CLEANING TECHNOLOGY OF THE HVAC SYSTEMS

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ABSTRACT

The aim of the experiment was to study the efficiency of three duct cleaning methods. The methods used were (1) rotating brushes, (2) compressed air cleaning, and (3) wiping by hand. The air handling systems under investigations had been in use 26 and 30 years after the construction phase and the systems had not been cleaned since buildings were completed. Accumulated amount of dust in the supply air duct was determined by *BM-Dustdetector*, tape method, and by visual inspection before and after cleaning.

The amount of dust on the duct surface was decreased with all three cleaning methods. The best cleaning result was achieved by hand wiping. However, significant amount of residual dust was found on duct surfaces after cleaning with all three cleaning methods. The level of dust on the bottom surface of the supply air duct was on average 15–21% after cleaning. Significant differences in the cleaning result of the ducts were observed between the methods.

INTRODUCTION

Many studies have shown that the air handling system may be a source of pollutants in a building [1, 2, 7]. Dust and other pollutants may accumulate in duct systems during the operation of air handling system before the system is cleaned. Dust may affect the perceived air quality of the supply air and cause problems to occupants.

Several cleaning techniques are used to clean air handling systems. The most commonly applied methods are brushing, compressed-air washing, vacuuming by hand, washing by hand and power washing [5, 6]. The cleaning method should be chosen according to the component of the air handling system and the amount of accumulated dust. Finnish guidelines present limit values of 2 g/m^2 (category P1) or 5 g/m^2 (category P2) for accumulated dust [3]. According to North American Standards residual dust on the duct surface should be equal to or less than 1 mg/100 cm^2 after air duct cleaning [6]. Both guidelines specify the limit values with a vacuum testing method.

METHODS

Buildings under investigation

Two office buildings from the metropolitan area of Helsinki were selected to the study. Both buildings had an air handling system where air is supplied into corridor and exhausted through the registers in the offices. Air handling units were located on the underground floor and outdoor air was taken from an opening located 2 meters height from ground. The cleaned ducts were rectangular, and did not have any residual oil on the surfaces from manufacturing process. Supply air ducts had been cleaned never before.

Building (A) was a head office, which had been completed 30 years ago and had three floors. The ventilation systems included filters (EU6), a heating coil, and a centrifugal fan. Until the end of 1980's a humidifier was used, but for energy saving it was not used any more. A supply fan was replaced in 1994. Its air flow was 3.6 m^3/s. The total length of supply air ducts was 305 m. The ducts in building (A) were cleaned with brushing.

The other office block (B) was in the center of Helsinki. This building had five floors. The building was used as school until it was renovated in 1972. The building was served by six air handling units, three of these were included into the study. The air flow of the air handling unit AHU1 was 6.1 m^3/s, and the length of the supply air duct 320 m. This system was cleaned by brushing. The air flow of the air handling system AHU2 was 2.6 m^3/s, and the length of the supply air duct 90 m. Air handling unit AHU2 was cleaned by compressed air cleaning. The air flow in the air handling system AHU3 was 1.5 m^3/s and the length of the supply air duct 20 m. This system was cleaned by hand wiping. The air handling system AHU2 consisted of a pre-filter, a fine filter, a humidifier, and an axial fan. Air handling systems AHU1 and AHU3 did not have humidifiers.

CLEANING METHODS

Supply and exhaust air ducts are usually cleaned mechanically. Dust, which has accumulated in the duct, is dispersed by hand brushing, by a rotating brush, or by compressed air washing. Two of the methods, air washing and brushing with rotating brush, employ a low-pressure fan which removes and transfers loose dust from the duct to a terminal filter. Components in the air handling system such as fans, heat exchangers, and terminal units are cleaned by water and detergent, forced air, and chemical agents. Very dirty ducts such as exhaust duct of a kitchen or grill, where pollutants has adhered on the duct surface, can also be cleaned with water and detergent.

Hand vacuuming is commonly used to clean components of the air handling system. Vacuuming is also effective in removing dust from porous surfaces such as the fiber glass material. Special vacuum cleaners for the air duct cleaning have already been developed. Hand vacuuming is also used to finish the mechanical cleaning.

Brushing

All supply air ducts in the building (A) and one air handling system (AHU1) in the building (B) were cleaned by rotating brushing. Most of the air ducts were rectangular, the total length of the duct system was 625 m. Ducts were brushed with similar brushes used to clean circular ducts. The bristles of the brushes were selected according to the type of duct and to the composition of contaminants to be cleaned away. Most of the used brushes were made of nylon. Also softer brushes made of special fiber with a diameter of 0.4–0.5 mm were used. The brushes were connected to a flexible whirling arm with variable length. The brushes were guided into the ducts with flexible rods. Brushes were rotated slowly, about 300–400 r/min, by an electrical motor. Ducts were brushed several times before an acceptable level of cleanliness was achieved. The speed of the air which carried the loose dust out from the duct was 18–20 m/s.

Compressed air cleaning

One air handling system (AHU2) was cleaned with compressed air cleaning. During the cleaning all the terminal units of the supply air were sealed carefully. Compressed air was led into the ducts from the compressor unit, which was located outside the building. A low-pressure fan was connected to the air duct to remove loose dust from the surface to a terminal filter. A compressed air nozzle had a volume flow rate of 0.1 m^3/s compressed air. Ducts were cleaned twice to ensure good cleaning quality. The length of the cleaned supply air duct was 90 m. The speed of the air which carried the loose dust out from the duct was 18–20 m/s.

Hand Wiping

The third duct cleaning method was wiping by hand. One air handling unit (AHU3) was cleaned first by rotating brushing and then wiping by hand. The cleaner used manual tools such as brushes, cleaning cloths, and cleaning arm. The cleaned duct was rectangular with a cross section of 800 x 300 mm, and length of 20 m. No detergent was used. After hand wiping the air duct surface seemed to be clean by visual inspection (Table 3).

Measuring Methods

Accumulated dust was determined before and after the cleaning with an optical method and in some locations also with the tape method. The methods are described and compared elsewhere [4]. The samples were taken in three locations of the duct work: close to terminal units, middle of duct, and close to the air handling units. All the samples were taken from the rectangular duct. Additionally, the cleaning result and the composition of dust were evaluated visually.

RESULTS

The cleaning results measured with the optical method are presented in Table 1. The results show a significant reduction in the amount of the duct with all the tested methods. The reduction of the amount of dust was greatest on the bottom surface, where the dust accumulation was also highest. Surprisingly, the optical method showed the worst result with the samples taken from the duct that was cleaned by hand wiping comparing the results before and after cleaning. The best results were shown for the rotating brushing in building (A), which had high accumulation of dust in ducts. Before duct cleaning the amount of dust in the building (A) was actually higher than the range of the optical method, and the actual cleaning result was better than the numbers show.

When the cleaning results are compared (bottom surface) compressed air cleaning gave almost as good cleaning result (16%) was achieved as for hand wiping (15%). By brushing, a cleaning result of about 20–21% was achieved.

Before the cleaning the amount of dust on the bottom surface was 3.2–9.8 g/m^2 and after air duct cleaning 0.98–1.30 g/m^2 by using the tape method (Table 2). Based on the tape method the brushing was slightly better than compressed air cleaning.

Visual inspection of cleaning results gave a different result (Table 3). The best cleaning results were achieved by hand wiping.

Table 1. The amount of dust in ducts before and after duct as judged by percentage reduction in light transmission, distanced in duct are measured from the air handling unit.

Method	Before duct cleaning			After duct cleaning			Ratio
	Bottom (%)	Wall (%)	Top (%)	Bottom (%)	Wall (%)	Top (%)	Bottom after/before
Brushing							
Office building A							
Duct 5 m	53.10	31.90	10.10	15.4	11.60	7.40	0.29
Duct 15 m	53.10	21.00	14.20	10.5	11.60	7.90	0.20
Duct 30 m	53.20	29.30	9.80	34.1	20.60	6.00	0.64
STDEV	0.06	5.69	2.46	12.45	5.20	0.98	
Average	53.10	27.40	11.37	20.00	14.60	7.10	0.38
Office building B							
Duct 25 m (AHU1)	49.50	6.40	8.80	26.10	6.50	2.70	0.53
Duct 35 m (AHU1)	49.90	6.70	7.80	16.80	2.60	1.60	0.34
Duct 40 m (AHU1)	48.90	10.60	7.50	20.50	5.00	1.70	0.42
STDEV	0.50	2.34	0.68	4.68	1.97	0.61	
Average	49.43	7.90	8.03	21.13	4.70	2.00	0.43
Compressed air							
Office building B							
Duct 10 m (AHU2)	34.30	5.30	6.40	15.10	2.70	1.90	0.44
Duct 15 m (AHU2)	49.00	32.00	6.30	16.90	7.30	2.30	0.34
STDEV	10.39	18.88	0.07	1.27	3.25	0.28	
Average	41.65	18.65	6.35	16.00	5.00	2.10	0.38
Hand wiping							
Office building B							
Duct 12 m (AHU3)	23.10	18.20	3.10	15.10*)	15.20*)	3.70	0.65
Duct 20 m (AHU3)	22.90	17.00	2.60	15.00*)	15.10*)	2.60	0.66
STDEV	0.14	0.85	0.35	0.07	0.07	0.78	
Average	23.00	17.60	2.85	15.05	15.15	3.15	0.65

*) When duct was cleaned by hand wiping, residual dirt on the duct surface caused problem on optical measuring method. The duct surface seemed to be clean after hand wiping by visual inspection.

Table 2. Cleanliness of ducts measured with tape method before and after cleaning.

Method	Before cleaning	After cleaning	Bottom after/before
	Bottom (g/m^2)	Bottom (g/m^2)	
Brushing			
Office building B			
Duct 25 m (AHU1)	9.8	2.29	0.23
Air washing			
Office building B			
Duct 10 m (AHU2)	3.20	0.98	0.31
Duct 15 m (AHU2)	4.57	1.30	0.28

Table 3. Quality of dust in duct, and cleanliness of ducts by visual inspection before and after cleaning.

Building	Components of dust in the air duct					
	Brushing		Air washing		Hand wiping	
	Before	After	Before	After	Before	After
Building (A)	Very dusty duct: sand, pieces of bricks and dust from outdoor	Residual sand and dust in the corner of rectangular duct				
Building (B)	Thin layer of dust: "black" dust from the traffic, and some sand from construction phase	Residual dust in the corners of rectangular duct	Thin layer of dust: "black" dust and some sand from construction phase	Residual dust in the corners and bottom of rectangular duct	Thin layer of dust: some sand and dust	Ducts looked: No dust, no sand

DICUSSION

The amount of accumulated dust decreased in the ducts with all the applied cleaning methods. The best cleaning result was achieved by hand wiping (Table 1 and 3). The greatest change of accumulated dust in the air duct between before and after cleaning was achieved using brushing in the building (A).

The air ducts of the building (A) had more accumulated dust than building (B) by visual inspection. The composition of the accumulated dust in the building (A) was sand from the construction phase and dust from outdoors. Accumulated dust in the air duct of building (B) had more pollutants from the traffic, such as carbon dust.

The dust samples were taken from the close location before and after the duct cleaning. The sampling locations were selected close to the air handling units, middle of the duct, and close to the terminal units. Most of the dust was accumulated on the bottom surfaces of the ducts, and places where air speed was decreased as close to terminal units.

Brushing was a suitable method to clean round air ducts. With brushing it was possible to loose congealed dust from the surface of the air duct. It was very important to select suitable brush depending on the type of dust and make sure that dust is removed from the duct with air speed over 20 m/s. Air ducts were brushed at least twice to good ensure level of cleanliness.

During air duct cleaning by compressed air washing all the openings were sealed carefully to prevent contamination from spreading into indoor air (buildings were occupied during the cleaning). Dust was not congealed on the duct surfaces, and even compressed air cleaning

without any mechanical brushing removed most of dust from the surfaces of the ducts in the building (B).

Wiping by hand resulted in the best cleaning result. Manual tools such as brushes and cleaning cloths were applied. All terminal units were washed with detergent.

Brushing was the fastest cleaning method. In air cleaning most of the time was used to preliminary arrangements, such as sealing all the openings, and leading compressed air into the building. Brushing was about two times faster than air washing and four times faster than hand wiping.

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REFERENCES

1. Björkroth, M, Seppänen, O, Torkki, A. 1997. Effect of Pollution From Ducts on Supply Air Quality. In: Woods, JE, Grimsrud, DT, Boschi, N. *Proceedings of Healthy Buildings '97.* Healthy Buildings/IAQ '97, Washington DC, USA. Vol. 1, pp. 581–586.

2. Björkroth, M, Seppänen, O, Torkki, A. 1997. Components of the Air Handling Unit and Air Quality. In: Woods, JE, Grimsrud, DT, Boschi, N. *Proceedings of Healthy Buildings '97.* Healthy Buildings/IAQ '97, Washington DC, USA. Vol. 1, pp. 599–603.

3. FiSIAQ Publication 5E. 1995. Classification of Indoor Climate, Construction, and Finishing Materials. Finnish Society of Indoor Air Quality and Climate. Espoo. 32 p.

4. Holopainen, R, Palonen, J, Seppänen, O. 1999. Measuring Methods for Determining The Level of Dust in The Air Duct. *The 8th International Conference on Indoor Air Quality & Climate – Indoor Air '99.* Laboratory of Heating, Ventilating and Air Conditioning. Helsinki University of Technology.

5. Luoma, M, Pasanen. A-L, Pasanen, P. 1993. Ilmastointilaitosten puhdistustekniikka (Cleaning of Air Conditioning Systems). Technical Research Centre of Finland. Research notes 1492. Espoo. 59 p. + app. (In Finnish).

6. NADCA Standard 1992-01. 1992. Mechanical cleaning of non-porous air conveyance system components. National Air Duct Cleaners Association. Washington DC. USA. 11 p.

7. Pejtersen, J. 1994. Forureningskilder i ventilationsanlæg. Laboratoriet for Varme- og Klimateknik. Danmarks Tekniske Højskole. Marts. 130 s. + app. (In Danish).