Study of HEPA Filter and Finding its Efficiency with Change in Air Pressure

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Abstract— The physical behaviors of indoor air particles were studied in order to test the efficiency of air filter. The filteration characteristic of filter media in terms of its efficiency and effectiveness, were evaluated and analyzed. During testing, the efficiency of filter medium showed maximum efficiency of 93.9% with drop in pressure from 80.73kg/m³ to 75.73 kg/m³. The ability of filter to capture particles depends on the size of particles passing through its fibers as well as the velocity of the flow passing through the filter. The velocity of air depend on energy provided, therefore filter media should be energy efficient. In-situ measurements were taken using a manometer which is placed to measure the pressure drop between the two sections just before and after the filter, thus it displays the pressure drop induced by filter medium. The pressure drop increases with time because the resistance to the air is increased with the particles captured in the filter. As the resistance to the air increases, more energy is required to maintain the same air pressure. The ability of filter to move air through the system is reduced when the pressure drop increases. When this ability is reduced, more energy is required to provide the same air flow. When the efficiency of a filter increases, the pressure drop usually increases too.

Key words: HEPA, Air Filter, Filter Pressure, HEPA Filter, Efficiency

I. INTRODUCTION

Indoor air quality of a building is average 2 to 5 times more polluted than that of outdoor air, filled with allergens and airborne irritants. With humans spend about 80% of their lifetime indoor environment [1], it is no surprise health problem related to poor indoor air quality are on the rise. Conditions caused by indoor air are often divided into two categories, Building-Related Illness and Sick Building Syndrome. Building-Related Illness is related to identified microbes, or fungi, that can be linked to various diseases. Sick Building Syndrome occurs when occupants of a building claim to have symptoms which cannot be traced.

The role of air filter in providing relief for people with allergic respiratory illness has been studied for more than 40 years [2]. In a 2010 rostrum article, Sublett provided a comprehensive review of air filtration. The authors described the characteristics of airborne particulates, including allergens, to be filtered, and he pointed out that choosing cleaning devices, initial cost and ease of regular maintenance should be considered. Especially with HEPA filters, especially those that filter the breathing zone during sleep, appear to be beneficial to human health.

Johnson et al. [3], in a single study of over 219 children with asthma from 186 homes, tested the effectiveness of simple low-cost home interventions, including WHF, in improving health scores. His Interventions included the use of a high-efficiency (MERV 12) furnace filter (72.3%) and HVAC service (78.2%) for homes identified with (HVAC) problems. He also included a room air cleaner (69.3%) placed in the child's bedroom, basement dehumidifier (54.5%), and dryer exhaust ventilation (35.6%). All four interventions were used in 33.7% of the homes. The most effective interventions relative to symptoms were HVAC servicing with improved air filtration and dehumidifiers Room air cleaners were also beneficial, but the study did not indicate which homes had both the HVAC filtration plus additional room air cleaners.

In a year-long, parallel study, Francis et al. [4] measured the clinical outcomes for the use of HEPA air cleaners in both the bedroom and living room of 30 adult asthmatics, they were both sensitized to and lived with (against medical advice) an indoor cat or dog. The control group and the active group also used cyclonic HEPA vacuums twice per week. Primary end points in combined asthma outcomes (bronchial reactivity and treatment requirements) were statistically improved in the treatment group over the controls. Secondary end points of lung function and allergen levels improved in both groups and were not statistically significant.

HEPA filters [5]. Were first developed in the early 1940s and used first by the Manhattan Project to control the spread of airborne radioactive contaminants around the city. HEPA filters were introduced commercially in the following decade to eliminate viruses, bacteria, airborne fungi, pollen, human hair, and particulate from the air in buildings. HEPA filters grew in popularity and necessity as technological advances that accompanied the Cold War saw the growth of industries in need of highly efficient air filters, such as the computer, electronics, aerospace, and nuclear power industries. Hospitals and pharmaceutical manufacturers also kept the filters in high demand, while the emergence of strict air pollution laws in the United States and other countries beginning in the 1970s raised awareness about the importance of clean air.

Unlike membrane filters, HEPA filters typically involve a pleated sheet of randomly arranged fibreglass fibres with diameters usually between 0.5 and 2 micrometres [6]. A motorized fan passes air through the filter, where particles are trapped when they adhere to the fibres or become embedded in them. The smallest particles collide with gas molecules. Such collisions slow the passage of those particles through the filter and increase their likelihood of becoming trapped.

The Centers for Disease Control (CDC) of US has categorized biological agents in terms of dissemination and mortality. The U.S. government considers the more stable, reliable, effective, and deliverable of these agents as potential weapon [7]. The categories of military chemical weapons are nerve agents, blood agents, blister agents, choking agents, tear gas agents, incapacitants or psychochemicals, and industrial chemicals. Some agents are gases. Others need to be delivered as aerosols. A discussion of potential industrial chemicals that could be used in a terrorist attack is beyond the scope of this article [8].

Air filters are physically simple, yet technically complicated devices. There are four mechanical principles [9], They include impaction, interception, diffusion, straining, and electrostatic attraction, which can temporarily enhance the particle collection efficiency of the applicable mechanical principle. Each mechanism is responsible for filtration of particles in a certain size range [10].

A filter's ability to capture particles depends on the particle size passing through its fibers as well as the velocity of the flow passing through the filter. Contrary to popular belief, a fibrous filter does not simply capture all particles above a certain size. Three mechanisms are predominant in determining a filter's efficiency versus particle size. These are: interception, inertial impaction, and diffusion. Large particles above 0.4 µm in dia, will be captured due to both the impaction and interception mechanisms. Medium particles, generally considered as the most penetrating, in the 0.1 to 0.4 µm range, are captured by both the diffusion and interception filtration mechanisms. Small particles, below 0.1 µm, are captured by the diffusion mechanism [9].

II. Experiments

A. *Model Constructed*

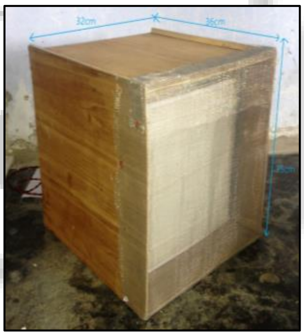


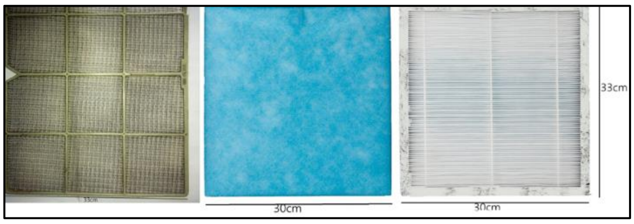
Fig. 1: Model (36cm*32cm*35cm)

The model is made up of wood-cased cased open-face HEPA filters is shown in Fig. The core is made by pleating a continuous web of fiber paper (the medium) back and timber frame which add strength to the core and form air passages between the folds. The face of medium is protected by aluminium grid in front.

The core is sealed into a full-depth wood casing (frame), usually with a wooden adhesive. The filter papers consist of very fine (submicron) fibers in a matrix of larger (1 to 4 p) fibers. A wooden strips is added to hold the fibers for the air flowing process. The filter paper is extremely weak and fragile, and the filters must be handled with care to avoid damage.

Fig. 2: Model

The model consist of a powerful fan placed in a timber frame and installing pre-filter, HEPA filter and anti-bacterial filter in front of the fan the edges of the unit is glued and sealed to ensure that air will properly flow through the filters and the fan.



Pre- filter Anti- bacterial filter HEPA filter

Fig. 3: Model

B. *Testing of Filter*

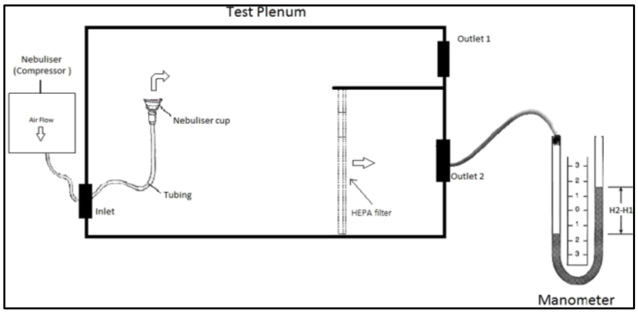


Fig. 4: Test Setup

1) HEPA Filter Testing Unit consisted of the following components:
   - Transparent Glass frame of size 17*12*10* inch
   - Nebulizer as a compressor of capacity 35psi
   - Manometer connected in the outlet. The purpose of the manometer is to indicate the pressure drop across the filter.
   - HEPA filter of size 30*33*2 cm
2) Location

The testing setup is locted environment laboratory in the M.H. Saboo Siddik College of Engineering, Mumbai was identified which is large enough for the “HEPA Filter Testing Unit” and operator support equipment such as a desk, storage shelves and file cabinets. The laboratory is in a well isolated secured area where the nebulizer with proper ventilation could be operated without disturbing other work.

- HEPA Filter Testing Unit - Set up of the “HEPA Filter Testing Unit” included the assistance of mechanical and electrical ventilation system with the oversight of the proffesors of the college.

The “HEPA filter testing unit” was assembled (Figure below) with the main components arranged in the following order: (1) a nebulizer connected with silicon pipe ; (2) a nozzle connecting the pipe into the glass hole ; and (3) a filter housing consisting of a mixing chamber, a filter frame (equipped with four brackets to hold the filter in place) and two ports for connecting a manometer air filter gauge used to measure and adjust the pressure drop across the HEPA filter installed within the filter frame.

After the system was installed, it was leak checked to assure of the system integrity. Also, a u–tube manometer was installed in the HEPA Filter Testing Unit. The manometer consisted of two pressure tight compartments separated by a water as the density in the tube. The purpose of using a manometer was to indicate the pressure drop across the filter.

Fig. 5: Testing of HEPA filter at MHSSCOE

III. RESULT AND CALCULATIONS

A. *Pressure Drop*

Pressure drop measurements were done for the tested filters at accordance to nebulizer air flows. To perform these experiment, the manometer is placed to measure the pressure drop between the two sections just before and after the filter; thus it displays the pressure drop induced by the filter.

Pressure of nebulizer (P1) = 35psi = 80.73kg/m³

Height difference in manometer (H2-H1) = 0.5cm= 0.005m

Using bernoulli's equation,

$$\frac{P1}{\rho} + \frac{V1}{\delta g} + H1 = \frac{P2}{\rho} + \frac{V2}{\delta g} + H2$$

As velocity is uniform,

$$H2 - H1 = \frac{P1}{\rho} - \frac{P2}{\rho}$$

$$P1 - P2 = 1000 \times 0.005$$

$$P1 - P2 = 5$$

$$80.73 - P2 = 5$$

$$P2 = 75.73\ kg/m^3$$

The pressure drop increases with time because the resistance to the air is increased with the particles captured in the filter. As the resistance to the air increases, more energy is required to maintain the same air pressure. However, if the nebulizer pressure is not controlled, the the pressure drop will increases.

According to the experiments done, pressure drop got increased due filter media from 80.73kg/m³ to 75.73 kg/m³.

B. *Filter Efficiency*

Filtration efficiency [11] depends on how pressure a filter require to remove airborne particles. From this definition, the filtration efficiency, E can be calculated:

$$E = \frac{P1}{P2} \times 100$$

Where, P1 is the average pressure of air, in kg/m3, at the downstream location and P2 is the average average pressure of air, in kg/m^3 at the upstream location, before the filter.

$$\therefore E = \frac{75.73}{80.73} \times 100$$

$$\therefore E = 93.9\%$$

Thus the ability of filter to move air through the system is reduced when the pressure drop increases. When this ability is reduced, more energy is required to provide the same air flow. When the efficiency of a filter increases, the pressure drop usually increases too.

IV. CONCLUSION

High Efficiency Particulate Air filters are the most efficient filters available for the capture of small particles. The study shows that HEPA filters theoretically can remove at least 99.97% of dust, pollen, mold, bacteria and any airborne particles within a size of 0.3mm in diameter.

After discussing particles size, various filter option s, particle collection mechanisms and filter performance test ing, it is evident why HEPA filters are the industry standard in biological safety. Particles generated in biological work f all efficiently trapped by HEPA filters.

The experiments shows the pressure drop increases with time because the resistance to the air is also increased with the particles captured in the filter. As the resistance to the air increases, more energy is required to maintain the same air pressure. However, if the nebulizer pressure is not controlled, the pressure drop will increases.

The pressure of air required is more when there is increase in pressure drop. With the increase in efficiency the pressure drop increases too.

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