REQUIREMENTS AND HAND-OVER DOCUMENTATION FOR ENERGY-OPTIMAL DEMAND-CONTROLLED VENTILATION

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ABSTRACT

Demand controlled ventilation (DCV) considerably reduce the ventilation airflow rates and energy use compared to Constant Air Volume (CAV) systems. DCV in commercial buildings is probably a prerequisite to achieve ambitious energy-goal. However, evaluation of real energy use demonstrates that the energy saving potential is seldom met. DCV-based ventilation systems must become more reliable to close the gap between theoretical and real energy-performance. These unfortunate experiences with DCV have many causes, including: inadequate specifications and hand-over documentation, balancing report not suitable for DCV, communication errors and lack of knowledge about DCV-systems among decision makers.

There is also a significant difference in performance between DCV-systems and simpler systems that, for example, vary the airflow rate with pre-set air damper positions, or that use a single sensor for several rooms. In order to verify that a DCV system fulfils the expectations in terms of indoor climate and energy use, one must specify measureable objectives of performance.

In this paper, the most important control points during commissioning of a DCV system are described. Measureable objectives of performance should be specified. In particular, recommendations are given in terms of:

- control and measurement of Specific Fan Power
- balancing procedures and control of airflow rates
- requirements for sensors and dampers
- hand-over documentation
- deviations during commissioning and corrective procedures.

KEYWORDS

Energy use, Demand controlled ventilation, Specific fan power

1 INTRODUCTION

Demand controlled ventilation (DCV) considerably reduces the ventilation airflow rates and energy use compared to Constant Air Volume (CAV) systems. DCV in commercial buildings is probably a prerequisite to achieve Nordic and European energy-goal (IEA and Nordic Energy Research, 2014).

When correctly implemented, DCV can reduce the energy consumption of ventilation by more than 50 % (Maripuu, 2009). However, evaluation of real energy use demonstrates that the energy saving potential is seldom met (Mysen et al., 2010). DCV-based ventilation systems must become more reliable to close the gap between theoretical and real energy-performance. These unfortunate experiences with DCV have many causes, including: inadequate specifications and hand-over documentation, balancing report not suitable for DCV, communication errors and lack of knowledge about DCV-systems among decision makers. Based on this experience from case-studies, an expert group has developed new requirements and hand-over documentation (Mysen and Schild, 2013). The work is carried out in the Norwegian R&D-project reDuCeVentilation (http://www.sintef.no/Projectweb/reDuCeVentilation/).

DCV systems are ventilation systems in which the air flow is controlled automatically according to a measured demand at room level. This means that DCV-systems must have a sensor in the room giving a continuous measurement of the indoor air quality. This signal is then used to control the airflow rate according to the desired indoor air quality level.

VAV stands for Variable Air Volume. It is a broader term than DCV, as it encompasses all systems with variable airflow rate, irrespective of type of control. Only VAV-systems that control the airflow rate according to a measured demand in the room, and not according to a preset value, are considered as DCV in this paper. Normal VAV-dampers in DCV systems are denoted DCV-damper in this paper.

The commissioning, balancing, and control of a DCV-system consist of the following work steps:

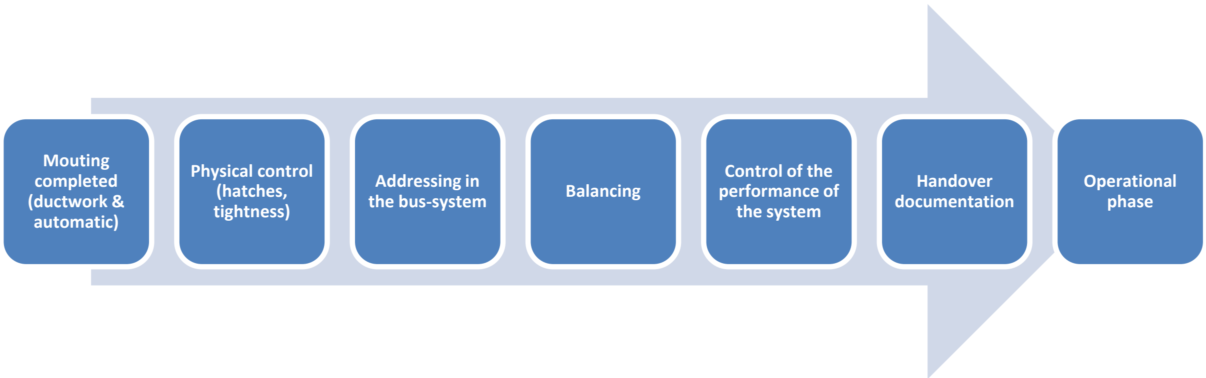


Figure 1. Recommended work steps subsequent to the mounting of the ventilation system.

This paper addresses only requirements and the balancing, control- and hand-over steps.

2 DCV- PRINCIPLES AND BALANCING PROCEDURE

2.1 General

There are several DCV-systems, but they can roughly be divided into the following principles:
"Pressure Controlled DCV", "Static Pressure Reset DCV", "Damper optimized DCV" and "Variable Air Supply Diffusor DCV". These principles are defined and described by Mysen (Mysen and Schild, 2011). Some of the DCV-principles require special balancing procedure and this paper address "Pressure Controlled DCV" and "Damper optimized DCV". Balancing

procedure for “Static Pressure Reset DCV” is similar to "Pressure Controlled DCV". Balancing procedure for "Variable Air Supply Diffusor DCV" is similar to “Damper optimized DCV".

2.2 Pressure controlled DCV

Pressure Controlled DCV (PC-DCV) is the traditional DCV systems (Figure 2). The purpose of static pressure control is to indirectly control the airflows by controlling the pressure in a strategic duct position. PC-DCV requires installation of active DCV-units, or known as VAV-units, controlling supply and exhaust air flows to each DCV-room/zone. Controlling fan speed to maintain a constant static fan pressure rise, will result in unnecessary throttling along the critical path during most of the air-handling-units (ahu's) operating time, and therefore unnecessary fan energy use. The duct path with the greatest flow resistance from the ahu to any terminal, is called the ‘critical path’ dimensioning necessary fan pressure rise.
One unfortunate experience of pressure controlled DCV system is that minor changes in room demand just redistribute airflow in the duct system with the airflow in the AHU being more or less constant. The consequence is that no energy saving is achieved, or the supply air is insufficient. This is normally caused by inadequate precision or wrong placement of the pressure sensor.

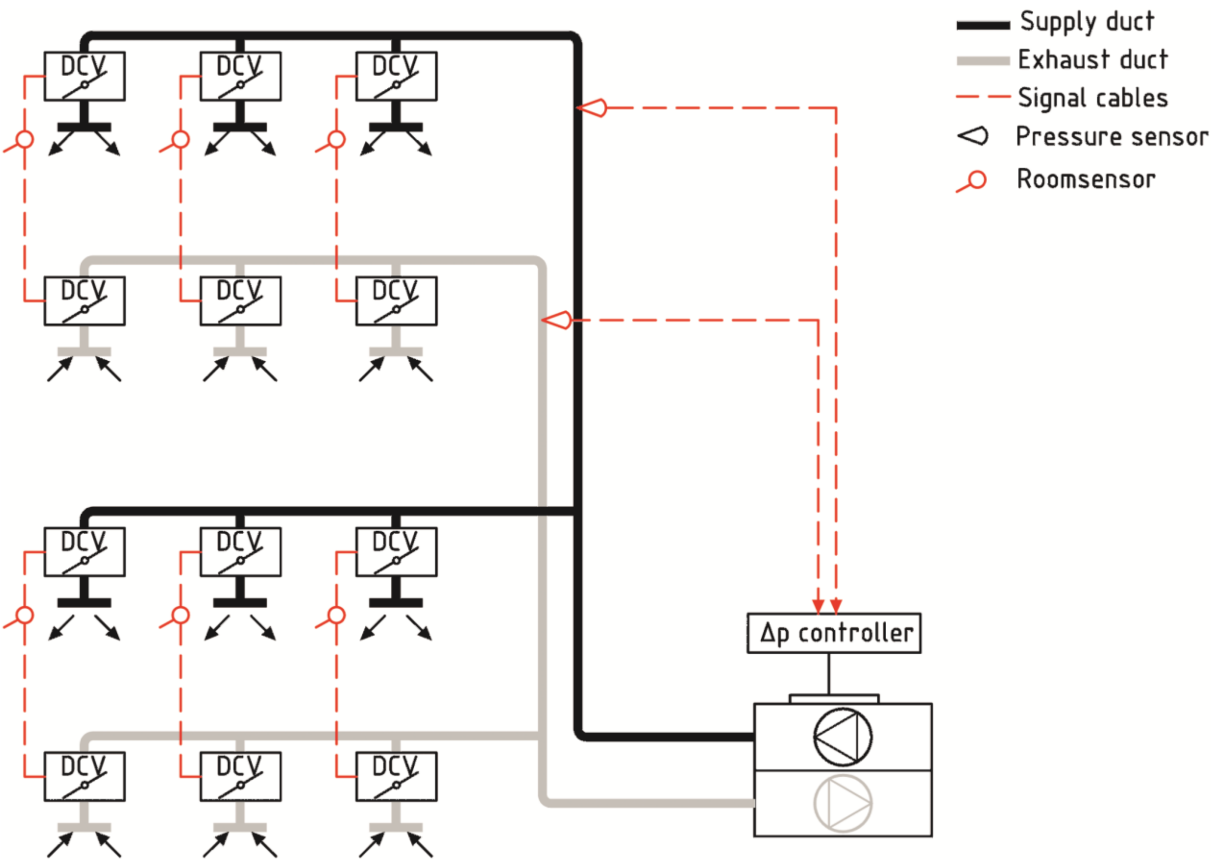


Figure 2. Pressure controlled DCV system. The fan speed is controlled so as to keep constant static pressure in the main ventilation duct, at the location of the pressure tap.

The main purposes of balancing a pressure controlled DCV system are:

- controlling the placement of the pressure sensor
- setting the right pressure set point

In addition, the balancing will reveal connection and communication errors.

Balancing of a pressure controlled DCV-system consists of the following steps:

- Control that all the DCV-units have supply voltage and no polarity error
- Control that the pressure sensor is mounted on a location with stable static pressure or uniform velocity profile, by performing measurements over the duct cross section with a Pitot-tube or a hot-wire anemometer.
- Select a pressure set point which is slightly higher than necessary. This can be deduced from pressure drop calculations or empirically.
- Program the actual maximum and minimum airflow rates values (V_{max} and V_{min}) on each DCV-damper and set the dampers to automatic mode. Control that all the DCV-dampers get the maximum airflow rate, and read the degree of opening. Find the index damper, which is the damper with the highest degree of opening.
- Adjust the pressure set point until the index DCV-damper gets the maximum airflow rate without throttling (about 80 % degree of opening). You have then found the energy optimal pressure set point, which is the lowest pressure set point which provides the right airflow rates according to the designed values.
- Complete the VAV control form. The completed control form should be included in the documentation of the ventilation system.

2.3 Damper optimized DCV

Damper optimized DCV consists in controlling the airflow rate in the main duct according to the position of the dampers, such that at least one of the dampers is in a maximum open position (Figure 3). The purpose is to ensure minimum fan energy consumption by looking for a minimum pressure rise over the fan. This is achieved if one duct path (critical path) is always open. With damper-optimized DCV, the required airflow rate, the supplied airflow rate as well as the damper angle are recorded for all the DCV-dampers. This information is sent to a controller which regulates the fan speed.

Balancing of DCV-units in damper-optimized systems is very simple, and consists in specifying minimum and maximum design airflow rate for each DCV-unit. This can be done either through the bus-system or by connecting a programming device directly on the DCV-units. Various programming devices are used by the different suppliers.

Balancing of a Damper optimized DCV -system consists of the following steps:

- Control that all the DCV-units, room sensors/ room regulators etc. have supply voltage and no polarity error
- Program the actual maximum and minimum airflow rates values (Vmax and Vmin) on each DCV-damper and set the dampers to automatic mode.
- If the DCV-units do not give the expected response, check the polarity on the supply voltage.
- Complete the VAV control form. The completed control form should be included in the documentation of the ventilation system.

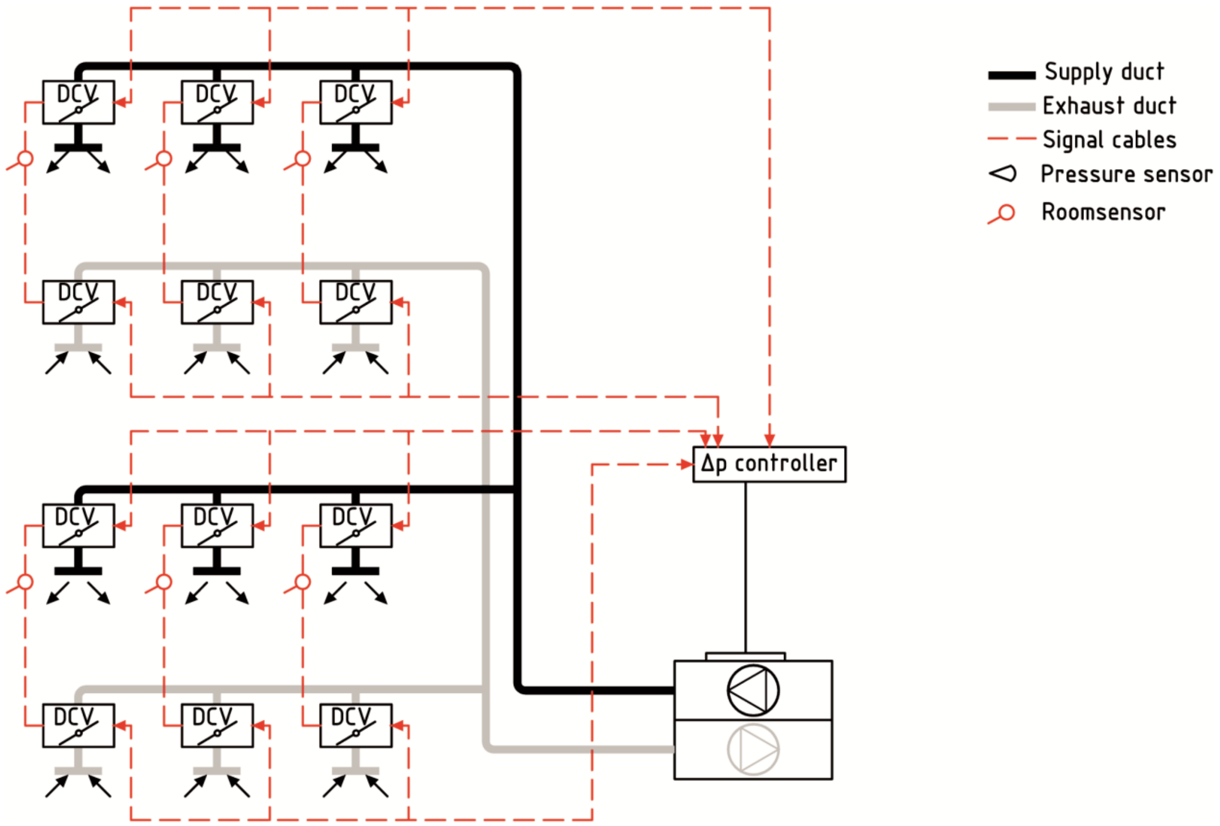


Figure 3. Damper-optimized DCV-system.

3 REQUIREMENTS

It must be possible to control the specified requirements. Specific Fan Power (SFP) is normally required and controlled at maximum air flow. However a DCV system will typically have air flow rates between 30 and 80% of maximum air flow, depending mainly on diversity factor for dimensioning and base ventilation level. At maximum airflow, there are only small differences between the system's SFP (Figure 4, r=1), but at lower airflow rates there are major differences depending on the control strategy. It is important to require maximum SFP-value for two operating scenarios, maximum airflow and reduced airflow rate, to ensure an energy efficient control strategy (Figure 4).

Fitting a DCV-system, typically involves several contracts including BMS (Building Management System), Ventilation system and Electrical Equipment. However, the overall responsibility for the system functionality should be clearly defined and placed in one contract.

Adequate specifications, hand-over documentation and balancing report suitable for DCV-systems must be used.

Critical components, such as sensors, must have proper functionality and acceptable measurement uncertainty throughout their predicted life expectancy, for instance:

- CO_2-sensors +/- 50 ppm
- Temperature sensors +/- 0.5 ^{o}C

Some of the critical components like CO_2-sensors should be controlled at site. One control point for CO_2-sensors is to check if they all give the same ppm-results when the building is empty during evening/night.

An airflow change in any room should give approximately the same change of the total airflow through the air-handling-unit (ahu). This test will reveal pressure controlled DCV system that redistributes parto of the airflow caused by inadequate precision or wrong placement of the pressure sensor.

A DCV is a dynamic system and should be tested and tuned in for both summer and winter conditions. There should be an inspection, function test and review of the DCV- system after a period of normal operation, e.g. 1 year.

The most important control points are presented in figure 4.

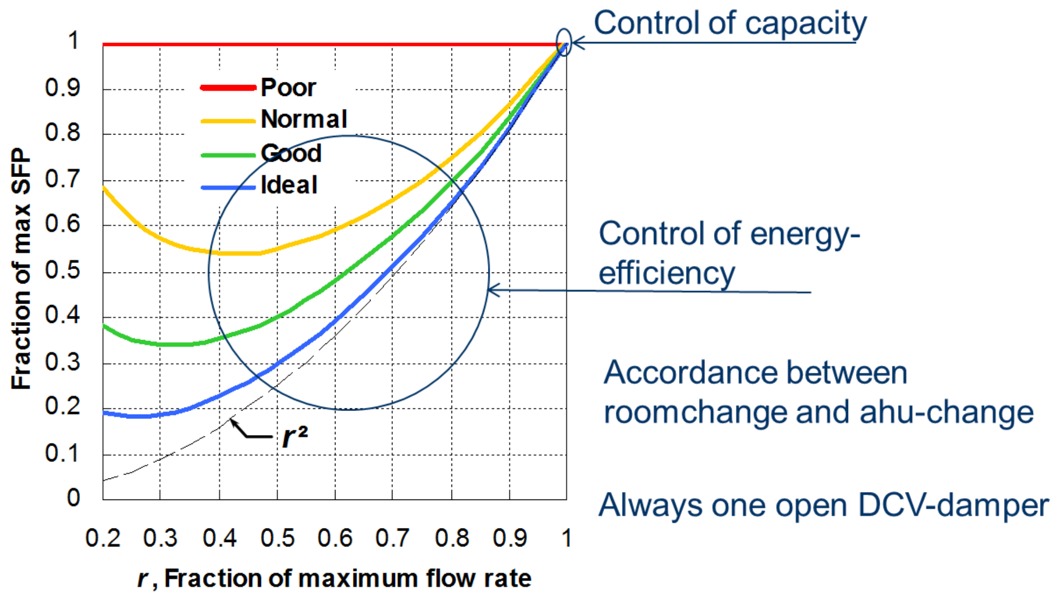


Figure 4. The most important control points. Measurement of SFP with partial load, control of the compliance between airflow rate at room level and total airflow rate, and control that there is always a DCV-damper in max open position with the help of the BMS (Schild&Mysen, 2009).

SFP shall be measured such that power losses in Variable Speed Drives are included, preferably using a suitable 3-phase energy analyzer, or read directly on the AHU.

Deviations during commissioning are normal and should be expected. Therefore, it is important to either forecast time to improve the system, or to create a model for economic compensation to take into account the deviations from the requirements which affect the energy consumption.

Furthermore, new discrepancies will occur during the operational life. It is essential that the automatic controls and the Building Management System (BMS) make it easy to detect faults. It is also important that the control components are accessible for inspection, service and replacement. DCV- dampers in exhaust ducts are especially exposed for dust and must be accessible for inspection and cleaning.

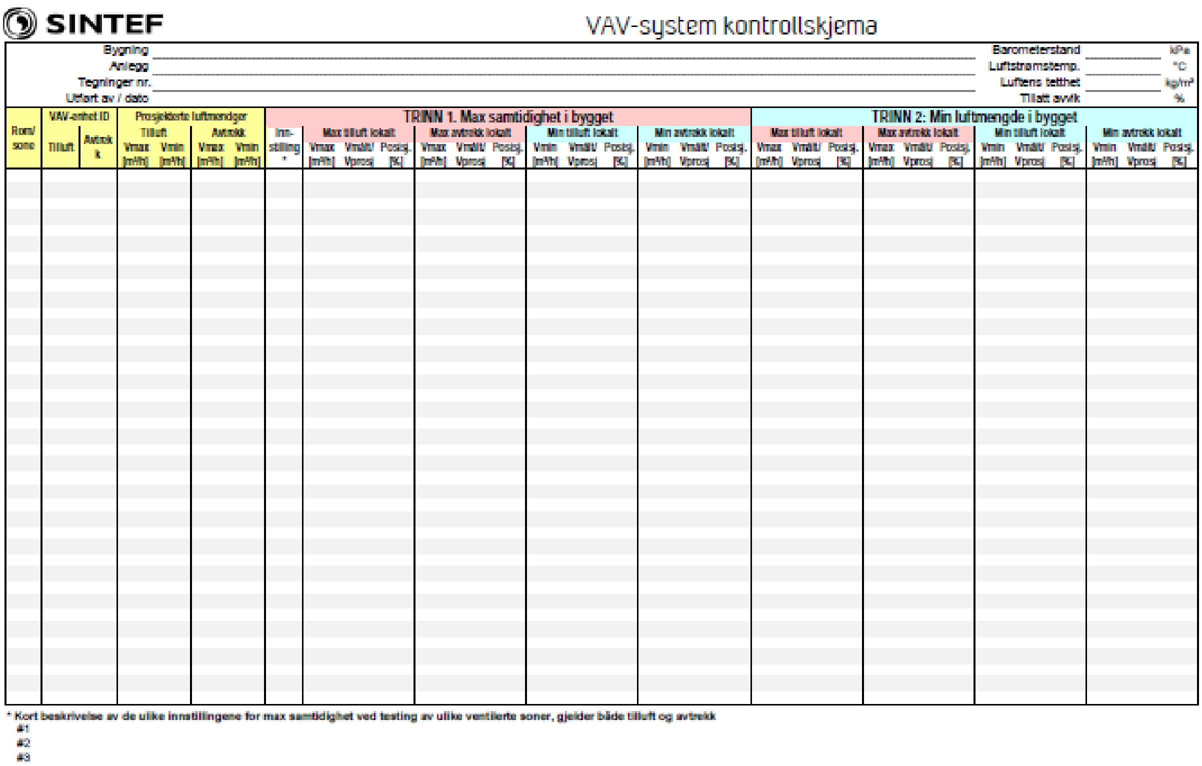
4 HAND-OVER DOCUMENTATION

4.1 VAV-control form

Problems during operation occur most often at maximum or minimum airflow rates. Tests should therefore be carried out for these two operating situations. For each of these situations, it is necessary to consider each DCV-unit and override the control signal from the roomsensor (eg. temperature) in order to force the DCV-unit to respectively max and min airflow rate, and document both airflow rate and degree of opening. The degree of opening tells whether the DCV-units work in a favorable range (40 to 80%) and whether the pressure set point is balanced.

This requires four control measurements per DCV-unit. Such a control procedure is particularly relevant for DCV-systems with pressure control and limited control possibilities from the BMS.

A special VAV-control form is designed for this purpose (Figure 5).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VAV-system kontrollskjema

Bygning

Anlegg

Tegninger nr.

Utført av / dato

Barometerstand kPa

Luftstrømstemp. °C

Luftens tetthet kg/m³

Tillatt avvik %

Rom/ sone	VAV-enhet ID		Prosjekterte luftmengder				TRINN 1. Max samtidighet i bygget													TRINN 2: Min luftmengde i bygget											
	Tilluft	Avtrekk	Tilluft		Avtrekk		Inn-stilling *	Max tilluft lokalt			Max avtrekk lokalt			Min tilluft lokalt			Min avtrekk lokalt			Max tilluft lokalt			Max avtrekk lokalt			Min tilluft lokalt			Min avtrekk lokalt		
			Vmax [m³/h]	Vmin [m³/h]	Vmax [m³/h]	Vmin [m³/h]		Vmax [m³/h]	Vmålt/ Vprosj	Posisj. [%]	Vmax [m³/h]	Vmålt/ Vprosj	Posisj. [%]	Vmin [m³/h]	Vmålt/ Vprosj	Posisj. [%]	Vmin [m³/h]	Vmålt/ Vprosj	Posisj. [%]	Vmax [m³/h]	Vmålt/ Vprosj	Posisj. [%]	Vmax [m³/h]	Vmålt/ Vprosj	Posisj. [%]	Vmin [m³/h]	Vmålt/ Vprosj	Posisj. [%]	Vmin [m³/h]	Vmålt/ Vprosj	Posisj. [%]

* Kort beskrivelse av de ulike innstillingene for max samtidighet ved testing av ulike ventilerte soner, gjelder både tilluft og avtrekk

#1

#2

#3

Figure 5. Recommended VAV-form (http://www.sintef.no/Projectweb/reDuCeVentilation/)

There are developed procedures for load tests at maximum and minimum loads/airflow rates (Mysen and Schild, 2013).

4.2 Automated load test

Manual load test are time consuming, and it has proven to be very difficult to override DCV-units in a load test. One should therefore strive to automate the load test completely by programming it in the control panel or in the BMS. This has several advantages: it can be a complete test (not spot-checking) with all combinations of overriding, it reduces costs significantly, and can be repeated as often as needed (one time per year during normal operation, or after changes in the system).

5 REFERENCE

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