Cleaning Initiation Criteria for Heating, Systems in Non-Industrial Buildings

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INTRODUCTION

Ventilation systems can be potential sources of pollutants due to the accumulation of dust in their air systems. Building managers have to consider a wide range of proposals from specialized cleaning companies and have difficulty arriving at a decision because there is no recognized or standardized method (required by law) 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 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, but if decontamination is required, allows the cleaning methods to be chosen.

In North America, the initiation of air system cleaning is currently based on visual inspection. However, this is subjective and has the potential to be impractical for major cleaning work. The National Air Duct Cleaners Association (NADCA) published criteria for cleanliness acceptance after cleaning. However, these criteria do not address when to clean HVAC system networks. 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 the non-porous air systems of clean rooms and related controlled environments clean. 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.

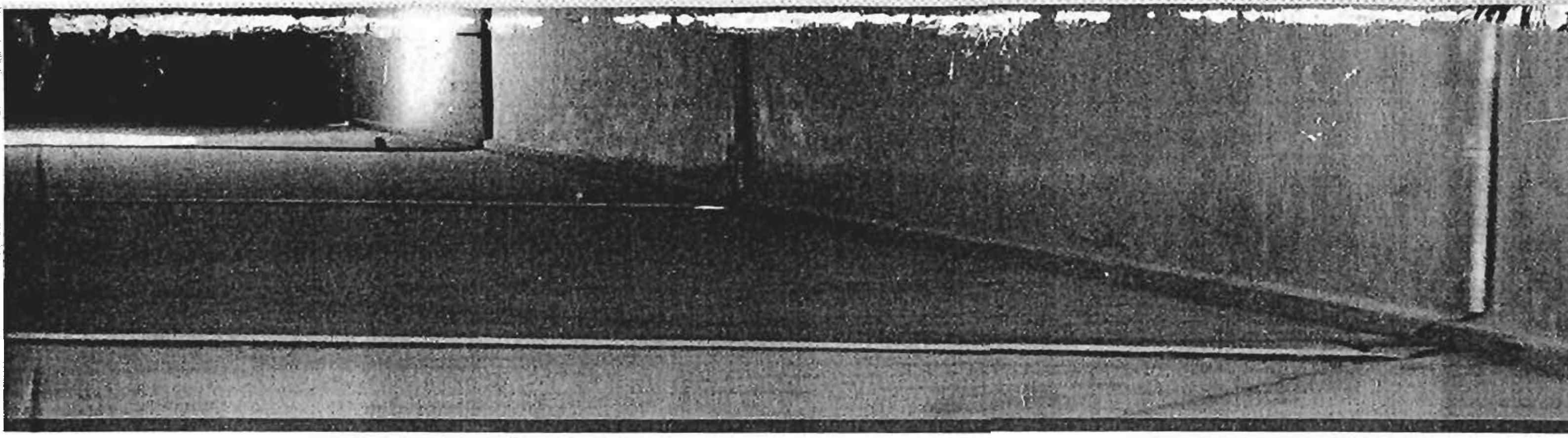
This table shows that these criteria are accompanied by different dust sampling methods, thus making comparisons difficult. According to ASPEC, these methods can be applied only to rigid and non-porous ducts of sufficient dimensions, i.e., larger than 30 cm (11.8 inches) in diameter for round components; in addition, the ducts must be horizontal; and finally, the walls must be dry (ASPEC 2004). Sampling must be done on a layer of dust distributed on the bottom surface, and not on an accumulation of dust (ASPEC 2004).

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 polyvinyl chloride membrane.

However, this surface sampling method has not yet been evaluated. The objective of this paper is to compare this last method with the other sampling methods reported in the literature (NADCA and ASPEC).

PROCEDURES

The steps in this project are: to develop a dust contamination chamber, to choose the most appropriate surface sampling method for dust based on laboratory experiment, to determine a concentration for initiating cleaning, and to validate these laboratory results in the field.



Ventilation and Air-Conditioning (HVAC)

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

Country	Cleaning initiation criterion based on surface density (g/m²)	Cleaning initiation criterion based on thickness (µm)	Post-cleaning acceptance criterion (g/m²)	Sampling method
United States (NADCA 2006)	-	-	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 at 15 L/min
Finland (1995)	Blowing: 2 Exhaust: 5	-	-	Surface sampling on membrane at 15 L/min (sampling tube)
France (ASPEC 2004)	Blowing: 0.4 Exhaust: 6	-	0.1	Surface sampling on membrane at 15 L/min (sampling tube)

Development of the dust contamination chamber

This chamber was designed with smooth and non-porous surfaces. It is equipped with a PALAS RBG 1000 dust generator (Karlsruhe, Germany). The standard dust used is the dust recommended by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE). It consists of:

- 72 percent fine test dust (Arizona road dust)
- 23 percent carbon powder (Molocco black)
- 5 percent number cotton linters.

Twelve control substrates (aluminum filters, 47 mm in diameter, MSP Corp., Shoreview, MN, USA) uniformly distributed over the entire surface (300 X 908 mm) of

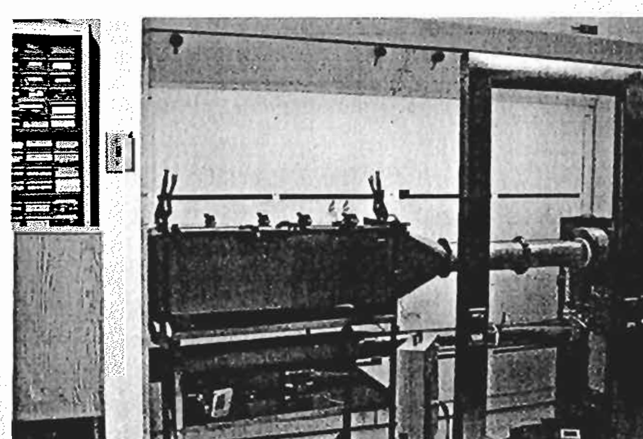


Figure 1. Picture of the dust chamber

the base were used for each dust contamination test. Figure 2 presents their location on the collection tray. The minimum value used for concentration calculations was the method's reported minimum value, 25 µg divided by the square root of 2. The comparison tests of a total of 396 weighings equally distributed between the first third and second third of the surface, between the first third and last third, and between the second third and last third are all statistically non-significant ($p \leq 0.05$). The deposits are therefore considered as uniform over the entire surface of the collection tray.

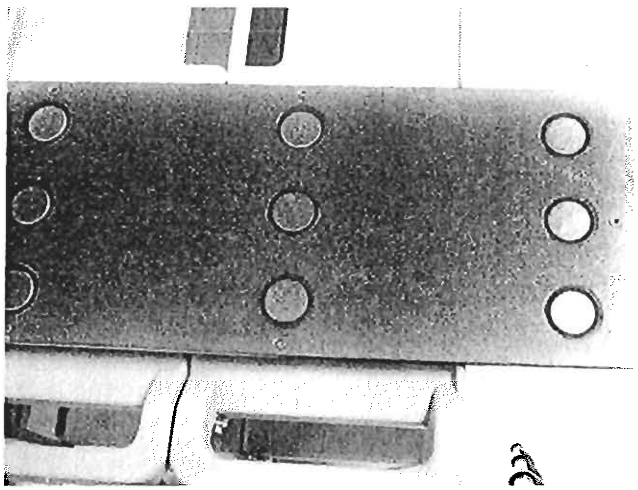


Figure 2. Distribution of control substrate

Choice of sampling method

Three sampling methods were used to evaluate the dust contamination in the chamber. The first one was the NADCA principle. It involves vacuuming dust over a predefined 100 cm² duct surface from a template 0.381 mm thick and of collecting it on a pre-weighed 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

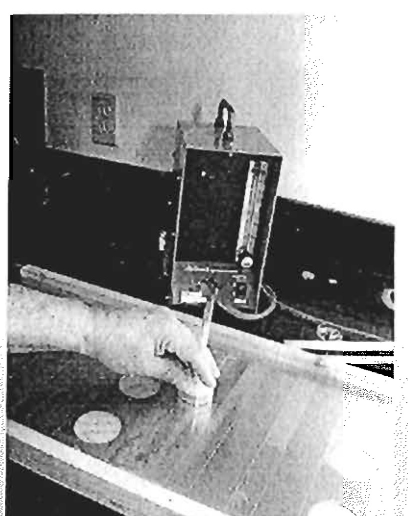


Figure 3. NADCA method

The second sampling method was the ASPEC method. 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 100 square centimeters. Figure 4 presents this method.

The third method was the method recommended by the IRSST in order to reduce the losses on the inner walls of the sampling cassettes and the variation related to humidity. 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 the weight. To be able to compare this method to the NADCA method, the cassette is slipped onto a template, leaving a 1.5-mm space between the sampling cassette and the duct surface. Figure 5 presents this latter method. All the sampling flows were 15 L/min.

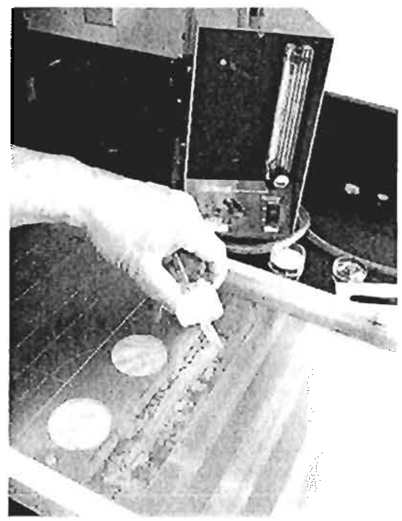


Figure 4. ASPEC method

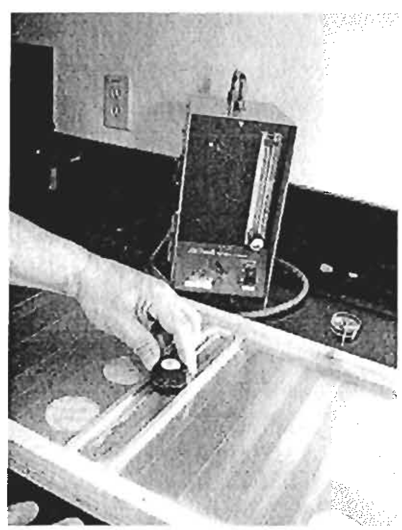


Figure 5. IRSST method

Nine (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 performed. The statistical tests were done on the natural logarithms because of the log-normal distributions of the data. 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%.

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. This committee consisted of seven specialists (chemists, certified industrial hygienist, building and physics engineers and microbiologist), all from the IRSST.

This assessment, based on direct visualization of deposits obtained at different concentrations and unknown to this committee, 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. Level 2 corresponds to the limit concentration (or concentration range) for initiating cleaning.

Initiation criterion

Comparisons of the median votes of the committee of experts in relation to the average weighings for each of the methods evaluated, including the control Substrates, were done. Therefore, for a median vote of 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.

These methods are all 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 median vote of 2.

Validation of the laboratory results

In the field, the IOM cassette (IRSST method) was made of stainless steel rather than plastic, which eliminated the weight fluctuations attributable to the moisture absorption associated with plastic.

Three simultaneous sampling procedures were performed for each of the systems, using once again, the three methods previously evaluated in the laboratory. Insofar as possible, the samples were taken from the supply diffusers in the rooms, at a reasonable distance from the last elbow and at the furthest accessible point in the air duct. Weighings were performed using the IRSST's standard method. Figure 5 shows a duct undergoing evaluation using a template.

In total, 44 different ducts or components were evaluated, giving a total of 132 samples (44 sites X 3 methods each). Two-factor (ducts and methods) and three-level (surface dust concentrations obtained using three methods) variance analyses (ANOVA) were performed on the logarithm values to determine whether there were statistically significant differences ($p \leq 0.05$).

The final step involved, once again, subjective assessment through the visual inspection of cleanliness levels by the same committee of experts that took part in the laboratory study. This evaluation consisted of the visualization of the deposits shown in photographs that were taken from angles both parallel to and perpendicular to the ducts evaluated. The three-level rating scale previously described was used. Given the discrete nature of the ratings, the median value was used to calculate an average rating for each system, with a value of 2 corresponding to the initiation of cleaning.

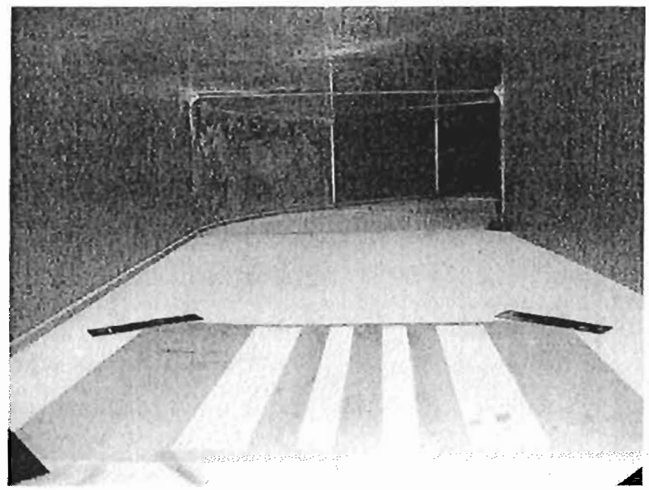


Figure 6. Duct outfitted with sampling template

Criteria under real conditions

Table 2 shows that 20 out of 44 ducts obtained a median rating of 2, hence a recommendation that cleaning should be carried out. The cleaning initiation criteria corresponding to the geometric mean obtained using each of the three methods for the 20 ducts were 0.6 g/m² for the IRSST method, 0.2 g/m² for the NADCA method, and 2.3 g/m² for the ASPEC method.

Table 2. Cleaning initiation criteria for the two conditions and the three methods

Criteria	IRSST	ASPEC	NADCA
Laboratory results[1]	0.6 g/m²	0.3 g/m²	0.2 g/m²
Real conditions[1]	0.6 g/m²	2.3g/m²	0.2 g/m²

[1] *statistically significant differences among the three sampling methods*

In the laboratory study, the criteria for these same methods were 0.6 g/m² for the IRSST method, 0.2 g/m² for the NADCA method, and 0.3g/m² for the ASPEC method. The field criteria obtained were therefore similar to the laboratory criteria with respect to both the IRSST and NADCA methods. Only the ASPEC criterion changed. We repeat that the two other methods did not involve direct contact with the dust. In fact, there was a distance of 0.381 mm between the cassette and the duct surface, such that only the surface dust was aspirated and aspiration was incomplete.

A statistically significant correlation exists among these three methods. These correlation coefficients confirm that any of the three methods can be used, provided that its specific initiation criterion is applied.

Conclusion

We established initiation criteria under real dust-accumulation conditions inside the components of non-industrial HVAC systems (e.g., schools, office buildings, or hospitals). These criteria were 2.3 g/m² for the ASPEC method, 0.6 g/m² for the IRSST method, and 0.2 g/m² for the NADCA method. These criteria were identical to those obtained in the laboratory for the IRSST and NADCA methods. All three methods can therefore be used, provided that their specific cleaning initiation criterion is applied.

Acknowledgements

The authors wish to thank the non-industrial establishments and the HVAC cleaning companies (NADCA members) that facilitated entry into the HVAC systems. Special thanks to technician Yves Beaudet.

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**This article was not completed by or commissioned by any person associated with NADCA.*