Development of contamination testing protocol for ventilation system components

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ABSTRACT

In time, ventilation ducts and accessories get dirty and this may lead to malfunction of ventilation equipment, fire hazard and especially a decrease in supply air quality. Repeated cleaning of the components can prevent these adverse effects. The frequency of cleaning depends on how easily different components get dirty. Although reduced dirtiness in ventilation duct surfaces also reduces cleaning demands, there is still no accepted test method to determine the propensity of the components to accumulate dirt.

VTT Technical Research Centre of Finland has developed a fast component-related test method called KOLITEST. With this method, HVAC-components can be arranged into order of superiority by their propensity to accumulate dirt.

The aim of this study was to establish the KOLITEST -method's needs for further development and carry out a development plan. The development plan included examination of the function and quality of old KOLITEST -equipment, the creation of new KOLITEST -equipment and testing their suitability for testing ventilation ducts and accessories for their propensity to accumulate dirt.

Several tests were made with the new KOLITEST -equipment. The test results showed that the reproducibility of the new KOLITEST -method is good and different kind of dust accumulation rates can be produced into the test section of the KOLITEST -equipment. The renewed KOLITEST -method can be used as a test method to determine the propensity of the components to accumulate dirt. In the future this method will be used in a study of soil repellent materials. Producers of ventilation ducts and accessories will benefit most from this test method. Component manufacturers can receive information about their products and their tendency to get dirty. These results can be used in their product development.

INDEX TERMS
Ventilation duct, Contamination, Dust feeder, Test dust, Sampling

INTRODUCTION
Outdoor air is filtered, warmed and humidified before it is transported indoors through mechanical supply ventilation systems. Supply air is usually clean, but the situation may be different if supply ventilation ducts are dirty. It is known that poor ventilation is responsible for many problems produced by indoor air, and ventilation ducts have been shown to act as sources for odours and microbes (Pasanen *et al,* 1993 and 1995). Dirty surfaces of ventilation ducts may lead to malfunction of ventilation equipment, fire hazard and especially a decrease in supply air quality.

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In the 1990s attention was paid to the cleanliness of inner surfaces of ventilation ducts. At the end of the 1990s the Clean Ventilation Systems project was started. It was financially supported by the National Technology Agency (Tekes), Finnish industry and participating research organisations. The aim of the study was to improve the hygiene of new ventilation systems. The project invested in industrial design to prevent hygiene drawbacks and malfunctions, the idea being that a reduction of contaminations in ventilation ducts and accessories also decrease cleaning needs. Although a reduction of dirtiness in ventilation duct surfaces reduces cleaning needs, there is still no accepted test method to determine the propensity of the components to accumulate dirt. During the 1990s VTT Technical Research Centre of Finland developed a fast component-related test method called KOLITEST. With this method, HVAC-components can be arranged into order of superiority by their propensity to accumulate dirt. In 1993-1997, a project was carried out to develop the KOLITEST -method. The aim of that project was to generate a contamination testing protocol for ventilation system components. The KOLITEST -method was further developed in connection with the Clean Ventilation Systems project, where some ventilation accessories were tested (Kovanen, 2000 and 2001). During these tests, observations were made about KOLITEST equipment functions, which had affected the method's repeatability and reliability. These observations about the characteristics and function of the equipment led to settling the KOLITEST method's development needs.

METHODS

Settling the development needs

Settling the development needs required some initial tests with the old equipment. These tests included measurements of airflows in old KOLITEST -equipment and one dust feeding test with an old feeding belt dust generator. A thermoanemometer was used to measure air stream velocity. A five point measuring technique was applied according the Finnish standard SFS 5512 (Finnish Standard Association, 1989). Airflow in the test duct was calculated from measured air stream velocity results. Testing arrangements for measuring air stream velocity are shown in Figure 1. The material of the test duct was sheet metal and its diameter was 160 mm.

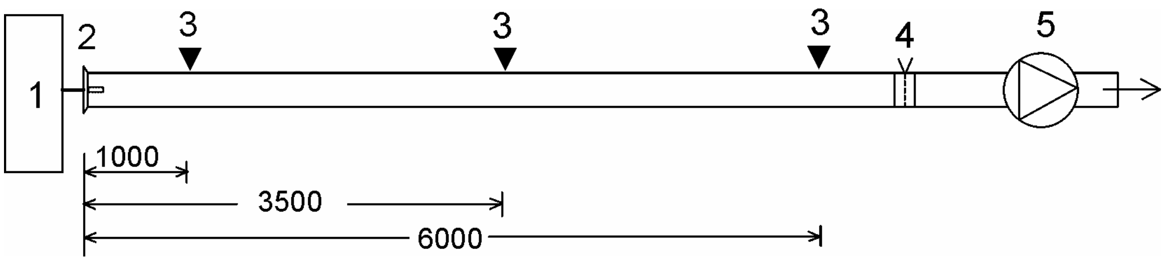

Figure 1 Testing arrangements for measuring air stream velocity. 1 = belt grinding dust feeder, 2 = dust feeder nozzle, 3 = measurement point, 4 = Ø 160 mm graduated collar, 5 = fan.

When testing airflow velocity, it was noticed that measured airflow rates were nearly 30 % bigger than the adjusted airflow in every measurement point. As a conclusion, adjusted airflows with old KOLITEST -equipment were not very accurate regarding repeatability and reliability. To improve repeatability and reliability of the air volume flow, compressed air stream, which came out from nozzle of the dust feeder, was centred in the middle of the duct's mouth and the graduated collar was protected from getting dirty by the test dust.

One dust feeding test with the old feeding belt dust generator was also carried out. The dust used was ASHRAE test dust, which was manually scattered onto the feeding belt. Test dust flowed along the belt to the brush wheel and funnelled further into the test duct within compressed air. Testing arrangements for the dust feeding test are shown in Figure 2. After feeding the test dust, dust accumulation rates were measured from five measuring points by using a vacuum test method (Pasanen *et al.* 1992).

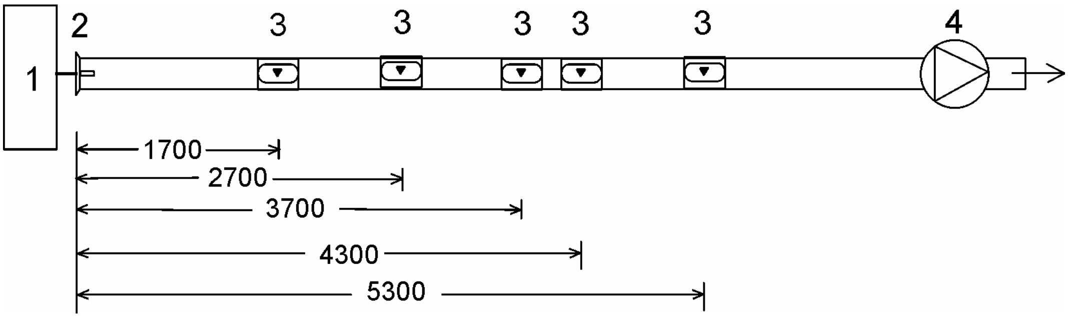

Figure 2. Testing arrangements for dust feeding test. 1 = dust feeder, 2 = dust feeder nozzle, 3 = access doors and measuring points, 4 = fan.

Problems with the feeding of test dust were irregularity of feeding and the dusting of test dust. Dusting was a consequence of a non-encapsulated structure of the dust feeding device. The irregularity of dust feeding varied depending on the person who scattered test dust onto the feeding belt. During the feeding test, it was noticed that only 62,5 % of the test dust was transported into the test duct. There were also some problems in producing comprised air with an air compressor. ASHRAE -test dust showed to be problematic during the sampling. It did not attach properly on the walls of the duct. When access doors were opened for taking the sample, the opening of the access door caused the test dust to fall off the walls, onto the bottom of the test duct.

Implementation of development plan and testing the new equipment

Initial tests had shown some problems, which were now corrected. Implementation of a development plan included obtaining a new dust feeder device. The repeatability and reliability of feeding the dust were defined as the most important characteristics of the new dust feeder. The dust feeder was to be encapsulated and equipped with an automatic feeding device and the feeding nozzle was to be adjustable. ASHRAE -test dust was exchanged with another test dust, which better describes the impurities in ventilation ducts. ASHRAE -test dust contains fairly large sand particles (International Organization for Standardization, 1997), which do not normally occur in ventilation ducts. Those particles caused problems with dust accumulation sampling, as was described earlier. A new rotating brush was invested in for cleaning the test duct. A better settling method was developed for the templates, which were used in dust accumulation sampling. This improved the repeatability of the vacuum test method. The effectiveness of the vacuum test method for the new test dust was also studied.

Several tests were made with the renewed KOLITEST -equipment (Alén, 2002). Repeatability of the air volume flow was ensured by air stream velocity measurements. Repeatability of the feeding was studied by defining the feeding rate of the test dust and the volume of unfed test dust. Dispersion of the test dust into the duct's surface was studied by making visual observations and by taking dust samples using a vacuum test method (Pasanen *et al.* 1992). The effectiveness of a vacuum test method for the new test dust as well as the effectiveness of the cleaning method were also studied. The repeatability of the KOLITEST method was ensured with test duct's fouling test, where dust samples were collected from three measuring points after dust feeding. The test was repeated ten times. The KOLITEST -equipment and testing arrangements of duct's fouling test are shown in Figure 3.

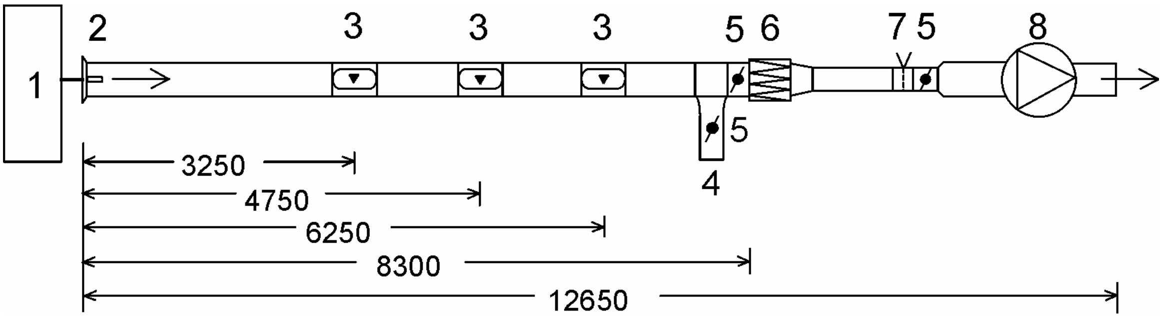

Figure 3. KOLITEST –equipment. 1 = dust feeder, 2 = dust feeder nozzle, 3 = access doors and measuring points, 4 = branch tubing for cleaning, 5 = damper, 6 = filter, 7 = Ø 125 mm graduated collar, 8 = fan.

RESULTS

The average air volume flow in the renewed KOLITEST equipment was 51,7 dm^3/s when the adjusted airflow was 50 dm^3/s (Table 1).

Table 1. Air volume flow (dm^3/s) in the test duct measured using a 5-point method. The first measuring point was situated 3,25 m, the second was 4,75 m and the third was 6,25 m from the dust feeder nozzle.

Measuring point	Air volume flow (dm^3/s)
1	51,1
2	51,6
3	52,3
Average	51,7

In all measurement points air volume flows differed less than 5 % from the adjusted value. There is always some disturbance in air stream velocity profiles and totally developed profiles form up only rarely in a measurement situation. The uncertainty of air volume flows measured by 5-point method (Finnish Standard Association SFS, 1989) is 4,5 %. Air volume flows in measurement points 1 and 2 (Table 1) were within the limits of uncertainty of the measuring method. Air volume flows in measurement point 3 differed only little from the limit of uncertainty of the measuring method. Repeatability of the air volume flow showed much better results compared to the old KOLITEST -equipment's air volume flow, where measured air volume flows differed an average of 30 %.

It is possible to feed a specified amount of test dust with the new dust feeder. The mass flow was 0,21±0,01 g/s in the feeding rate's repeatability test with the used adjustments. Unfed mass flow was only 0,15±0,04 mg/s. It can be said that the mass flow of test dust with the used adjustments is very reproducible. The volume of test dust, which remained within the device, was small enough not to have any practical meaning. The feeding of 40 g of test dust took 190,5 seconds. In that time 0,029 g of test dust remained in the dust feeder, which counts for 0,07 % of the fed mass.

The effectiveness of the vacuum test method for new test dust was 92,5 %. The test dust mass, which was used in the effectiveness test, corresponded as 5 g/m² accumulated dust in the duct's surface. An average of 4,8 % of the test dust remained in the sampling nozzles and 2,7 % remained in the used surface of the duct. In terms of accumulated dust, 0,22±0,06 g/m² of dust remained in sampling nozzles. The mass, which remained in the sampling nozzles, was observed in all measurements. When also the test dust which remained in the sampling nozzles was observed, the efficiency of the vacuum test method was 97±1 %, which can be said to be good.

KOLITEST method's repeatability was ensured with test duct's fouling test, where dust samples were collected from three measuring points after dust feeding. The test was repeated ten times and the test duct was cleaned after every dust feeding test. To ensure the quality of the duct's fouling test result, the efficiency of the cleaning method was studied before conducting the duct's fouling test. After cleaning the duct with a brush, the cleanliness of the duct was visually inspected and dust samples were taken using a vacuum test method. Visual observation revealed that the inner surface of the duct was not totally clean after cleaning. Test dust was found especially on the seals of the access doors. The average accumulated dust rate on the inner surface of the test duct was 0,4±0,2 g/m². A variation of accumulated dust rates supported visual observations of irregular cleanliness of the duct. Because cleaning with a brush was inadequate, test duct's access doors and measuring points were also cleaned with a vacuum cleaner and wiped with a damp cloth after every fouling test.

In duct's fouling test, the dispersion of test dust into the duct's surface was studied by making visual observations and by taking dust samples using the vacuum test method. Visual observations revealed that the test duct was covered by a thin white dust layer which became thinner towards the end of the test duct. The same result was detected in connection with the measurements. Results of average accumulated dust in the duct's fouling test are shown in Table 2.

Table 2. Results of average accumulated dust in the duct's fouling test. The first measuring point was situated 3,25 m, the second was 4,75 m and the third was 6,25 m from dust feeder nozzle.

Measuring point	Accumulated dust (g/m²)
1	10,0 ± 0,4
2	4,7 ± 0,4
3	2,6 ± 0,3

Results proved that standard deviations changed only little, whereas relative standard deviations grew the further the feeder's nozzle was from the measurement point (Table 2). The template position on the bottom of the duct has a great influence on dust sample's mass, especially at the first measurement point, where the highest amount of accumulated dust was measured. The template was set manually onto the duct's surface. The settling of the template was noticed to be the biggest single factor to influence the test results.

DISCUSSION

Several tests were made with the new KOLITEST -equipment. The test results suggest that the reproducibility of the renewed KOLITEST -method was good and different kinds of dust accumulation rates could be produced into the test section of the KOLITEST -equipment. The placing of templates manually onto the surface of the test duct when taking dust samples was noticed to be the biggest single factor to influence the test results. Although the vacuum test method had some weaknesses, it is still the most suitable sampling method for these kinds of fouling tests. As a collection method it is efficient, especially when test dust mass, which has remained inside the sampling nozzles, is also observed.

Although different kinds of dust accumulations can be produced with good reproducibility into the test section of the KOLITEST -equipment, the dust particle motion of test dust should be modelled also by calculations. Knowledge of KOLITEST -equipment's characteristics should be complemented with mathematical examination of particle motions.

CONCLUSION AND IMPLICATIONS

VTT Technical Research Centre of Finland has developed a fast component-related test method, which is called KOLITEST. The renewed KOLITEST -method can be used as a test method to determine the propensity of the components to accumulate dirt. In the future this test method will be used in a study of soil repellent materials. Producers of ventilation ducts and accessories will benefit most from this test method. Component manufacturers can receive information about their product's tendency to get dirty and the test results can be used in their product development.

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