A VISUAL INSPECTION METHOD TO EVALUATE CLEANLINESS OF NEWLY INSTALLED AIR DUCTS

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ABSTRACT
Visual inspection is a subjective method to evaluate cleanliness level of duct. Although it is subjective, it is mostly used for estimating necessity to clean a ductwork. The aim of this study was to develop the visual inspection method more objective and to create a procedure for estimation of cleanliness level of an air duct. A visual inspection form and a visual cleanliness scale were applied in recently installed supply air ducts with a panel consisting ten members. The visual scale has been designed for evaluation if the ducts should be cleaned or not. Therefore, it is focused for the amount of accumulated dust from clean to dirty corresponding values <0.1 to 4 g/m^2 measured with the vacuum test method. The developed visual inspection method offers a suitable tool for evaluation of cleanliness especially in new installations. The more objective sampling methods are needed in borderline cases when opinions of customer and client differ.

INDEX TERMS
Air duct, Cleanliness level, Visual inspection form, Visual cleanliness scale.

INTRODUCTION
Visual inspection is a primary method to verify the cleanliness of the ductwork. When inspecting newly installed supply air ducts, the inspector must be able to determine whether the dust accumulation on the inner surface of the ducts exceeds the limit value. According to the Finnish guideline for Indoor climate (FiSIAQ, 2001), the limit value for dust accumulated in newly installed ducts is 1.0 g/m^2 in cleanliness category P1, and 2.5 g/m^2 in category P2. Because visual inspection is based on inspector's experience it needs a procedure. However, an objective sampling method is needed if the inspector has no experience in visual inspection or inspector cannot decide if the ductworks clean enough.

The aim of the study was to develop a visual inspection method to evaluate the cleanliness of newly installed air ducts. The developed visual method consists of an inspection form and a visual cleanliness scale. The inspection form was developed together with professional inspectors. The visual cleanliness scale was created from a photo gallery of photos taken from the surfaces of the newly installed supply air ducts. The purpose of the study was also that the building owner is confident that the cleanliness of air ductwork is monitored carefully enough if the visual inspection is made following a developed visual inspection procedure. The visual inspection method was tested in a newly installed supply air ductwork.

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METHODS

The visual inspection form

The visual inspection method is based on the notion that an inspector is able to evaluate quite accurately the average weight of dust accumulation on the inner surface of the duct relying on his own judgement. A visual cleanliness scale has been created to unify the notion of cleanliness level on the duct surface. The developed visual inspection method consists of an inspection form and a visual cleanliness scale to evaluate cleanliness of the air duct.

An inspection form has been designed for recording the observations of the inspectors. The type of the contaminants is described by using standardized terms (SFS 4619, 1996). The contaminants are divided in to two main categories: dust and other impurities (e.g. residual oil, sand, steel filings, gypsum powder dust and organic impurities). The type of contaminant can use to figure out the stage of the construction process during which the ducts have become contaminated (Table 1).

Table 1. The type of contaminant and the contamination stage

The Type of Contaminant	*The Contamination Stage of the Construction Process*
Residual oil	Manufacturing process
Fine dust	Storage at the manufacturer
Sand or stains	Storage at construction site
Steel filings or chips	Installation
Gypsum powder	Construction work
Organic impurities	Use of the air-handling system

Residual oil in a duct is a serious matter because in both cleanliness categories (P1 and P2) supply air ducts and fittings should be manufactured using cleanliness class M1 air-handling components for which the amount of residual oil should not exceed 0.05 g/m^2. The location of the contaminants in the duct should also be recorded to the inspection form because the cleaning method of the duct depends on how far from an access door the contaminants extend to. The visual method is essentially based on filling in the inspection form and recording the results systematically in that form.

The cleanliness of terminal units should always be assessed before handing over the air-handling system because they are often the only components of the system the user of the building can see. The cleanliness level of the terminal units can also be evaluated visually, referring to the visual cleanliness scale when necessary, and using the "wiping-with-finger" technique as an aid.

The visual cleanliness scale

The visual cleanliness scale consists of six photographs fixed on an A4-sized sheet of cardboard which display six dust accumulation levels. The selected dust accumulation levels are <0.1; 0.1; 0.7; 1.0; 1.5 and 4.0 g/m^2 and these values have been printed on an upper corner of the photographs (Figure 1). The amount of dust in the photographs was measured using the vacuum test method with a template of 100 cm^2 (Pasanen et al., 1999). In addition, the researchers have wiped clean with their fingers 10 cm of the inner surface of the duct, at about 10 cm from the dust sampling area. Then the researchers were taking photographs on the duct surface. When evaluating the need to clean a supply air duct, the dust accumulation in the duct can be compared to the visual cleanliness scale immediately at the inspection point or, alternatively, a photograph of the inside of the duct at the inspection point may be taken which can then later be compared to the reference photographs of the visual cleanliness scale.

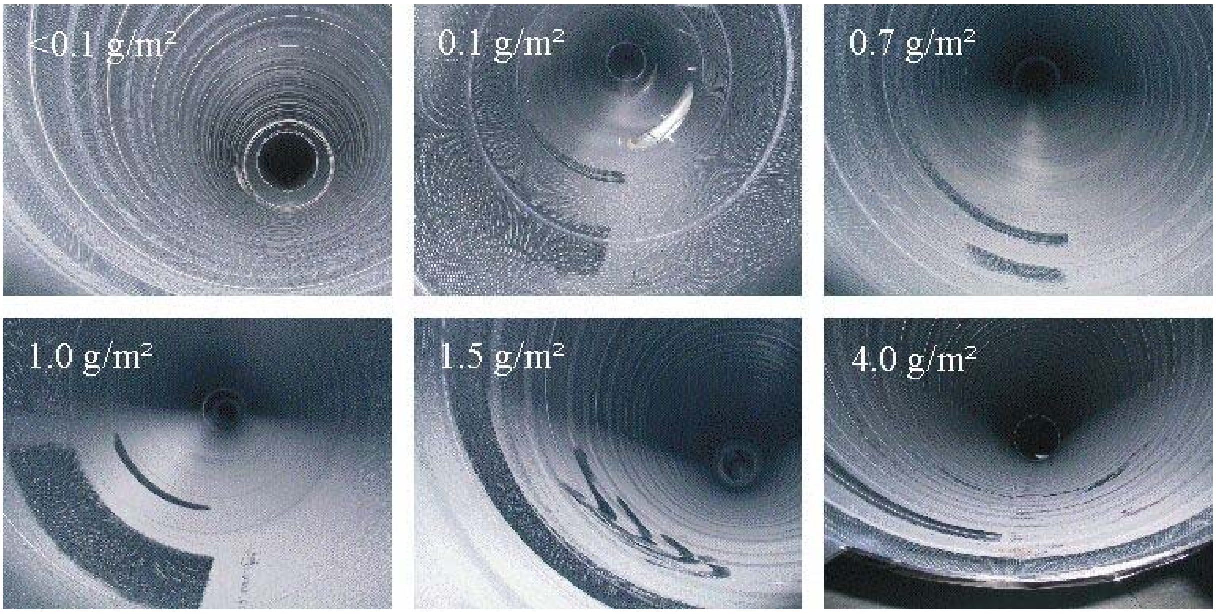

Figure 1. Photographs of visual cleanliness scale.

The number and location of the inspection points

The inspection of air ducts is primarily carried out through the access doors of the ducts. The sufficient number of inspection points and the properly selected location points are the most important factor for the evaluation of the cleanliness of the ductwork. According to NADCA (1992), the number of sampling points depends on the length of the ductwork. In practice, it is recommended that at least five inspection points shall be chosen (or at least all main ducts shall be inspected) from the main supply ducts on each floor of the building (Vasara, 2001). If the building has separate sections, such as wings, four to six inspection points are chosen from each floor of each building section. The final number of inspection points depends on the length of the ductwork and the size of the building complex.

APPLICATION OF VISUAL METHOD

Building

The developed visual inspection procedure was tested in a newly installed supply air ductwork. An office building was chosen for the study. The air-handling system was constructed according to cleanliness category P1. The studied supply air ducts were round spiral ducts, which were manufactured without oil lubricants and protected against dust accumulation during the transportation, storage and construction phases. The air-handling system was typical for new buildings in Finland consisting of a supply air intake grill, a filter unit, a heat recovery unit, a heating coil, a constant or variable air volume air-handling units and cooled beams in the room. The air-handling units were situated on the top floor of the building.

Visual inspection panel

A visual panel consisted ten members (two professional inspectors, two consults and six researchers). Each of them evaluated the amount of dust on the inner surface of the duct at each inspection points by comparing the dust accumulation to the visual cleanliness scale (Figure 1). The intensity of the illumination was taken into account by using the same flashlight at each evaluation and the results were recorded on the visual inspection form systematically.

After the inspector had evaluated the cleanliness in the all points he had to make a clear conclusion. The inspector might also suggest an appropriate cleaning method. It was recommended that if the inspector has ticked the box in column ”Needs to be cleaned” at least 20% of all the inspection points, all the ductwork should be cleaned.

Dust measuring methods
The amount of dust was measured using the vacuum test method (Pasanen, 1999). The sampling device of the vacuum test method consisted of a suction hose, a pre-weighed membrane filter (0.8 µm pore size), a filter cassette, an air pump and the templates (100 cm^2). The airflow of the pump was 10 dm^3/min. Before and after the sampling, the filter cassettes with the filters were weighed together using a laboratory balance (METTLER AE 240 Dual Range Balance) with a resolution of 0.00001 g. The theoretical detection limit of the method was 0.001 g/m^2.

RESULTS

The mean amount of accumulated dust determined by the vacuum test method was 4.7 g/m^2 (0.6–13.7 g/m^2) and by visual method 2.7 g/m^2 (1.0–5.5 g/m^2) depending on the measuring points in the ductwork. The standard deviation of visual estimation varied from 0.2 to 4.6 g/m^2. Evaluated mean amount of total dust by each member of visual panel varied between from 0.9 to 5.6 g/m^2 on the inner surface of the ductwork. The results are shown in Figure 2.

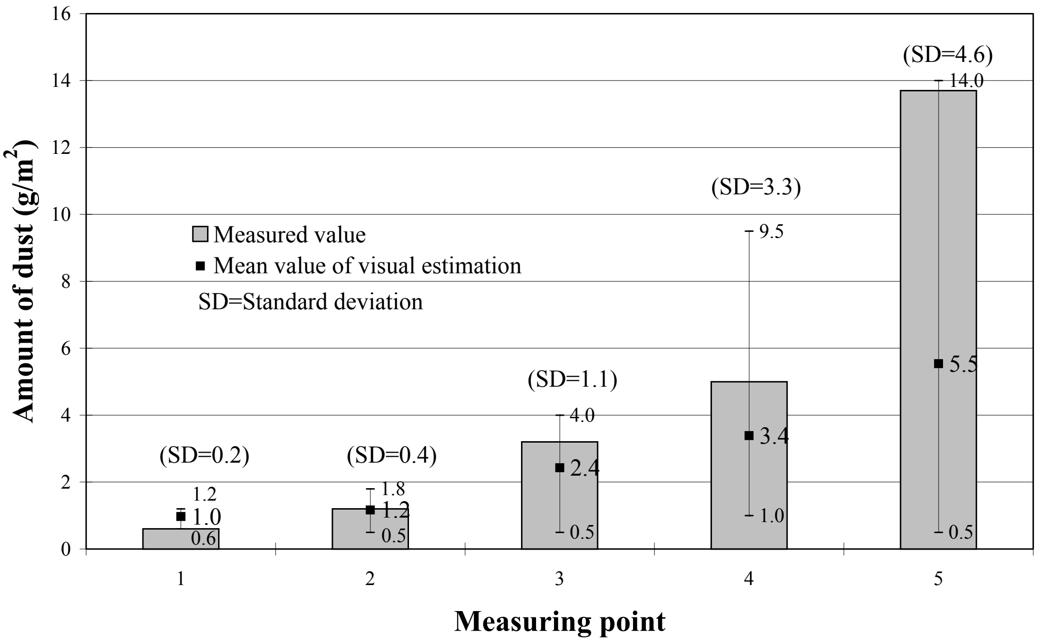

Figure 2. The amount of dust with vacuum test method and visual inspection method with minimum and maximum values and standard deviation.

The results of visual inspection are compared with the vacuum test method in Figure 3. Each data point represents one sampling point. The results of the visual inspection are averages of ten estimation values. Single samples were taken with the vacuum test method. The multiple correlation coefficient (R^2) between the results of visual inspection and the vacuum test method was 0.95.

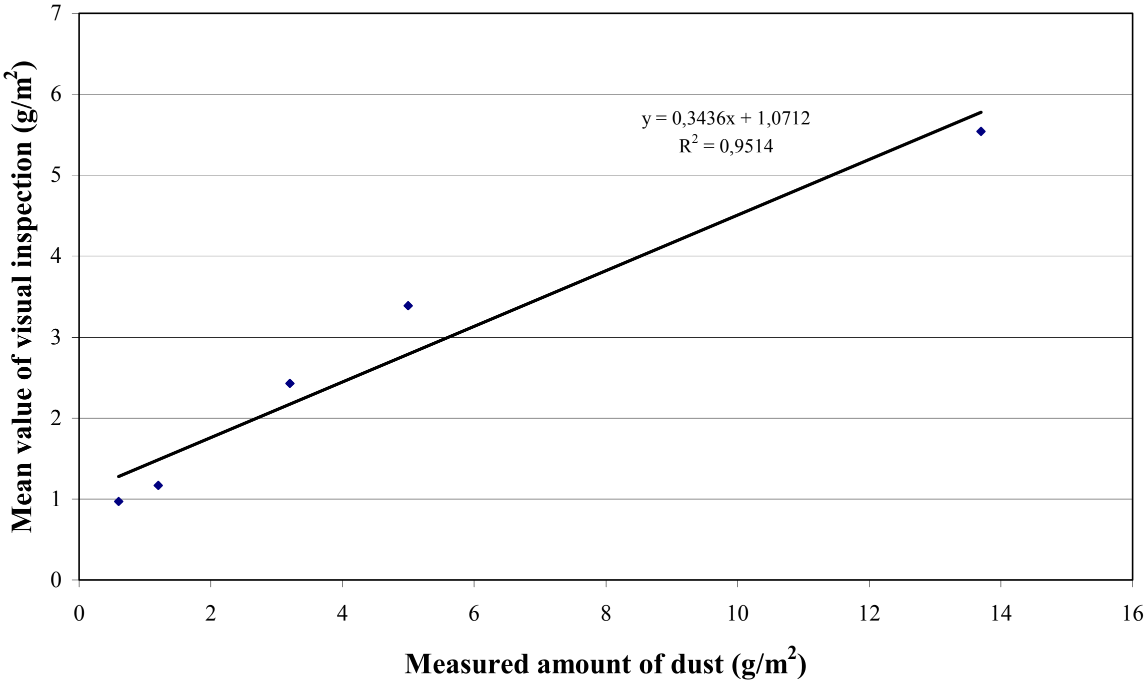

Figure 3. The results from the visual inspection and the vacuum test (n=5).

DISCUSSION

The results showed that inspectors could evaluate the amount of dust accurately enough in relatively clean air ducts. Visual inspection gave approximately the same result than measured values when the amount of dust was 0.6 and 1.2 g/m^2 on the duct surface (Figure 2). The visual panel evaluated on average too low dust accumulation compared with the measured value when amount of dust was higher than 1.6 g/m^2 (Figure 3). A good correlation between evaluated and the measured was found. The evaluation of the mean amount of dust of one member of visual panel was 0.9 g/m^2 which did not exceed the limit value of cleanliness category P1 (1.0 g/m^2). Whereas four members of visual panel evaluated that the mean amount of dust in the ductwork was higher than the limit value of cleanliness category P2 (2.5 g/m^2). Two members of visual panel evaluated higher mean amount of dust than measured value 4.7 g/m^2. In some of the inspection points, there were also a lot of steel filings where ducts have been cut with an abrasive cutting machine. The density of steel is much higher than that of other dust, and increased the mass of the samples containing steel particles. The results indicated that without good experience it is quite difficult to evaluate the amount of steel dust (g/m^2) visually. One way to help visual inspection may be to create a visual cleanliness scale for steel filings.

The purpose of the developed visual inspection method is to support the subjective evaluation of inspectors, constructors and building owners. After short training for the visual inspection scale each member of the panel is able to memorize the cleanliness scale. However, it is reasonable that inspector carries the visual cleanliness scale during visual inspection. Beside this, the intensity of the illumination should be taken into account during visual inspection. It is recommended to wipe the surface of the duct with a finger from the side of the duct to the bottom to help the evaluation task. If dust adheres onto the finger but does not form a little heap on the bottom of the duct, the dust accumulation is most probably under 1.0 g/m^2, which means that duct fulfils the requirements of cleanliness category P1 considering the dust accumulation. When the amount of dust exceeded 1.0 g/m², the border of the dust is clearly observed in the middle part of the duct surface.

CONCLUSION

The visual inspection is the most commonly used method for assessing the need to clean a newly installed ductwork. Following the developed visual inspection procedure it is possible to do visual inspection of cleanliness more systematically and objectively. However, the training is needed to compare different levels of dirtiness in ducts containing dirt from manufacture, storage and installation period of the ducts. Visual inspection method can be used accurately enough for estimating low amount of dust (1–2 g/m^2) on the duct surface and for evaluation for necessity of cleaning air ductwork.

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REFERENCES

FiSIAQ. 2001. The Classification of Indoor Climate 2000. FISIAQ publication 5E, The Finnish Society of Indoor Air Quality and Climate (FiSIAQ), Espoo, Finland. 40 p.

NADCA. 1992 Mechanical Cleaning of Non-Porous Air Conveyance System Components. An Industry Standard Developed by the National Air Duct Cleaners Association. Washington, DC. NADCA 1992-01.

Pasanen P. 1999. “Verification of Cleanliness of HVAC–Systems”. In: Loyd, S. (ed.) *Proceedings of VHExCo99,* The International Ventilation Hygiene Conference and Exhibition, Birmingham, UK.

SFS 4619. 1996. Siivoussanasto (Cleaning vocabulary). 43 p. (in Finnish).

Vasara J. 2001. LVI-mallityöselitys (Specification of HVAC System). Puhdas ja toimiva ilmanvaihtojärjestelmä - Puhtaan ilmanvaihtojärjestelmän suunnitteluohje (Clean Ventilation System – a guide for the designing of a clean ventilation system) Insinööritoimisto Granlund Kuopio Oy. 5 p. (in Finnish).