INNOVATIONS IN VENTILATION TECHNOLOGY

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# LESSONS LEARNED FROM THE APPLICATION OF THE SWEDISH BOVERKET-OVK PROCEDURE IN BELGIUM

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# 1. Synopsis

In the framework of the Flemish "Kantoor 2000" research project, the BBRI invited a Swedish inspector to apply the Boverket-OVK procedure for checking the ventilation installations in three Belgian buildings.

This experience was most illustrative for the actual status of ventilation systems in Belgium. The procedure being very simple to apply was still very effective and able to detect most problems with ventilation installations encountered in these buildings.

To control the quality of ventilation systems, three aspects of the building process are important:

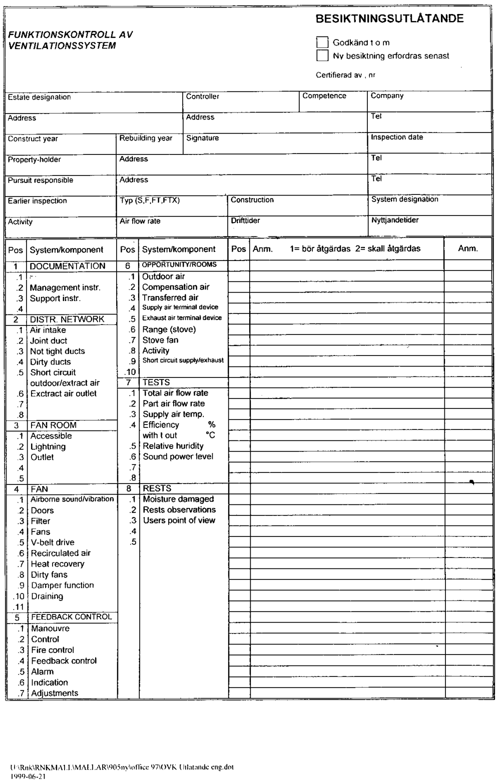
- Effective and correct design: even in a most prestigious building, main errors in the design were encountered. With correct procedures for commissioning, this kind of errors should be eliminated before the building is occupied.
- Good inspections and maintenance: most errors encountered were related with bad controls (wrong settings, wrong airflow rates…) and bad maintenance (dirty installations with poor performances…). The lack of good maintenance and operating controls is responsible for a whole range of secondary problems (damage to the installation, bad indoor air quality, high energy-consumption…).
- Continuous commissioning: checking the installations on a regular base seems to be a very effective way to improve the encountered poor performances of ventilation installations. The Swedish example supports this opinion very strongly: since the procedure is established, the quality of ventilation has improved in a very impressive way.

## 2. Introduction

The Swedish National Board of Housing, Building and Planning (Boverket) has developed the procedure "Checking the performance of ventilation systems" or OVK (Compulsory Ventilation Check) to improve the performance of ventilation systems in Sweden. In the framework of the TIP-VENT and KANTOOR 2000 projects, the BBRI has applied this procedure to three office buildings in Belgium.

A formal description of this procedure can be found in ([1]). In order to apply this procedure, the BBRI has asked the collaboration of Mr. Reinhold Larsson who is an experienced inspector with a national authorisation certificate class K (valid for all types of ventilation systems) in Sweden.

## 3. Procedure



*FUNKTIONSKONTROLL AV VENTILATIONSSYSTEM*

**BESIKTNINGSUTLÅTANDE**

☐ Godkänd t o m
☐ Ny besiktning erfordras senast

Certifierad av , nr

| | | | |
|---|---|---|---|
| Estate designation | Controller | Competence | Company |
| Address | Address | | Tel |
| Construct year | Rebuilding year | Signature | Inspection date |
| Property-holder | Address | | Tel |
| Pursuit responsible | Address | | Tel |
| Earlier inspection | Typ (S,F,FT,FTX) | Construction | System designation |
| Activity | Air flow rate | Drifttider | Nyttjandetider |

| Pos | System/komponent | Pos | System/komponent | Pos | Anm. 1= bör åtgärdas 2= skall åtgärdas | Anm. |
|---|---|---|---|---|---|---|
| 1 | DOCUMENTATION | 6 | OPPORTUNITY/ROOMS | | | |
| .1 | | .1 | Outdoor air | | | |
| .2 | Management instr. | .2 | Compensation air | | | |
| .3 | Support instr. | .3 | Transferred air | | | |
| .4 | | .4 | Supply air terminal device | | | |
| 2 | DISTR. NETWORK | .5 | Exhaust air terminal device | | | |
| .1 | Air intake | .6 | Range (stove) | | | |
| .2 | Joint duct | .7 | Stove fan | | | |
| .3 | Not tight ducts | .8 | Activity | | | |
| .4 | Dirty ducts | .9 | Short circuit supply/exhaust | | | |
| .5 | Short circuit | .10 | | | | |
| | outdoor/extract air | 7 | TESTS | | | |
| .6 | Exctract air outlet | .1 | Total air flow rate | | | |
| .7 | | .2 | Part air flow rate | | | |
| .8 | | .3 | Supply air temp. | | | |
| 3 | FAN ROOM | .4 | Efficiency % | | | |
| .1 | Accessible | | with t out °C | | | |
| .2 | Lightning | .5 | Relative huridity | | | |
| .3 | Outlet | .6 | Sound power level | | | |
| .4 | | .7 | | | | |
| .5 | | .8 | | | | |
| 4 | FAN | 8 | RESTS | | | |
| .1 | Airborne sound/vibration | .1 | Moisture damaged | | | |
| .2 | Doors | .2 | Rests observations | | | |
| .3 | Filter | .3 | Users point of view | | | |
| .4 | Fans | .4 | | | | |
| .5 | V-belt drive | .5 | | | | |
| .6 | Recirculated air | | | | | |
| .7 | Heat recovery | | | | | |
| .8 | Dirty fans | | | | | |
| .9 | Damper function | | | | | |
| .10 | Draining | | | | | |
| .11 | | | | | | |
| 5 | FEEDBACK CONTROL | | | | | |
| .1 | Manouvre | | | | | |
| .2 | Control | | | | | |
| .3 | Fire control | | | | | |
| .4 | Feedback control | | | | | |
| .5 | Alarm | | | | | |
| .6 | Indication | | | | | |
| .7 | Adjustments | | | | | |

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**Figure 1 OVK checklist**

The timetable of the compulsory ventilation checks and the inspector's required qualifications are well defined in ([1]) and therefore not discussed in this report.

The practical procedure is supported by a checklist, a single page document mentioning the checks to be performed. Most of these controls are visual but some require measurements. Especially when visual inspections lead to remarks, supplementary measurements are carried out. Only defective points are reported on the document, in which two gradations are possible. A '1' has to be improved at the latest on the next inspection, while a '2' is considered to be a severe deficiency and has to be improved in the short term (i.e. about 3 months), followed by a new inspection.

In this document, only mechanical ventilation systems are discussed. A similar practical procedure exists for natural and hybrid ventilation systems.

The following text briefly describes the issues on the inspection form and the encountered shortcomings in the three examined buildings.

Beforehand, these buildings are briefly presented.

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[1] The Swedish National Board of Housing, Building and Planning, General Guidelines 1992:3E "Checking the performance of ventilation systems"; Boverket, Publikationsservice Box 534, S-371 23 Karlskrona, Sweden

## 3.1 Examined Belgian buildings

| | Building A | Building B | Building C |
|---|---|---|---|
| **Year of construction** | 1975 | 1991 | 1998 |
| **Office floor surface** | 1120 m² | 3250 m² | >10.000 m² |
| **Ventilation type** | Mechanical supply | Balanced | Balanced |

**Table 1 Examined buildings**

- Building A is a rather small office building, constructed in the seventies but renovated in the nineties with much attention for energy and comfort related topics. The users are aware of energy-use and comfort 'above normal' and therefore the situation was expected to be good, if not very good.
- Building B is a typical property developer project constructed in the early nineties. Some problems with indoor air quality and thermal comfort were already encountered and it was therefore expected that there would be some remarks in this OVK-check.
- Building C is a new prestigious office building from one of the main banking companies in Belgium. The building was in the stage of commissioning at the moment of the OVK-check. In Sweden too, it is considered normal that a first OVK-check leads to some remarks on the ventilation installation.

## 3.2 Documentation

The first issue to be checked is the existence and correctness of documentation on the inspected installations. This documentation consists of drawings, schemes, manuals, maintenance programs…etc.

Incomplete or missing as built plans, manuals, maintenance instructions… are considered to obstruct good management of the ventilation system.

| Building A | Building B | Building C |
|---|---|---|
| 2 | 2 | 2 |

**Table 2 Score (-, 1 or 2) on the OVK checklist**

As shown in table 2, none of the three ventilation installations was well documented. In fact in buildings A and B some documents were missing, other were incomplete or showed incorrect information (e.g. as built plans ). Building C had no documents available at all, as these were handed over to a maintenance company, without having a copy near the installation.

## 3.3 Distribution network

The complete ductwork through which the air is transported is inspected very closely, since dirty or non-airtight ducts and grids cause energy-losses and are possible sources of bacteriological contamination and dust.

### 3.3.1 Air Intake

The air-intake should be clean and protected against water infiltration, insects, animals…etc.

| Building A | Building B | Building C |
|---|---|---|
| 2 | 2 | - |

**Table 3 Score (-, 1 or 2) on the OVK checklist**

Two of the three buildings had already a severe shortcoming at the air intake. Maintenance and cleaning was impossible in building A due to a fixed grid, building B had precipitation water infiltrating the installation through the air intake. Being a severe design mistake, this last problem causes a lot of other secondary problems, such as corrosion, moulds and bacteriological contamination.

### 3.3.2 Duct joints and airtightness

Lack of airtightness of a ductwork is often due to inaccurate assembly, which causes air-open joints. Furthermore, the quality of the ducts themselves is variable. In general, circular ducts are more airtight than rectangular ones, which have however the advantage of not taking so much place. Good joints have seals.

Smoke tests visualise air leaking through joints. When severe leaking is observed, pressurisation of the ductwork makes it possible to quantify the problem. Pressurisation is not a standard test in this OVK-procedure.

| Building A | Building B | Building C |
|---|---|---|
| 1 | 1 | 1 |

**Table 4 Score (-, 1 or 2) on the OVK checklist**

The airtightness of the ductworks in building A and B has been measured and documented in the framework of the SAVE-DUCT-project (4), where more information on this subject can be found. Building A is known to have a well performing class C-ductwork, building B does not even reach class A, thus having a poor airtightness.

In Building C important leaks were detected at installation level and easily accessible parts of the ductwork, leading to a '1'-remark. However there was no time or budget available to quantify the real airtightness of the ductwork.

As important as the airtightness is the cleanliness. The hygienic standard in Sweden is max 1 g of dust pro $m^2$ developed duct surface. Each installation should therefore have a maintenance program that provides the regular cleaning of the ducts, which have to be equipped with inspection and cleaning openings. Visual inspection is predominantly sufficient to determine the condition of the ductwork.

None of the three buildings had a ductwork maintenance program, nor were the necessary cleaning devices present. Furthermore building C showed the importance of correct handling of the ducts during the construction phase: although new and unused, the ductwork showed important pollution coming from the construction phase.

### 3.3.3 Short circuits between outdoor and extracted air

Ill positioning of air intake and outlet often leads to short-circuits between exhaust and supply. Positioning can be easily inspected, e.g. on a rooftop. In case of doubt, the use of tracer-gas techniques can give a decisive answer. In the examined cases there were no apparent problems with this subject.

## 3.4 Fan Room

The technical room, containing the ventilation installations should be easily accessible, clean, well lighted and ventilated in order to make it easier to operate the system well. Therefore some basic inspections are effectuated.

Good accessibility, lighting and ventilation of the technical room are basic conditions to operate the installation in a proper way.

This issue was approved in each of the examined buildings.

## 3.5 Fan

The air handling unit (AHU), containing the fans, heat exchangers, heating, cooling and humidifying batteries…etc. is the heart of the installation. Therefore many visual inspections, complemented with measurements are effectuated.

### 3.5.1 Airborne sounds/vibrations

The procedure provides a check of sound-levels when installations are inspected for the first time (new installations or first-time visits to existing buildings) or when sound-levels are evidently too high. Sound-levels however, are influenced by maintenance-conditions. Fans operating in bad conditions (dirt, huge pressure drops…) produce more noise.

No acoustic tests were effectuated.

### 3.5.2 Doors/accessibility

It is important to have access to each compartment of the AHU. Therefore doors or removable panels should be provided and easy to open. This is necessary for good maintenance: changing filters, cleaning the installation, changing belts, greasing…

| Building A | Building B | Building C |
|---|---|---|
| - | 2 | - |

**Table 5 Score (-, 1 or 2) on the OVK checklist**

Building B has a major design mistake, as the heating battery compartment is not accessible.

### 3.5.3 Filters

Not only the degree of pollution is checked, also correct positioning of the filters is controlled. When clearly dirty or in bad condition, it is interesting to measure pressure drop and temperature rise over the filters. A typical pressure drop is 100 pa, while the temperature should not increase more than 1°C.

| Building A | Building B | Building C |
|---|---|---|
| 2 | 2 | 2 |

**Table 6 Score (-, 1 or 2) on the OVK checklist**

The filter system in building A showed an important anomaly, as the filtered dust reappeared on the outside of the filter and as a consequence entered the supply duct. Due to the infiltration in the installation (cfr.3.3.1), filters in building B were in an abominable condition. Building C had no filter between the supply air and a heat exchanger (rotating wheel exchanger), with disastrous consequences for the latter. Once again, this is a design mistake.

### 3.5.4 Fans and fan motors

Fan-blades get a visual inspection. Energy consumption of the motors can optionally be measured. Important is to measure the pressure-drop over the fan. Both energy consumption and pressure drop should be compared with initial requirements, prescribed in the documentation.

| Building A | Building B | Building C |
|---|---|---|
| - | - | 2 |

**Table 7 Score (-, 1 or 2) on the OVK checklist**

The underpressure over the supply fan in building C exceeded the design value by 50% and caused stagnant water in the humidification battery.

### 3.5.5 Driving belts

The condition of the belts is controlled by visual inspection. The use of flat belts in stead of V-belts is recommended. The latter are easier when it comes to line up fan and motor (larger tolerance), flat belts however, are less energy consuming. An alternative is the use of direct-drive-fans (thus without belts).

None of the visited installations had flat belts or directly driven fans. Belts were however in good condition.

### 3.5.6 Recycled air

The air-tightness of heat exchangers, dampers and valves between exhaust and supply is of great importance. The system can only function under well-defined conditions if each device functions properly itself. Several measurement campaigns show that recycling rates are often more important than foreseen.

Therefore, when air recycling devices (e.g. dampers between exhaust and supply) are present, their airtightness is most important to obtain well controlled and quantified recycling degrees.

| Building A | Building B | Building C |
|---|---|---|
| - | - | 2 |

**Table 8 Score (-, 1 or 2) on the OVK checklist**

Building C had an involuntary recycling degree of 20%, measured with tracer gas techniques, due to a badly executed exhaust/supply damper.

### 3.5.7 Heat recovery

Deficiencies of heat recovery devices mostly concern air-tightness and cleanliness. Very often involuntary recycling of extracted air is caused by leaky heat exchangers.

| Building A | Building B | Building C |
|---|---|---|
| - | 2 | 2 |

**Table 9 Score (-, 1 or 2) on the OVK checklist**

In both buildings B and C secondary problems appear with the heat exchanger. Due to corroded damper-flaps the cross-plate heat exchanger in building B is not functioning, while the rotating wheel heat exchanger in building C is blocked with dust and dirt coming from the unfiltered supply air.

### 3.5.8 Draining

Condensers and humidifying devices in general require special attention. Some dated types should not be used any more, because they cause rather high pressure-drops and create favourable conditions for micro-organisms. Water coming from condensers and dampers should be evacuated immediately for the same hygienic reason.

Building C had a severe secondary problem with this item: as already mentioned in 3.5.4 there was stagnating water in the humidification battery.

## 3.6 Feedback control

In general the operating system and/or switchboards need manuals, easy layout, clear functioning (cf. alarm-lamps…), good labels…etc. Good feedback and controls are a conditio sine qua non to operate the system properly.

All three buildings being rather recent or recently renovated, the control panels complied with actual demands.

## 3.7 Room level

At room level a diversity of checks can be performed. However, in the framework of this 3-day-visit of the Swedish inspector less attention was paid to this part of the OVK-procedure.

## 3.8 Tests

In completion to the standard checks and measurements of the OVK-procedure, a number of tests can be done to obtain more information on the observed shortcomings. Hereafter follow some results from measurements performed in these 3 buildings

### 3.8.1 Building A

- The measured and calculated airflow rate (with tracer gas techniques) at installation level is a little low: about 15% lower than expected. Measured value is 500 $m^3/h$, while 600 $m^3/h$ is expected.

- As a consequence partial airflows at room level are a little low too. Moreover the distribution of the air over the rooms is not optimal.

  Some results:

| Inlet position | Airflow in room 232 a | Airflow in room 237 | Airflow in room 239 a |
|---|---|---|---|
| 1 (25 m³/h) | 23 m³/h | 18 m³/h | 23 m³/h |
| 2 (50 m³/h) | | 30 m³/h | |
| 3 (75 m³/h) | | 40 m³/h | |
| 4 (100 m³/h) | 56 m³/h | 73 m³/h | 74 m³/h |

### 3.8.2 Building B

- The measured supply air flow rates are 33% lower than the design values. This is only 5% for the extracted air.

| | $Q_{\text{supply offices 0-1-2-3}}$ | $Q_{\text{exhaust offices 1-2-3}}$ |
|---|---|---|
| Design value | 10560 m³/h | 6100 m³/h |
| Measurement | 7110 m³/h | 5885 m³/h |

- As a consequence, the pressure is higher in the garages than in the office section of this building. Part of the pollution of the cars in the garages enters into the offices.
- The electrical consumption of the fans for the supply in the offices is very high:

| | |
|---|---|
| Exhaust offices | 2.98 W/(l/s) |
| Supply offices | 8.46 W/(l/s) |
| Exhaust garage | 4.25 W/(l/s) |
| Supply garage | 3.46 W/(l/s) |

### 3.8.3 Building C

- Due to high pressure drops in different components, the supply fan is working very hard in comparison to the measured airflow rate.

  Pressure drop was about 1600 Pa, the fan working at 42 Hz (50 Hz being maximum) for a flow rate of about 35000 m³/h.

  In ideal conditions the maximal pressure drop should be 1200 Pa (design value for this installation) at 50 Hz (maximum flow rate). At 42 Hz the flow rate should be about 48000 m³/h (according to fan characteristic)
- SFP (specific fan power) is very bad (3 W/(l/s) in stead of 1,5 W/(l/s) as a normal value), due to these problems. If the supply fan runs 12 hours on 24, the dirt on the heat exchanger is responsible for easily 13000 kWh/year. Moreover, running under correct pressure conditions would save at least an extra 35000 kWh/year.

# 4. Important lessons learned from this OVK-experience in Belgium

While paragraph 3 might be considered as a cheap summing up of spectacular shortcomings and mistakes (which it partly is), it shows however some important weaknesses of the actual construction market, in particular where ventilation is considered.

## 4.1 Condition of ventilation installations in Belgium

The most evident conclusion from this OVK-experience is the rather bad condition of the visited installations. Visits in 92 other office buildings in Flanders and Brussels in the framework of the Kantoor 2000 project mainly confirm this conclusion.

Three main reasons are at the base of this situation:

1. Design mistakes are not detected, because efficient commissioning procedures are non-existing at the moment and little attention is paid to commissioning as a whole.
2. As there are no other boundary conditions, such as energy and comfort parameters imposed by authorities, price is in most cases the only and decisive parameter in the selection of the installation. In other words, in the actual market situation and financial climate there is no stimulation toward better installations with regular profound maintenance and inspections.
3. There is little user awareness of the possible problems occurring with ventilation installations. Therefore, in many cases maintenance and inspections are limited to an absolute minimum.

In the Swedish context procedures such as Boverket-OVK have largely shown the capability to overcome these problems:

1. Although design mistakes should already be detected at the time of commissioning, Boverket-OVK is applied to the new installation before the building comes into use and is therefore a final examination to pass.
2. As Boverket-OVK is a compulsory check, it creates a legal context in which there is no room for low quality ventilation installations. Without OVK-approval, a building owner does not get his exploitation-permit.
3. As building-owners are a concerned party, their awareness of high quality ventilation is stimulated, as well as the importance of good and regular maintenance and inspection. Moreover, although compulsory, the OVK-procedure has an advisory philosophy. More than punishing building owners by depriving them of their exploitation permit, an inspector will try to advise the owner to improve his installations.

## 4.2 Efficiency of simple pragmatic procedures

The experience with the OVK-procedure is a plea for simple pragmatic procedures to obtain a good base level of quality with rather little effort. As illustrated in paragraph 3, all the checks and measurements are feasible in a limited time with limited means. Most measurement equipment can be carried away in a normal sized suitcase.

On the other hand this does not mean that the test can be performed by anyone at any time. The force of this type of procedures lies in the experience and knowledge of the inspector, allowing him to assess installations quickly and accurately.

In a market where automated control systems are winning ground, one should remark that these valuable systems can only function properly with a good underlying base, i.e. a well functioning installation with maintained and checked components.

## 4.3 Importance of good commissioning at an early stage

Some major shortcomings encountered in paragraph 3 were clearly mistakes in the design. Boverket-OVK-like procedures are unable to prevent this kind of costly mistakes. OVK can only state the mistake and advise the building owner with possible solutions to the detected shortcoming. Consequently the commissioning process should start at an early stage, earlier than nowadays. This can happen in different ways:

1. Components used in installations might be quality-certified by means of labels, attributed by authorised organisms
2. The installation design could be checked at the time of construction license assignment.
3. Final commissioning of the installation should start in an earlier stage, independent of the commissioning of the building, and run over a longer period. E.g. a one year period with addressed monitoring activity to refine the controls of the installation.

## 4.4 Importance of good maintenance and inspection – continuous commissioning as a support

The Swedish experience has shown an enormous decrease of shortcomings in ventilation installations, since the introduction of the OVK compulsory ventilation check. Not only because this compulsory check detects these shortcomings and problems, but also because preventive maintenance has increased.

In a way, a procedure such as OVK can be considered as a kind of continuous commissioning. Its working domain is even larger: where commissioning mainly considers new or renovated/refurbished buildings and installations, OVK is applied in a regular way and therefore more effective.

It might be interesting to have this kind of procedure in other domains (HVAC, but also other parts of the building and its equipment).

## 4.5 Potential for energy saving

Finally, the most essential point is that OVK has improved the quality of ventilation installations and thus indoor comfort and energy use. Although OVK gives no direct stimulus toward the use of energy-friendly components, the general stimulus toward quality that lays in the regular check and the fact that well maintained and controlled installations are a lot more efficient, leads to a considerable energy saving.

## 5. References

(1) Granqvist Per, Kronvall Johnny. 1994. *Checking the performance of ventilation systems: the Swedish approach.* Air Infiltration Review, Vol 15, No 2, pp. 1-4

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(3) Engdahl F. 1998. *Evaluation of Swedish ventilation systems.* Building and Environment, Vol. 33, No 4, pp. 197-200

(4) Wouters, Carrié, Andersson. 1999 *Improving Ductwork – A time for tighter air distribution systems.* AIVC, Coventry