conferred by a combination of such features remains

to be explored.

2 When there is a relatively cohesive and/or coarse particulate challenge to the HEPA filters, uneven dust deposition may lead to restriction and partial closure of the channel entrances. Such phenomena may cause premature resistance rises resulting in under-use of much of the media area (and consequent higher frequency of change out and accompanying elevated disposal costs).

REFERENCES

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ACKNOWLEDGMENTS

Acknowledgement is due to AAF Ltd, MC Air Filtration Ltd and Trox Brothers Ltd who supplied filters for this work. The work was carried out by AEAT Harwell under contract to the MoD.

DISCUSSION

DORMAN: Carbon black is notorious for forming long chains and is therefore more likely to cause "bridging"than small single particles. I am, however, somewhat surprised that relatively coarse particles size (conclusion 2) may have the effect of closing channel entrances. Cold you give a size to "relative" and also say how uneven the deposits were?

DYMENT: The aerodynamic MMD of the airborne carbon black as measured by cascade impactor was 2μm, with 35% below 1 μm, with 35% below 1 μm. The phenomenon of "uneven depostion" of test dust related to its observed tendency to accumulate more rapidly near the entrances to the pleats, causing eventual flow restriction. We are not able to quantify the degree of uneveness but we assume it results from increased local inertial deposition favored by the local flow pattern and the known cohesiveness of the dust.