Cleaning initiation criteria for heating, ventilation and air conditioning (HVAC) systems in non-industrial buildings

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SUMMARY

The objectives of this study are to reproduce in the laboratory different levels of cleanliness in non-porous ducts of HVAC systems, to compare a new method for sampling surface dust in ducts with those methods cited in the literature, to compare the numerical evaluation method to the visual method, and to propose objective cleaning initiation criteria. For each of the simulated cleanliness conditions, a committee of specialists did a visual assessment based on a scale of 3, where level 1 meant normal, 2 meant above normal, and 3 meant serious. According to these assessments, the established initiation criteria correspond to 0.2 g/m² for the NADCA method, 0.3 g/m² for the ASPEC method, and 0,6 g/m² for the new method. These criteria are significantly different ($p \leq 0.05$). Any of the surface sampling methods can be used, insofar as the corresponding initiation criterion is used.

INTRODUCTION

Ventilation systems can be potential sources of pollutants due to the accumulation of dust in their air systems. Building managers have to deal with a wide range of proposals from specialized cleaning companies and have difficulty arriving at a decision because there is no recognized or standardized method for assessing a system's dust contamination. Ventilation systems must therefore be maintained under optimal cleanliness conditions. For the optimal maintenance of facilities, it is therefore important to be able to measure the amount of dust that has been deposited in ventilation networks. In all cases, an objective diagnosis avoids unnecessary network cleaning, or if decontamination is required, allows the cleaning methods to be chosen (1).

In the United States and Canada, the initiation of air system cleaning is currently based on visual inspection (2,3). However, these criteria are subjective and rather impractical for major cleaning work. In 2005, the American National Air Duct Cleaner Association (NADCA) published criteria for cleanliness acceptance after cleaning. However, these criteria are inadequate if you want to know when to start cleaning HVAC system networks (4). As well, these criteria can only be applied on rigid and non-porous surfaces, meaning smooth surfaces (e.g., metallic surfaces).

The Association pour la prévention et l'étude de la contamination (ASPEC, association for the prevention and study of contamination) in France, has published a guide on methods for keeping non-porous air systems for clean rooms and related controlled environments clean (1). In this guide, the initiation criteria for tertiary environments (office buildings) and the methods used are reported for different countries. Table 1 presents these criteria.

Table 1. Criteria for initiating cleaning of non-porous ducts (1)

Country	Cleaning initiation criterion based on surface density (g/m^2)	Cleaning initiation criterion based on thickness (µm)	Post-cleaning acceptance criterion (g/m^2)	Sampling method
United States (NADCA 2005)	-	-	0.075	Surface sampling on membrane at 15 L/min (open cassette)
Great Britain (1998)	Blowing : 1 Exhaust: 6	Blowing : 60 Extraction: 180	0.1	Surface sampling on membrane for at 15 L/min
Finland (1995)	Blowing 2 Exhaust: 5	-	-	Surface sampling on membrane at 15 L/min (sampling tube)
France (2004)	Blowing : 0.4 Exhaust: 6	-	0.1	Surface sampling on membrane at 15 L/min (sampling tube)

This table shows that the criteria are accompanied by different dust sampling methods, consequently making comparisons difficult. According to ASPEC, these methods can be applied only to rigid and non-porous ducts of sufficient dimensions, i.e., larger than 30 cm in diameter for round components; in addition, the ducts must be horizontal; and finally, the walls must be dry (1). Sampling must be done on a layer of dust distributed on the bottom surface, and not on an accumulation of dust (1). Furthermore, the sampling methods have some deficiencies, mainly the absorption of moisture from the air by the cellulose ester membranes, and the adhesion of dust on the walls of the cassettes and sampling tubes.

One method that would eliminate these two problems would involve weighing a complete sampling cassette such as the IOM cassette (SKC Inc. Eighty Four, PA, USA) equipped with a cellulose ester membrane. However, this surface sampling method has not yet been evaluated. We will compare this cassette with the sampling systems mentioned in the literature in order to choose the most accurate method.

The objective of this activity is therefore to propose a methodology for measuring the dust contamination of ducts in order to compare the numerical value to the value obtained from the visual evaluation corresponding to the limit value that determines the need for cleaning.

METHODOLOGY

The steps in this project are: to develop a dust contamination chamber and technique, to choose the most appropriate surface sampling method for dust, and to determine a limit concentration for initiating cleaning.

Development of the dust contamination chamber

A preliminary study undertaken during the summer of 2004 at the IRSST led to the development of a chamber for the laboratory simulation of dust contamination of ducts (5). Figure 1 presents a diagram of this chamber.

This chamber was designed with smooth and non-porous surfaces. It is also equipped with a PALAS RBG 1000 dust generator. The standard dust used is the dust recommended by ASHRAE (5). It consists of (6):

- 72% fine test dust (Arizona road dust).
- 23% carbon powder (Molocco black).
- 5% No. 7 cotton linters.

The work undertaken by the IRSST in 2004 has shown that with this chamber, known and uniform concentrations of dusts can be obtained (5).

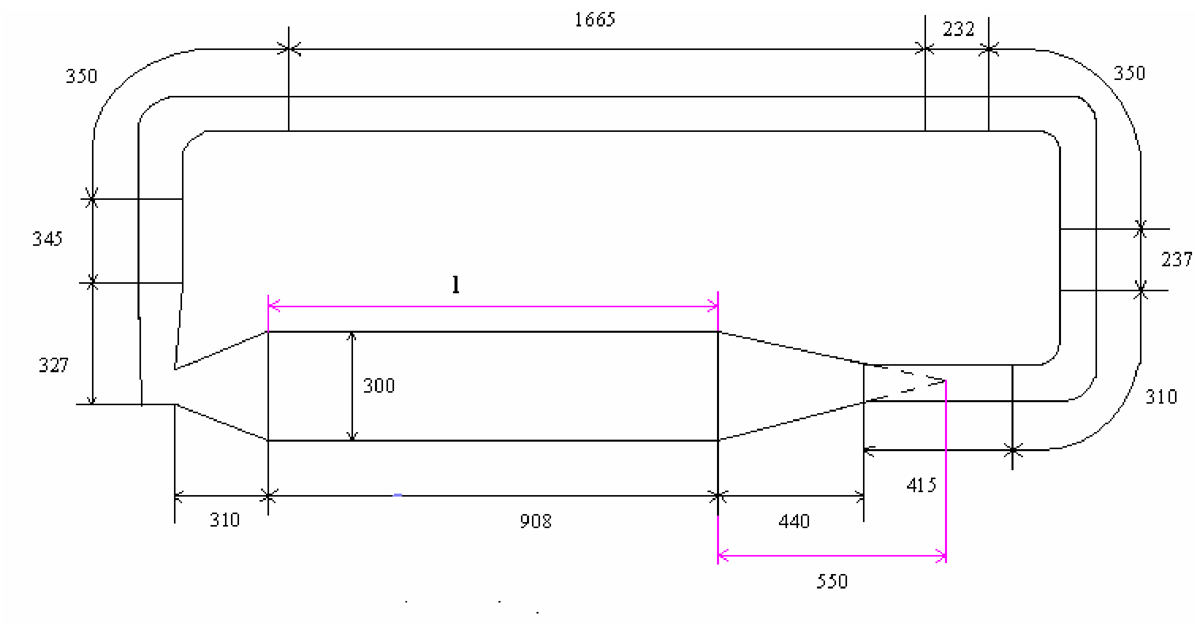

Figure 1. Diagram of the actual dust chamber (in mm)

However, to optimize this system, different improvements will have to be made in order to improve its performance. The following modifications will be made to the system (7,8):

- maximum extension of the sections
- elimination of asperities and interior joints
- replacement of the fan in order to eliminate leaks

Choice of sampling methods

Twelve control substrates (aluminum filters 47 mm in diameter, MSP Corp., Shoreview, MN, USA) uniformly distributed over the entire surface of the base were used for each dust contamination test. Figure 2 presents their location on the plate.

Three sampling methods were chosen for the dust contamination chamber. The first principle was the NADCA principle (4). It involves vaccuming dust over a predefined 100 cm² duct surface from a template 0.381 mm thick and of collecting it on a preweighed 0.8 µm cellulose ester membrane in an open cassette 37 mm in diameter (SKC Inc. Eighty Four, PA, USA), in order to determine the difference in surface density (Figure 3).

Figure 2. Distribution of control substrates

Figure 3. NADCA method

The second sampling method was the ASPEC method (1). It consists of a 0.8-µm pore size cellulose ester membrane in a 37-mm closed cassette (SKC Inc. Eighty Four, PA, USA) connected to a beveled tube. The aspirated duct surface is 50 cm^2. Figure 4 presents this method.

The third method is the method recommended by the IRSST. It uses an IOM cassette (SKC Inc. Eighty Four, PA, USA). In the latter, the entire 25-mm-diameter cassette including a 0.8-µm pore size polyvinyl chloride membrane is weighed (SKC Inc. Eighty Four, PA, USA). This avoids underestimations of weight. To be able to compare this method to the NADCA method, the cassette is slipped onto a template with a distance of 1.5 mm between the sampling cassette and the aspirated surface. Figure 5 presents this latter method. All the sampling flows were 15 L/min.

Figure 4. ASPEC method

Figure 5. IRSST method

Experimental plan

9 samples (3 per method) were collected each time in the dust chamber in order to compare the methods (paired Student's t-tests over a bilateral distribution). In total, 22 different tests were compiled. The tests were carried out on the natural logarithms due to the log-normal distributions of the data. Mulhausen and Damiano (1998) estimated that 6 to 10 measurements are required to suitably estimate a mean and a standard deviation (9). These tests were conducted by varying the fan operating time and the amount of dust in the generator. The average velocity of the air in the dust contamination chamber, measured with a hot-wire anemometer (TSI Inc., model 8384, Shoreview, MN, USA), was 0.59 (±0.15) m/sec (calculated using 50 measurement points). The precision of this instrument is ±3%. Weighing was done using the standard IRSST method (10) whose minimum reported value is 25 µg.

Visual inspection

In parallel with this dust sampling, a committee of experts from different disciplines related to air quality did a subjective evaluation based on visual assessment of the dust contamination. In addition to the four people in charge of this activity, this committee consisted of four other specialists (chemist, certified hygienist, building engineer and microbiologist), all from the IRSST. This assessment was based on direct visualization of the deposits with concentrations unknown to the committee. It involved a 3-level scale, where level 1 or normal, is characterized by clean ducts or ducts with a thin uniform layer of dust; level 2 or above normal, is characterized by a uniform layer and localized accumulations; and level 3 or serious, is characterized by significant accumulations (11,12). Level 2 corresponds to the limit concentration (or concentration range) for initiating cleaning.

RESULTS AND DISCUSSION

Initiation criterion

Table 3 presents the results of the corrected weighings of the control substrates. The minimum value used for concentration calculations is the method's reported minimum value, 25 µg divided by the square root of 2 (13,14).

Table 2. Corrected weighings[1] (mg) for the aluminum control substrates for the 22 tests

1st third of the base	2nd third of the base	3rd third of the base
0.004	0.020	0.111
0.004	0.020	0.111
36.375	34.661	30.895
5.509	5.329	5.883
12.545	11.976	10.053
3.625	3.501	3.218
20.579	19.366	17.902
8.510	8.410	7.342
4.825	4.939	4.857
3.228	3.273	3.289
2.367	2.749	2.775
5.576	5.995	5.703
6.464	6.551	6.307
12.979	12.913	11.773
24.551	23.127	21.096
5.535	5.765	5.024
2.546	2.882	2.780
7.368	7.183	7.235
9.360	9.158	8.072
5.399	5.412	5.150
28.045	25.659	23.138
31.430	27.336	25.362

[1]: Each of these values represents an average of six weighings

The paired Student's "t" comparison tests on the normal logarithms between the first third and second third ($p \leq 0.185$), between the first third and third third ($p \leq 0.279$), and between the second third and third third ($p \leq 0.393$) are all non-significant. The deposits are therefore considered as uniform along the entire base.

Table 3 presents the comparisons of the average votes of the committee of experts in relation to the average weighings for each of the methods evaluated, including the control substrates. Therefore, for an average vote of 1.6/3, or approaching level 2 which is characterized by a uniform layer and localized accumulations, the corresponding values are 0.2 g/m² for the NADCA method, 0.3 g/m² for the ASPEC method, and 0.6 g/m² for the IRSST method. All these methods are significantly different ($p \leq 0.05$) from one another. Despite the fact that there is generally a significant difference between the weighings for the control substrates and the IRSST method, the same value is obtained for these two methods, or 0.6 g/m² for a vote of 1.6.

Table 3. Results of the evaluation of the 3 methods (g/m²) in relation to the vote of the committee of experts

Substrate	IOM (IRSST)	ASPEC	NADCA	Committee's vote (n=6)
0.264	0.402	0.075	0.069	1.0
0.274	0.235	0.086	0.066	1.0
0.326	0.205	0.131	0.031	1.3
0.346	0.110	0.114	0.073	1.1
0.488	0.151	0.244	0.126	1.2
0.538	0.411	0.226	0.146	1.7
0.545	0.517	0.289	0.238	1.4
0.558	0.423	0.187	0.186	1.0
0.575	0.624	0.286	0.200	1.6
0.647	0.414	0.244	0.162	1.8
0.727	0.612	0.343	0.171	2.1
0.811	0.628	0.364	0.234	1.7
0.885	0.569	0.430	0.325	1.9
1.152	1.077	0.786	0.494	1.3
1.257	0.970	0.797	0.490	2.6
1.928	1.479	1.222	1.087	2.3
2.294	1.530	1.292	1.338	2.8
2.557	1.382	1.576	1.550	2.9
2.805	2.407	1.174	1.607	2.6
3.399	3.136	2.470	1.923	2.0

CONCLUSION

We can therefore state that the numerical criteria for initiating cleaning of smooth non-porous ducts were determined from a laboratory study. Clearly, the method recommended by the IRSST requires some adjustments before being used commercially. In addition, the method's conditions of application will have to be determined for existing smooth non-porous ducts from a ventilation system and with the actual dust from occupied buildings.

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