7.0

LabSystem

Clean room technology - Room pressure controllers

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1.1 What is clean room technology?

In many manufacturing sectors, increasingly more demanding industrial requirements result in the use of extraordinarily sophisticated technologies and process techniques, and the methods used are continuously becoming more precise and effective. In order to fulfil market demands - to produce top quality while at the same time using mass production - much stricter general manufacturing requirements must be adhered to, such as the requirement to keep production plants free of dust and germs.

One can no longer imagine any modern high-tech industry that does not have the production requirement for clean room technology as a chain of all measures for the prevention or reduction of harmful influences on products or people.

Clean room technology

- keeps the working area clear of particles from the surrounding air
- guarantees air filtering and air flow routing
- offers different levels of negative and positive pressure between rooms and room types
- maintains specific air conditions such as temperature and humidity
- makes it possible to add high purity media to the process
- ensures clean room compatible production technology and processes
- guarantees surface cleanness of the products, working surfaces and packaging
- discharges and disposes of the process exhaust air
- promotes behaviour on the part of the personnel that is adapted to the process and product and provides the necessary motivation and training

The international standards ISO 14644-1 and VDI 2083 define the Classification of Air Cleanliness. The US Federal Standard 209b has been replaced by the standards DIN ISO 14644-1 and DIN ISO 14644-2. Table 7.1 lists for each ISO class the maximum value for particle concentration (particles per m³).

According to the GMP requirements (guidelines for quality assurance of the production processes and production environment during the production of pharmaceutical products, active substances and medical products as well as foodstuffs and animal feed), clean room technology must provide ventilation systems for pharmaceutical, genetic and biotechnology, pharmacies and laboratories. This requires a great deal of knowledge and know how.

Table 7.2 lists the correlations between the US, VDI and ISO classes.

US-FS 209b	VDI-2083	DIN ISO 14644
Class 0.01	--	ISO Class 1
Class 0.1	--	ISO Class 2
Class 1	VDI Class 1	ISO Class 3
Class 10	VDI Class 2	ISO Class 4
Class 100	**VDI Class 3**	**ISO Class 5**
Class 1,000	VDI Class 4	ISO Class 6
Class 10,000	VDI Class 5	ISO Class 7

Table 7.2 Correlation of the US, VDI and ISO classes

US Class 100 corresponds to VDI Class 3 and defines a particle concentration of max. 100 particles with a size of more than **0.5 µm per foot³**, while DIN ISO Class 5 defines a particle concentration of max. 3520 particles with a size of more than **0.5 µm per m³**.

1.2 Good Manufacturing Practice

GMP (Good Manufacturing Practice) provides guidelines for quality assurance of the production processes and production environment during the production of pharmaceutical products, active substances and medical products, and also foodstuffs and animal feed.

In pharmaceutical manufacturing, quality assurance plays a central role, because here variations in quality can have a direct impact on the health of consumers.

Maximum values for particle concentration [particles per m³]						
Class	**0.1 µm**	**0.2 µm**	**0.3 µm**	**0.5 µm**	**1 µm**	**5 µm**
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1,000	237	102	35	8	
ISO 4	10,000	2,370	1,020	352	83	
ISO 5	100,000	23,700	10,200	3,520	832	29
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293
ISO 7				352,000	83,200	2,930
ISO 8				3,520,000	832,000	29,300
ISO 9				35,200,000	8,320,000	293,000

Table 7.1 ISO Classification of Air Cleanliness

A quality management system that meets the GMP requirements guarantees product quality and the fulfillment of the obligatory requirements imposed by health authorities for the marketing of the products.

- Control accuracy of the volume flow controller and volume flow difference (supply air - exhaust air)
- Running time and possible hysteresis of the actuators used

1.3 Minimum requirements of the rooms

Clean room classes are based on the supplementary guideline to the EU GMP code of practice for the manufacture of sterile pharmaceutical products. Critical work steps must be carried out in an area that corresponds to Clean Room Class A (highest requirement).

The controlled area should preferably meet the criteria of Class B, with appropriate evidence a room corresponding to Class C may be sufficient. When an isolator is used, Clean Room Class D is sufficient.

Access to the controlled area should take place via a room that serves as an air lock; the doors must be bolted shut against each other. Material should be introduced separately from personnel (e.g. via a materials air lock).

1.4 Clean room hierarchies

Access to the cleanest room usually takes place via a series of different clean room areas with decreasing clean room class. Normally clothes are changed between these areas. To keep contamination of objects that come into contact with the floor (e.g. shoe soles) to a minimum, special adhesive foot mats are placed in the individual access points. In addition, access to the cleanest room itself takes place via personnel and material air locks, in which strong air flows and filter systems disperse and extract existing particles so that no additional contaminants from outside are brought in.

1.5 The room pressure

Doors, windows and wall openings are sealed in order to prevent an exchange of air between the laboratory and its surroundings for environmental, hygiene or safety reasons. However, this not only prevents air exchange but also pressure compensation with the surroundings, which can result in inadmissible pressure differences.

Conditions in relation to the surroundings only remain constant when the supply air and exhaust air volume flows are equally high. Assuming a typical, maximum variance of the volume flow controllers of +/-5% percent during control operation, the usual room air tightness values are not a problem with today's building standards. However, as soon as increasing emphasis is placed on the air tightness of the building, undesired pressure differences arise.

The resulting room pressure is dependent on the following parameters:

- Size of the room leakage area
- Area of the overflow opening
- Set ratio of the supply and exhaust air volume flow

1.6 The room leakage

The room leakage is usually caused mainly by door openings and pipes fed into walls, untight windows and concealed wires in the room interior (e.g. electrical installations in pipes).

Increasingly airtight construction methods mean that these "natural" balancing openings are no longer present. Increasingly airtight rooms are very difficult to control with regard to room pressure maintenance (see section 6.1. ff.). To prevent this, overflow openings are purposely built in, but these must not be too narrow or sharp-edged, as this would result in whistling noises.

If an air change in the wrong direction must be avoided when the unit is switched off, the opening must be supplied with a weighted or spring-loaded check valve.

1.7 Pressure difference in relation to the surroundings

Under the application of fluidics the pressure drop via the room leakage behaves almost quadratically to the flow rate. This is why the resulting pressure difference in relation to the surroundings due to an unbalanced volume flow can be determined. If compensation takes place via a defined overflow opening, the resistance of the overflow element is to be equated with the pressure difference (see the Bernouilli formula, section 6.1 ff.)

1.8 Room pressure ratio with different supply air and exhaust air volume flows

If, for example, constant positive pressure in relation to the surroundings should be maintained, an air surplus should be planned accordingly. The exhaust air volume flow controller must be less than the supply air volume controller by the outflowing part. The volume flow difference is calculated as follows:

Volume flow difference = supply air - exhaust air

Room pressure control with volume flow controllers is only suitable when there is a sufficiently large room leakage, as the following example demonstrates:

Assumptions:

Room supply air	1500 m³/h
Room exhaust air	1360 m³/h
Volume flow difference	140 m³/h
Room leakage area	0.01 m²
Control variance of one controller	± 5 %
Consolidated control variance of both controllers	± 7.5 %

This example shows that now a volume flow of 140 m³/h must escape through "leakages". The size of the opening determines the resulting pressure difference in relation to the surroundings (not taking the control variance into account).

Taking into account the control inaccuracy of the volume flow controllers, a fluctuation range (differential volume flow) of 140 m³/h +/- 112.5 m³/h can be expected. As a result, e.g. with an opening area of 0.01 m² for example, the pressure fluctuations listed in Table 7.1 arise (see Diagram 7.1 in section 6).

	Volume flow supply air [m³/h]	Differential volume flow [m³/h]	Pressure difference [Pa]
V_{MIN}	1500-112.5	27.5	0.67
V_{MED}	1500	140	17.5
V_{MAX}	1500+112.5	252.5	56.9

Table 7.1: Pressure fluctuations in the case of a room leakage of 0,01 m² and the given values

The pressure difference range of 0.67 to 56.9 Pa is not acceptable for stable room pressure control. Possible measures that can be taken include increasing the room leakage or controlling room pressure maintenance with CRP room pressure controllers (see section 5.1 ff.) or, for critical room pressure control situations with a very small room leakage area, with SCHEIDER's patented VCP volume flow prioritised room pressure controller.

2.0 Air changes and air flow routing

Table 7.2 shows the air changes for various clean room classes.

During daytime operation, a laboratory typically requires 8 room air changes of 25m³/(h x m²). The demanding requirements of clean rooms with room air change rates of 20 to 600 quickly become apparent, i.e. 2.5 to 75 times higher air change rates than are required in laboratories.

Clean room class according to US-FS-209b	Volume flow [m³/(hxm²)]	Air changes [Number/h]
10	1,600-1,800	500-600
100	1,600-1,800	500-600
1,000	700-1,100	200-300
10,000	60-120	20-40
100,000	60	20

All specifications are recommended values

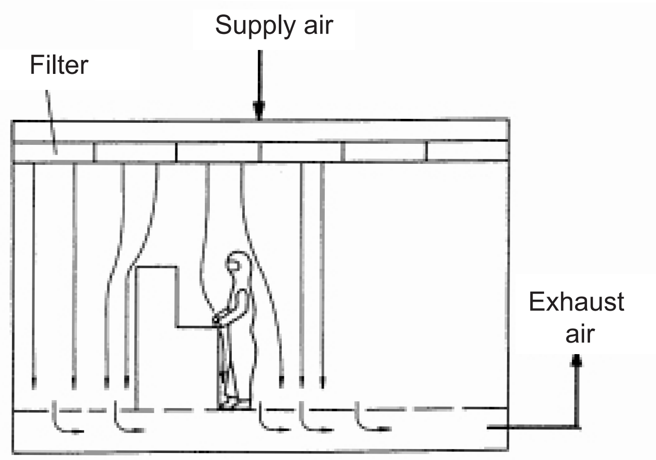
Table 7.2: Air changes for various clean rooom classes

The lower the permitted particle contamination, the more often the air must be changed.

2.1 Laminar Flow

The underlying idea of low turbulence displacement flow (laminar flow) is that particles are transported along with the flow lines. Since all flow lines are laid from top to bottom, lateral dispersion of the particles is not possible and contaminations are immediately removed from the air.

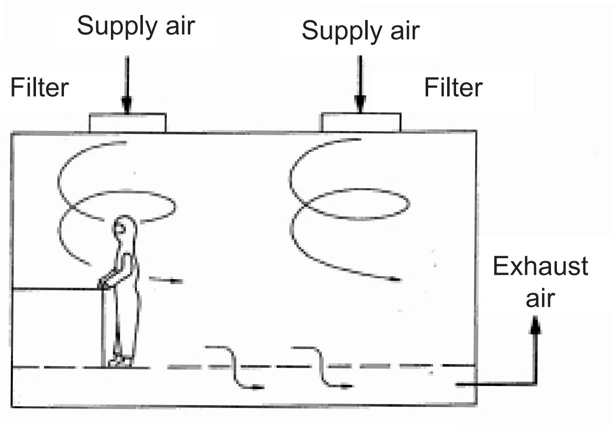
Together with usually multi-stage filtering and a high air flow rate, the cleanliness of the air should be guaranteed.



- The particle contaminated air is displaced by air with few particles and discharged along the flow lines through the holed floor
- A face velocity of approx. 0.45 m/s ± 0.05 m/s (as high as possible) is selected
- Thus high quality of the room air is possible
- Very cost-intensive
- For financial reasons, laminar displacement flow and turbulent mixed air flows are often combined

2.2 Turbulent mixed air flow

The underlying idea of turbulent dilution flow or mixed flow is based on the fact that the filtered, clean air is introduced to the clean room in a turbulent manner (swirled) and this results in constant dilution of the particle concentration.

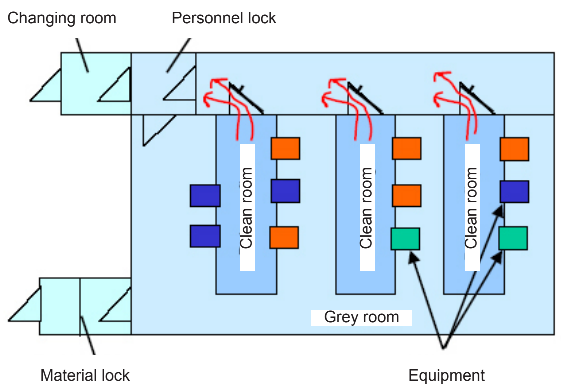


- The diluted air is extracted via a holed floor
- Turbulent flow results in a higher retention period of the particle contaminated air
- Thus the cleanliness class that is achieved is worse in comparison to laminar flow
- However, turbulent mixed flow is cheaper than laminar flow

2.3 Basic setup of a clean room

Positive pressure of approx. 30 Pa in the clean room prevents particles from penetrating the room. People and materials enter through separate air locks. This is necessary because otherwise the personnel could bring unnecessary pollutants into the clean room, or pollutants can be "blown" into the room by opening the doors.

In addition, for safety reasons, it must be possible to look into the room from at least two or preferably three sides.



The following information must be defined when planning a clean room:

- Clean room class
- Dimensions of the clean room
- Number of people permanently working in the clean room area
- Access possibilities
- Lighting

This information comes mostly from the user and is specified by the planner.

The clean room class determines the required ceiling filter area, for example, for Clean Room 7 in accordance with DIN ISO 14644-1 an area of 10 - 20 % and an air change rate of 133.

The supply air and exhaust air volume flows are calculated based on the room volume, the number of people and the air change rate.

2.3.1 Calculating the volume flow

In order to calculate the volume flow required for a Class 7 clean room in accordance with DIN ISO 14644, the following assumptions are made:

Assumptions:
Room surface area: 60 m²
Room volume: 210 m³

In accordance with the standard, the following requirements result:

Ceiling filter area: 10…20%
Number of air changes: 133/h

According to the calculation formula:

Volume flow = room volume x number of air changes

this results in

210 m³ x 133/h = 27,930 m³/h

This means that a clean room with a surface area of 60 m² and a height of 3.50 m requires for Clean Room Class 7 in accordance with DIN ISO 14644 a volume flow of 27,930 m³/h. Due to the required positive pressure of 30 Pa when the room leakage area is known, the difference volume flow (see Diagram 7.1 in section 6) and the required room exhaust air volume flow result.

It is already apparent that it is difficult to stably regulate a stable room pressure of 30 Pa with such high volume flows.

3.1 Clean room classes

The clean room classes A (high risk) to D are valid for the production of sterile pharmaceutical products in clean rooms.

There are special requirements for the manufacture of sterile products, in order to keep the risk of contamination with microorganisms, particles and pyrogens to a minimum. A lot depends on the ability, training and behaviour of the personnel involved. Quality assurance is of particular importance here and production must take place in accordance with carefully specified and validated methods and procedures. Sterility or other quality aspects must not be limited to the last manufacturing step or checking of the end product.

- **Class A (high risk)**
  The local zone for work processes with a high risk, such as the filling area, plugged containers, open phials and bottles, manufacture of aseptic compounds. Such conditions are usually guaranteed by a laminar air flow system. Laminar air flow systems should ensure an even flow velocity of 0.36-0.54 m/s (recommended value) in the workplace. Maintenance of the laminarity should be substantiated and validated. Directional air flow and lower speeds can be used in closed isolators and glove boxes.

- **Class B**
  For asceptic preparation and filling; this is the background environment for a class A zone.

- **Classes C and D**
  Clean areas for the less critical steps in the production of sterile products.

3.2 Classification of safety laboratories in accordance with GenTSV

The GenTSV (Genetic Engineering Safety Regulations) applies to genetic engineering plants, i.e. for facilities in which genetic engineering work is done in a closed system. Physical barriers are employed to limit contact between the organisms used and people and the environment. Safe genetic engineering work in laboratories is ensured by suitable biological, technical and organisational safety measures. For this purpose, constructional and technical prerequisites for laboratories with the safety levels S1 to S4 (high risk) are prescribed. Particular emphasis is placed on the safe maintenance of pressure levels over several zones.

- **S1 laboratory**
  In a genetic engineering laboratory with safety level 1, work is done which, according to the latest scientific findings, presents no risk for human health or the environment.

- **S2 laboratory**
  In a laboratory with safety level 2, genetic engineering work is done which, according to the latest scientific findings, presents only a low risk for human health or the environment.

- **S3 laboratory**
  In a laboratory with safety level 3, a moderate risk for human health or the environment is assumed. Safety level 3, that is, an S3 laboratory, is one in which, for example, work is done with pathogenic germs that are assumed to present only a moderate risk of infection.

- **S4 laboratory (high risk)**
  In S4 laboratories genetic engineering work is done which, according to the latest scientific findings, presents a high risk or a well-founded suspicion of such a risk for human health or the environment. In the area of a genetic engineering laboratory with safety level S4, one can expect to find pathogenic germs (e.g. the ebola virus) which present a high risk of infection.

4.1 SCHNEIDER room pressure and volume flow controllers

SCHNEIDER offers complete system solutions for the control of volume flow and room pressure in laboratory and clean room applications. The advantage for the user is that the entire system functions safely, flexibly and robustly without compatibility problems. Due to the stringent requirements with regard to room air tightness, systems with room pressure and volume flow controllers should be used both for supply air and exhaust air. This makes safe maintenance of pressure levels over several zones possible.

The following LabSystem products are used for room pressure and volume flow control:

- **Room pressure controller** — **CRP**
- **Volume flow prioritised room pressure controller** — **VCP**
- **Room pressure monitor** — **PM100**
- **Variable volume flow controller** — **VAV**

5.1 CRP room pressure controller

Room pressure controllers are used to maintain constant pressure, i.e. a defined room positive pressure or negative pressure is automatically regulated via a shutoff damper with an actuator. Depending on the area of application, the infiltration or leakage of contaminated or impure air with excess levels of dust is thus avoided. Laboratories are therefore by default kept in a state of negative pressure and clean rooms in a state of positive pressure.
This is achieved by means of a microprocessor controlled, rapid control system for constant pressure control of rooms. A high-speed control algorithm compares the constant setpoint value with the room pressure measured by the static differential pressure sensor and regulates the pressure quickly, precisely and stably. The constant negative pressure is freely programmable and is saved mains voltage failure-safe in the EEPROM. The control curve is automatically calculated in relation to the setpoint.

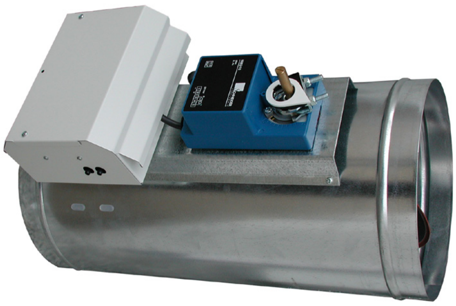


Figure 7.1 Room pressure controller with damper made of sheet steel

5.1.1 Control speed of the CRP controller

During the entire planning of the system, the focus is on the protection of the personnel and the environment. Room pressure changes must be recognised quickly and regulated with the required supply or exhaust air; this is why SCHNEIDER consistently relies on high control speeds. The control time is < 3 sec. motor running time for an angle of 90° and is freely programmable from 3 s to 24 s (running time delay). Thus the stringent requirements of the user and the legal regulations can be fulfilled.

The CRP room pressure controller automatically recognises when doors and windows are opened and automatically delays regulation of the required room pressure by a programmable time period (0...240 s). If, for example, the door is shut within this time, regulation takes place again only after the door has been shut. This novel control concept devised by SCHNEIDER reduces unnecessary control cycles and thus significantly increases durability and operating safety. Door contacts are not necessary for slow control times.

5.1.2 Control accuracy of the CRP controller

The control accuracy of a room pressure controller depends largely on the measuring range and the measuring accuracy of the static differential pressure sensor, as well as the positioning resolution of the servo motor.

In order to achieve a positioning resolution of < 0.5 °, SCHNEIDER consistently relies on direct actuation of the servo motor (Fast-Direct-Drive) by the control electronics. This achieves not only a good positioning resolution but also rapid and stable control behaviour.

The Fast-Direct-Drive actuation has considerable advantages over analogue motor actuation (0...10V DC), because the internal control electronics of the analogue (continuously) controlled servo motor have a hysteresis which can lead to control fluctuations if the volume flow or pressure differences that are to be regulated are small.

A feedback potentiometer integrated in the servo motor (Fast-Direct-Drive) reports the actual value of the current damper position to the control electronics and a special control algorithm quickly and directly "starts up" the required room pressure maintenance without overshoot.

When the servo motor is activated, a damper control concurrently checks whether the damper position is actually changed (damper control). This control concept with integrated servo motor monitoring functionality exceeds the stringent safety criteria for room pressure controllers.

The positioning accuracy of a constantly actuated servo motor (0...10V DC) is approx. ± 1.0°, which represents a considerable deterioration of the positioning resolution in comparison with the SCHNEIDER Fast-Direct-Drive servo motor (positioning accuracy < 0.5°), ie. with a constantly actuated servo motor the control accuracy is lower and the tendency towards oscillation is greater.

5.2 Room pressure control with CRP

5.2.1 Room plan 1

Room plan 1 displayed in Figure 7.2 shows an application with constant volume flow controllers (CAV) for the exhaust air of the various rooms.

The CRP room pressure controllers automatically regulate the programmable positive room pressure (+) for each room. The programmed values and the reference measurements of the differential pressure transmitter are shown in Table 7.3.

The air lock CRP measures and controls the differential pressure between the corridor (-) and the air lock (+), while the room 1 CRP measures and controls the differential pressure between the air lock and room 1. The positive pressure of room 1 therefore follows the positive pressure of the air lock with a differential pressure of +10 pa. The room 2 CRP now relates to the corridor again and maintains a constant positive pressure of +30 Pa.

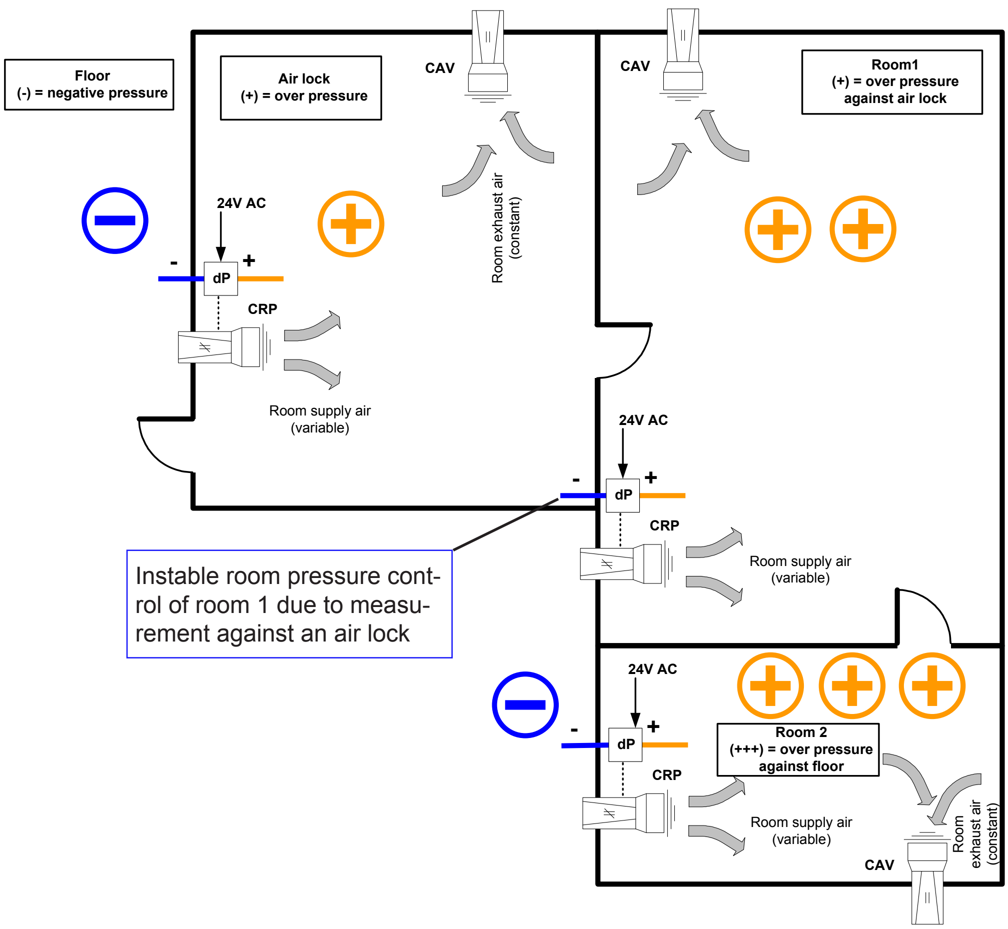
This model cannot be recommended, as room pressure maintenance is very unstable because increased oscillation occurs when rooms are measured in relation to one another (e.g. room 1 against the air lock). Room pressure changes, e.g. in the air lock, have an effect on room 1.

Room	Reference measurement against	Programmable value [Pascal]	Differential pressure against corridor (atmosphere) [Pascal]
Air lock	Corridor	+10	+10
Room 1	Air lock	+10	+20
Room 2	Corridor	+30	+30

Table 7.3: Sample values and reference measurements room plan 1

Depending on the application, any type of reference point measurement and CRP configurations (room supply air or room exhaust air) are possible, whereby control stability (low oscillation tendency) should, however, be taken into account.

Figure 7.2: Room plan 1 room pressure control



5.2.2 Room plan 2

Room plan 2 displayed in Figure 7.3 shows an application with constant volume flow controllers (CAV) for the exhaust air of the various rooms.

The CRP room pressure controllers automatically regulate the programmed positive room pressure (+) for each room. The programmed values and the reference measurements of the differential pressure transmitter are shown in Table 7.4.

All CRP room pressure controllers are summarised on the (-) = negative pressure side and measured against a common reference point. This preferred measuring method ensures the best stability, provided that the reference room or the reference point fulfils the following conditions:

- Pressure stable, non-ventilated room without volume flow or pressure control, without wind load and without connections (e.g. conduits, electrical pipelines, etc.) to ventilated rooms.
- For reference points against the outside atmosphere, the atmosphere must be free of dynamic wind pressure and sufficiently attenuated via a pneumatic RC element.

This model is preferable to room plan 1 due to the previously mentioned control stability.

Room	Reference measurement against a common reference	Programmable value [Pascal]	Differential pressure against corridor (atmosphere) [Pascal]
Air lock	Yes	+10	+10
Room 1	Yes	+20	+20
Room 2	Yes	+30	+30

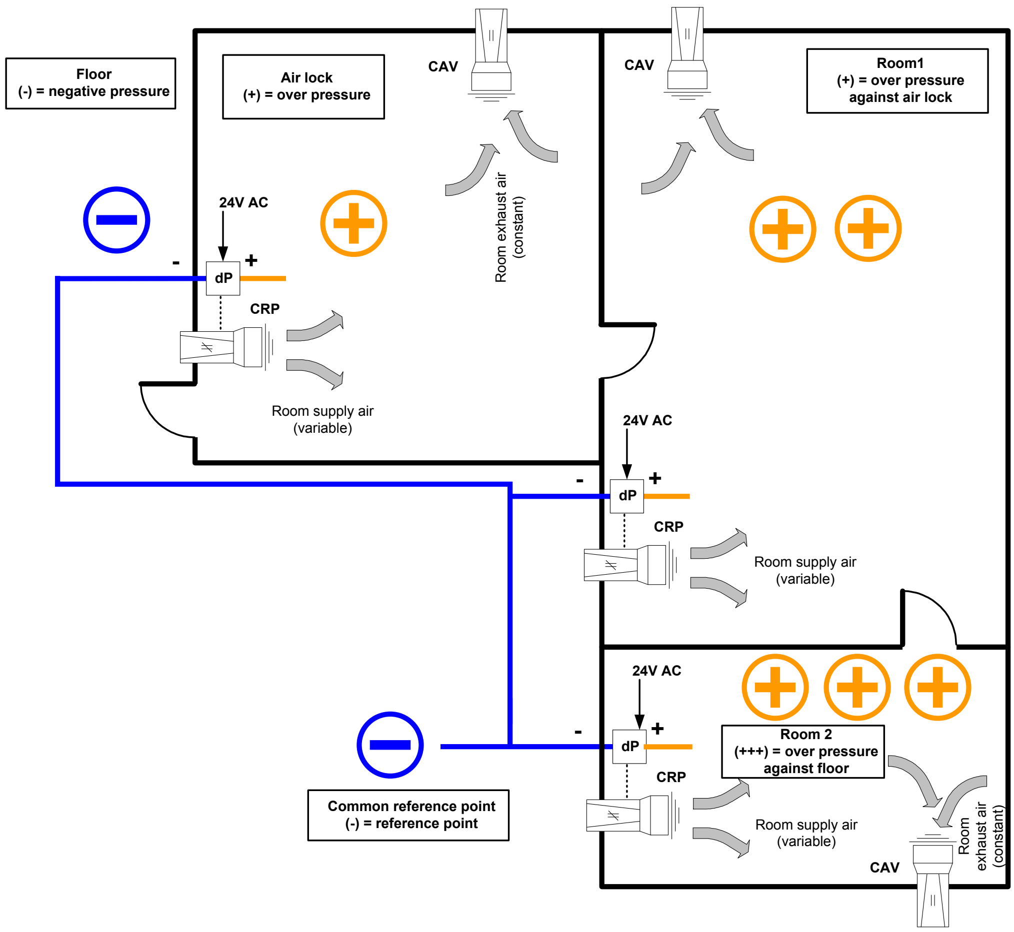
Table 7.4: Sample values and reference measurements room plan 2

In both room plans the constant volume flow controllers (CAV) can be replaced by volume flow controllers if variable room air change rates are required. Thus, for example, in rooms in which animals are kept, 12 to 30 room air change rates are required, depending on how the room is used.

The room air change rate is defined, for example, via the BMS (analogue or via the field bus) and the room supply air automatically follows in order to guarantee the required room pressure maintenance. Switchable room pressure maintenance (e.g. from 10 Pa to 25 Pa) is also possible.

In this area of application SCHNEIDER has comprehensive know how and first class references.

Figure 7.3: Room plan 2 room pressure control



6.1 Control of airtight rooms

Airtight rooms (clean rooms) and safety laboratories are subject to specific requirements with regard to control technology, depending on their safety class and thus the air tightness of the room. These include:

- Rapid room pressure maintenance in the case of disturbance variables, e.g. duct pressure fluctuations or the opening and closing of doors.
- Stable room pressure maintenance without overshoot or undershoot.
- Servo motor with the least possible hysteresis or preferably without hysteresis and high level of positioning accuracy (SCHNEIDER Fast-Direct-Drive).
- Precise and accurate room pressure control.
- Selection of a suitable reference room or reference point (as described in 5.2.2).
- Short room pressure measurement lines so that the control time of the controller is not reduced by unwanted RC elements
- Room pressure maintenance in airtight rooms must be done with a room pressure controller.
- Volume flow controllers (in the case of positive room pressure supply air volume flow > exhaust air volume flow is valid) are not suitable.

6.2 Room pressure ratios in a volume flow controlled airtight room

Room pressure maintenance of an airtight room (without leakages) by means of volume flow controllers results in serious problems, because the required control accuracy cannot be achieved.

The following calculation example shows the relationship between volume flow control and pressure increase in an airtight room.

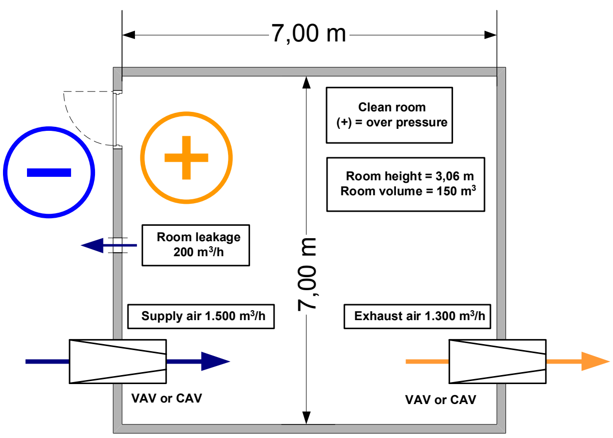


Figure 7.4: Room pressure control with volume flow controllers

6.2.1 Calculation of the differential pressure Δp

Using the Bernouilli formula the differential pressure in relation to the surroundings is calculated:

Bernoulli formula:

$$\Delta p = \frac{\rho}{2} \cdot \left(\frac{\dot{V}_{DIFFERENCE}}{A \cdot \mu \cdot 3600} \right)^2$$

Δp	= Differential pressure	[Pa]
ρ	= relative density	[kg/m³]
$\dot{V}_{DIFFERENCE}$	= Volume flow difference Supply air - exhaust air	[m³/h]
A	= Room leakage area	[m²]
μ	= Discharge coefficient = 0.72 (sharp-edged opening)	

The formula very clearly shows the influence of the volume flow difference and the room leakage on the pressure drop Δp. The pressure drop via the room leakage behaves quadratically to the volume flow difference (supply air - exhaust air). The more imprecisely the volume flow difference is regulated, or the smaller the room leakage is, the greater is the pressure drop and this may very quickly take on dramatic values (for a room leakage → 0, $\Delta p \rightarrow \infty$ ensues).

With a very small room leakage (room leakage of a perfectly airtight room = 0 m²), very high pressure values result, which at a maximum can reach the duct pressure values (e.g. 400 Pa), since a perfectly airtight room must be regarded as a duct.

A pressure difference of 400 Pa corresponds to a force of 40 kg/m²

This means that with a pressure difference of 400 Pa, for example, a force of approx. 80 kg may operate on a door, i.e. it can no longer be opened or no longer remains in its mounting frame (depending on whether it is a question of positive or negative pressure).

6.2.2 Influence of the control tolerance of a volume flow controller

The control variance (accuracy) of a volume flow controller is typically ± 5 %. With over-dimensioned volume flow controllers and/or an unfavourable fitting location (unfavourable or too short an inlet route of the measuring system), the control variance may take on even higher values. We will now calculate the relationship between control tolerance, room leakage area and the room pressure.

6.2.3 Sample calculation with a room leakage of 0.001 m² (10 cm²) with equal supply air and exhaust air volume flow

The area of 10 cm² corresponds to a square room leakage with a side length of 3.16 x 3.16 cm or a rectangular room leakage of 1 mm x 1 m, which corresponds to a door opening of approx. 1mm.

Given:

Room volume:	150 m³
Duct pressure supply air/exhaust air:	400 Pa
Room leakage area:	0.001 m² (10 cm²)
10 room air changes:	1500 m³/h
Volume flow supply air:	1500 m³/h
Volume flow exhaust air:	1500 m³/h
Control tolerance of one controller:	± 5 %
Control tolerance of both controllers:	< ± 7.5 %

Calculation of the maximum error (volume flow difference):

$$1500 \bullet \frac{7.5}{100} = \pm 112.5 \text{ m}^3/\text{h}$$

According to the Bernouilli formula there is a theoretical pressure difference (room to surroundings) of:

$$\Delta p = \frac{1.2}{2} \bullet \left(\frac{112.5}{0.001 \bullet 0.72 \bullet 3600}\right)^2 = 1{,}130.28 \text{ Pa}$$

Since the calculated pressure difference (1,130.28 Pa) cannot exceed the actual duct pressure, a maximum value of 400 Pa should be applied.

This example shows very clearly that pressure control with volume flow controllers and the given control tolerances (± 5 %) as well as the given room leakage area (10 cm²) is not possible.

6.2.4 Sample calculation with a room leakage of 0.01 m² (100 cm²) with equal supply air and exhaust air volume flow

If the room leakage area is increased tenfold to 100 cm², this corresponds to a square room leakage with a side length of 10 x 10 cm or a rectangular room leakage of 1 cm x 1 m, which corresponds to a door opening of approx. 1 cm.

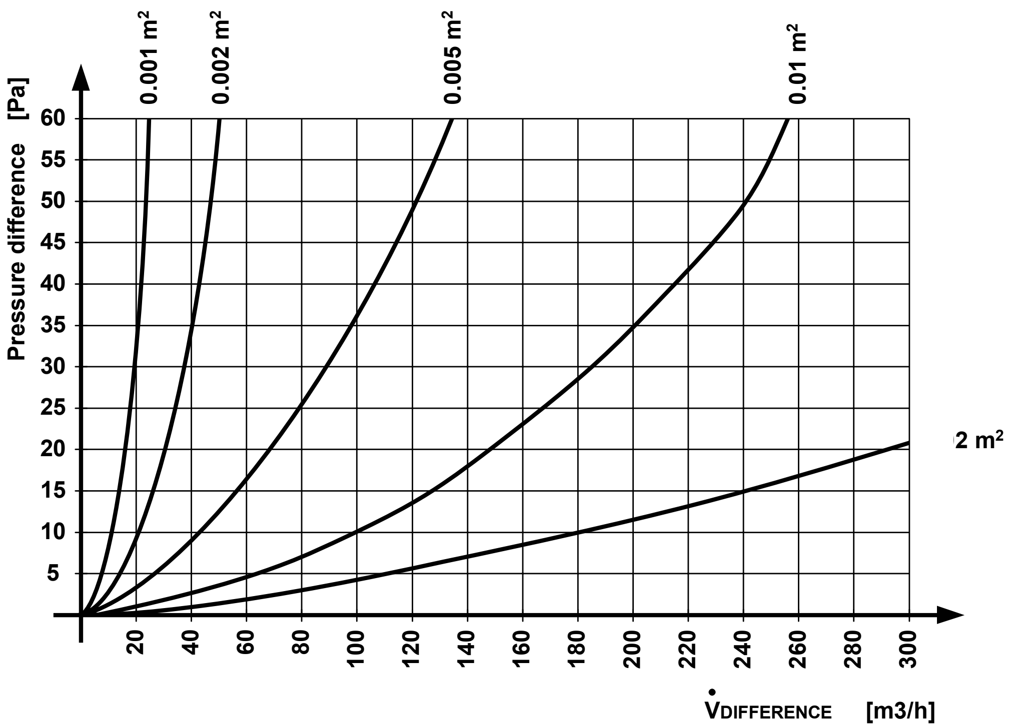
According to the Bernouilli formula, with the values given in section 6.2.3, the following pressure difference results:

$$\Delta p = \frac{1.2}{2} \bullet \left(\frac{112.5}{0.01 \bullet 0.72 \bullet 3600}\right)^2 = 11.30 \text{ Pa}$$

The calculated pressure difference of ± 11.3 Pa means that simply because of the error tolerance of the volume flow controller, the room pressure cannot be reliably maintained e.g. at 10 Pa.

Diagram 7.1 is a graphic representation of the Bernoulli formula and describes the room pressure = f (volume flow). Here you can easily recognise the relationship between the pressure difference (room to surroundings), the volume flow difference (supply air - exhaust air) and the room leakage area.

Diagram 7.1: Room pressure = f(volume flow)



6.2.5 Calculation example for a defined positive room pressure of 10 Pa with a room leakage of 0.01 m² (100 cm²)

If a room pressure of 10 Pa should not be underrun, with the given room leakage area of 100 cm² shown in diagram 7.1, the following volume flow difference results:

Supply air - exhaust air = 107 m³/h

Taking into account the maximum control tolerance of ± 112.5 m³/h, for the supply air volume flow controller the following value must be regulated:

$$\dot{V}_{SUPPLYAIR} = 1500 + 107 + 112.5 = 1719.5 \text{ m}^3/\text{h}$$

Given:

Room volume:	150 m³
Duct pressure supply air/exhaust air:	400 Pa
Room leakage area:	0.01 m² (100 cm²)
10 room air changes:	1500 m³/h
Volume flow supply air:	1719.5 m³/h
Volume flow exhaust air:	1500 m³/h
Control tolerance of one controller:	± 5 %
Control tolerance of both controllers:	< ± 7.5 %

Taking into account the maximum error, the following values can be set:

	Volume flow supply air [m³/h]	Differential volume flow [m³/h]	Pressure difference [Pa]
V_{MIN}	1607	107	10
V_{MAX}	1832	332	98

This example shows very clearly that pressure control with volume flow controllers and the given control tolerances (± 5 %) as well as the given room leakage area (100 cm²) is not possible, because here the room pressure would be between 10 and 98 Pa, which would, of course, not be acceptable.

Only with a room leakage area of 0.1 m² (1000 cm²), which corresponds to a square room leakage area with a side length of 31.6 x 31.6 cm or a rectangular room leakage of 10 cm x 1 m, with a volume flow difference of 332 m³/h for the given values does a pressure difference of approx. 1 Pa arise, which can be disregarded.

6.2.6 Conclusion room pressure control with volume flow controllers

Room pressure control with volume flow controllers is only possible with a sufficiently large room leakage area in relation to a small volume flow difference.

For 20 or 30 room air changes the problem of maintaining the room pressure becomes even more serious.

With a small room leakage area, constant regulation of the the room pressure with a room pressure controller is essential.

Here SCHNEIDER offers the products CRP (constant room pressure controller) for simple room pressure maintenance applications and the patented VCP volume flow prioritised room pressure controller for sophisticated applications in airtight rooms with very small room leakage areas.

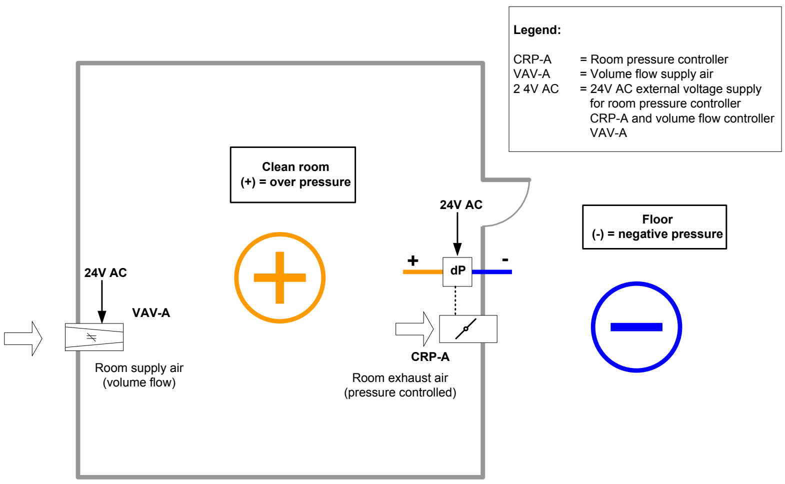
6.3 Room pressure control of an airtight room

Room pressure control in simple room pressure maintenance applications is done with the CRP (constant room pressure controller). However, the limits here are easily reached if airtight rooms with small room leakage areas must be regulated.

Decisive factors for control accuracy are the required volume flow (room air change rate), correct dimensioning and the control accuracy of the room pressure controller as well as the positioning accuracy of the damper motor.

In this example, the supply air volume flow, i.e. the room air change rate, is regulated via the volume flow controller (e.g. 20 room air changes). For this observation, the already know room data are valid. The CRP room pressure controller follows the supply air and should regulate a constant room pressure of 10 Pa.

Figure 7.5: Room pressure control with room pressure controllers



6.3.1 Influence of the control tolerance of a room pressure controller

The control variance (accuracy) of a room pressure controller is largely dependent on the positioning accuracy of the damper motor (resolution) and the volume flow that is to be regulated.

The resolution of an electric damper motor is typically ± 1 °. This control variance can have even higher values in the case of inaccurate differential pressure transmitters or unfavourable reference point measurements. We will now calculate the relationship between control tolerance, room leakage area and the room pressure.

6.3.2 Sample calculation with a room leakage of 0.001 m² (10 cm²) with constant supply air volume flow and a room pressure controller

The area of 10 cm² corresponds to a square room leakage with a side length of 3.16 x 3.16 cm or a rectangular room leakage of 1 mm x 1 m, which corresponds to a door opening of approx. 1mm.

Given:

Room volume:	150 m³
Duct pressure supply air/exhaust air:	400 Pa
Room leakage area:	0.001 m² (10 cm²)
20 room air changes:	3000 m³/h
Volume flow supply air:	3000 m³/h
Positive room pressure:	10 Pa
Volume flow exhaust air:	3000 m³/h - x
Control tolerance of the room pressure controller:	± 1 °

Calculation of the maximum error:

$$\frac{3000}{90°/1°} = \pm 33.3\ m^3/h$$

For reasons of simplification, a linear error of 90 steps each with 1° is assumed. Closer observation requires that the sinus for the individual damper position is included as well.

According to the Bernouilli formula there is a theoretical pressure difference of:

$$\Delta p = \frac{1.2}{2} \bullet \left(\frac{33.3}{0.001 \bullet 0.72 \bullet 3600} \right)^2 = 99\ Pa$$

The calculated pressure difference (± 99 Pa) shows the maximum possible error and at the same time illustrates quite clearly that pressure control with the room pressure controller and the given control tolerances (± 1 °) as well as the given room leakage area (10 cm²) at a rate of 20 room air changes is not possible.

6.3.3 Sample calculation with a room leakage of 0.01 m² (100 cm²) with constant supply air volume flow and a room pressure controller

If the room leakage area is increased tenfold to 100 cm², this corresponds to a square room leakage with a side length of 10 x 10 cm or a rectangular room leakage of 1 cm x 1 m, which corresponds to a door opening of approx. 1 cm.

According to the Bernouilli formula, with the values given in section 6.3.2, the following pressure difference results:

$$\Delta p = \frac{1.2}{2} \bullet \left(\frac{33.3}{0.01 \bullet 0.72 \bullet 3600} \right)^2 = 0.99\ Pa$$

The calculated pressure difference of ± 0.99 Pa means that room pressure control with an error tolerance of ± 0.99 Pa is possible for the given room leakage area. If the room leakage area is reduced, e.g. to 50 cm², an error tolerance of ± 4 Pa can be expected and thus is no longer suitable for regulating a room pressure of 10 Pa with sufficient accuracy.

6.4 CRP room pressure controller with double control accuracy

Thanks to the unique direct actuation of the servo motor (Fast-Direct-Drive) by the control electronics, with the CRP room pressure controller SCHNEIDER achieves a positioning resolution of the servo motor of < 0.5 °. This achieves not only a good positioning resolution but also rapid, stable and hysteresis-free control behaviour.

The maximum error when using a CRP is calculated as follows:

$$\frac{3000}{90°/0.5°} = \pm 16.67\ m^3/h$$

With the CRP room pressure controller, the error tolerance is reduced from ± 4 Pa to ± 1 for the room leakage area that is reduced in 6.3.3 to 50 cm². Thus with the given conditions and using a SCHNEIDER CRP room pressure controller, the desired room pressure of 10 Pa is regulated with sufficient accuracy.

This calculation example shows very clearly that the positioning accuracy of the damper motor considerably influences the control accuracy and stability of the system.

6.5 Observation of the control speed of the CRP room pressure controller

For observation of the pressure increase over time in a fully airtight room, the already known assumptions are made.

Given:

Room volume:	150 m³
Duct pressure supply air:	400 Pa
Duct pressure exhaust air:	300 Pa
Room leakage area:	0 (completely airtight)
20 room air changes:	3000 m³/h
Volume flow supply air:	3000 m³/h
Control tolerance of the room pressure controller CRP:	± 0.5 °
Control variance CRP:	± 16.67 m³/h

The pressure increase = f(time) is calculated using the following formula:

$$p_{\text{PRESSURE INCREASE}} = \frac{p_{\text{ATMOSPHERE}}\ (V_{\text{ROOM}}+\dot{V})}{V_{\text{ROOM}}} - p_{\text{ATMOSPHERE}}$$

16.67 m³/h / 3600 = 0.0046 m³/s

$$p_{\text{PRESSURE INCREASE}} = \frac{101325\ \text{Pa} \cdot (150\ \text{m}^3 + 0.0046\ \text{m}^3/\text{s})}{150\ \text{m}^3} - 101325\ \text{Pa}$$

= 3.1 Pa/s
========

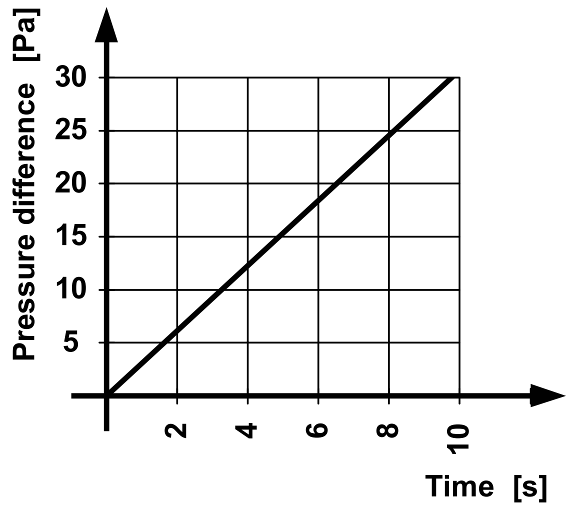
At a control variance of 16.67 m³/h there is a pressure increase of 3.1 Pa/s (see diagram Pressure increase = f (time), Diagram 7.2).

This quite clearly demonstrates the relationship between the control speed and the control accuracy. If the controller needs, for example, a control time of 10 s, the control variance is already 31 Pa, which of course would not be acceptable.

The SCHNEIDER CRP room pressure controller requires a control time of < 1 s to regulate the control variance. When planning room pressure control, it is essential to ensure that this value is not significantly exceeded.

With slow room pressure controllers, within 129 s the room pressure would reach the duct pressure of 400 Pa (400/3.1 = 129), which again illustrates the importance of a high-speed room pressure controller.

Diagram 7.2: Pressure increase = f (time)



6.6 Control of airtight rooms with the VCP volume flow prioritised room pressure controller

As already shown in the previous calculation example (see 6.3.2), even with the CRP room pressure controller, a very airtight room with a room leakage area of 0.001 m² (10 cm²) cannot be regulated with sufficient accuracy.

The maximum possible error here is ± 24.8 Pa for the given control tolerances (± 0.5 ° = ± 16.67 m³/h with a 20 room air changes of 3000 m³) and the given room leakage area (10 cm²).

For demanding applications such as this, SCHNEIDER provides the patented VCP volume flow prioritised room pressure controller.

The principle here is that control of the exhaust air volume flow takes place via an independent control circuit and room pressure control takes place via a second bypass control circuit. Both control circuits communicate with one another and depending on the required pressure and the volume flow are optimally linked to one another. Conflicting control behaviour, as is usual with separate, independent control circuits, is avoided. This novel concept very effectively prevents mutual oscillation and instable control behaviour.

6.6.1 Sample calculation with a room leakage of 0.001 m² (10 cm²) with constant supply air volume flow and VCP volume flow prioritised room pressure controller

For room pressure control of an airtight room, the already known assumptions apply:

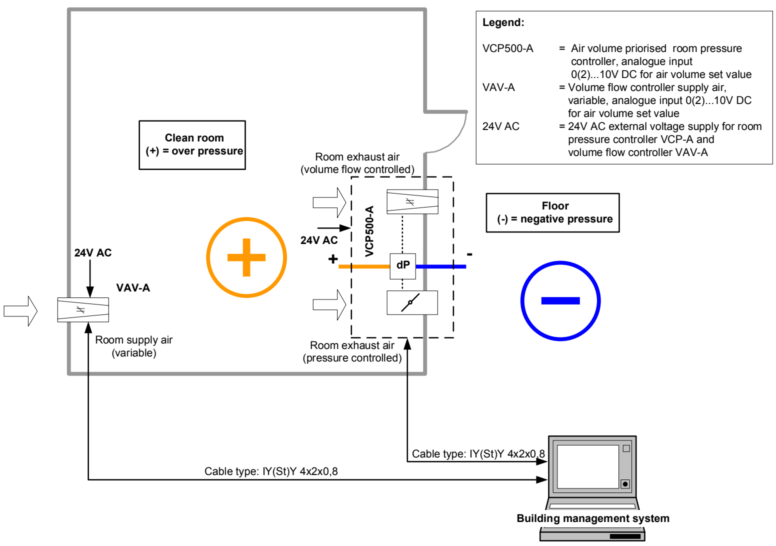


Figure 7.6: VCP volume flow prioritised room pressure controller

Given:

Room volume:	150 m³
Duct pressure supply air:	400 Pa
Duct pressure exhaust air:	300 Pa
Room leakage area:	0.001 m² (10 cm²)
20 room air changes:	3000 m³/h
Volume flow supply air:	3000 m³/h
Volume flow exhaust air:	3000 m³/h
Control tolerance of one volume flow controller:	± 4 %
Control tolerance of both volume flow controllers:	< ± 6 %
Positive room pressure:	10 Pa
Volume flow exhaust air:	3000 m³/h - x
Control tolerance of the VCP room pressure controller (bypass):	± 0.5 °
Control variance VCP (bypass):	± 1 m³/h

Calculation of the maximum error:

The control variance of the supply air volume flow controller and the exhaust air volume flow controller of the VCP (1st control circuit) together amounts to ± 5 % or ± 150 m³/h. This means that the room pressure control circuit of the VCP (2nd control circuit) must regulate max. 150 m³ in order to to regulate the room pressure of 10 Pa.

$$\frac{180}{90^{\circ}/0.5^{\circ}} = \pm 1 \text{ m}^3/\text{h}$$

According to the Bernouilli formula there is now a theoretical pressure difference of:

$$\Delta p = \frac{1.2}{2} \bullet \left(\frac{1}{0.001 \bullet 0.72 \bullet 3600}\right)^2 = 0.09 \text{ Pa}$$

The control variance of 0.09 Pa is marginal and means that at a volume flow of 3000 m³/h and a room leakage area of 10 cm² the room pressure controller has an error tolerance of only ± 0.09 Pa. This is an excellent value and with an electronic controller is currently only possible with the VCP.

7.1 VCP volume flow prioritised room pressure controller

The bypass control type VCP for airtight laboratories and clean rooms is a rapid control system for prioritised control of room supply air and room exhaust air volume flows with an internal second control circuit for constant pressure control. This volume flow prioritised control system, which is microprocessor controlled and available as a round model, ensures steady room pressure in laboratories (S1-S3), clean rooms (classes A-D), animal pens and air locks.

A high-speed control algorithm compares the setpoint with the actual value measured by a differential pressure transmitter and regulates the volume flow quickly, precisely and steadily, independent of pressure fluctuations in the duct system.

At the same time, a second internal control circuit ensures that the predefined room pressure is regulated via another damper with an actuator which is positioned in the bypass. The volume flow is shifted within programmable limits (V_{MIN} and V_{MAX}) until the desired room pressure can be regulated. The external room pressure transmitter continuously measures the room pressure and provides the controller with the analogue signal. The programmed constant negative or positive room pressure is thus maintained. The control curve is automatically calculated in relation to the external setpoint (0)2…10 V DC. Malfunctions (e.g. setpoint volume flow is not reached) are recognised and signalled by the malfunction notification relay.

All programmed values are saved mains voltage failure-safe in the EEPROM.

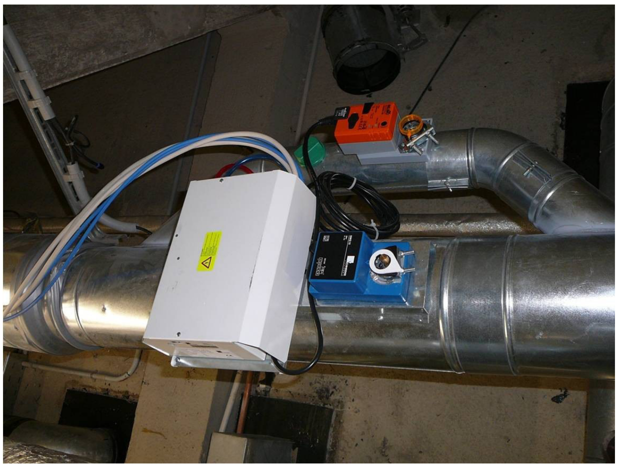


Figure 7.7: VCP volume prioritised room pressure controller with sheet steel dampers

Both 3 point drives without hysteresis are fast running actuators with direct drive mode and integrated recording of the delay angle of the damper position and require only 3 seconds for a rotation angle of 90 °. Rapid, stable control is supported by the use of only one controller for two control circuits that are optimally operated together and direct actuation of both servo motors.

The low-maintenance dampers that are used close airtight in accordance with DIN 1946 T4 and EN 1751 T2 and are equipped with non-ageing, silicon-free rubber seals.

Optionally the VCP volume flow prioritised controller can be connected via a field bus module in order to enable direct access by the building services management. BACnet, LON or Modbus field buses can be retrofitted.

7.1.1 Control speed of the VCP controller

During the entire planning of the system, the focus is on the protection of the personnel and the environment. Room pressure changes must be recognised quickly and regulated with the required supply or exhaust air; this is why SCHNEIDER consistently relies on high control speeds. The control time is < 3 sec. motor running time for an angle of 90° and is freely programmable from 3 s to 24 s (running time delay). Thus the stringent requirements of the user and the legal regulations can be fulfilled.

The VCP volume flow prioritised room pressure controller automatically recognises when doors and windows are opened and automatically delays regulation of the required room pressure by a programmable time period (0...240 s). If, for example, the door is shut within this time, regulation takes place again only after the door has been shut. This novel control concept devised by SCHNEIDER reduces unnecessary regulation cycles and thus significantly increases durability and operating safety. Door contacts are not necessary for slow control times.

7.1.2 Control accuracy of the VCP controller

The control accuracy of a room pressure controller depends largely on the measuring range and the measuring accuracy of the static differential pressure sensor, as well as the positioning resolution of the servo motor.

In order to achieve a positioning resolution of < 0.5 °, SCHNEIDER consistently relies on direct actuation of the servo motor (Fast-Direct-Drive) by the control electronics. This achieves not only a good positioning resolution but also rapid and stable control behaviour.

The control accuracy is described in detail in sections 6.1 to 6.6.1 of this chapter and can be referred to there.

7.1.3 Room plan VCP

The VCP room plan displayed in Figure 7.8 shows an application with variable volume flow controllers (VAV) for the supply air of the various rooms.

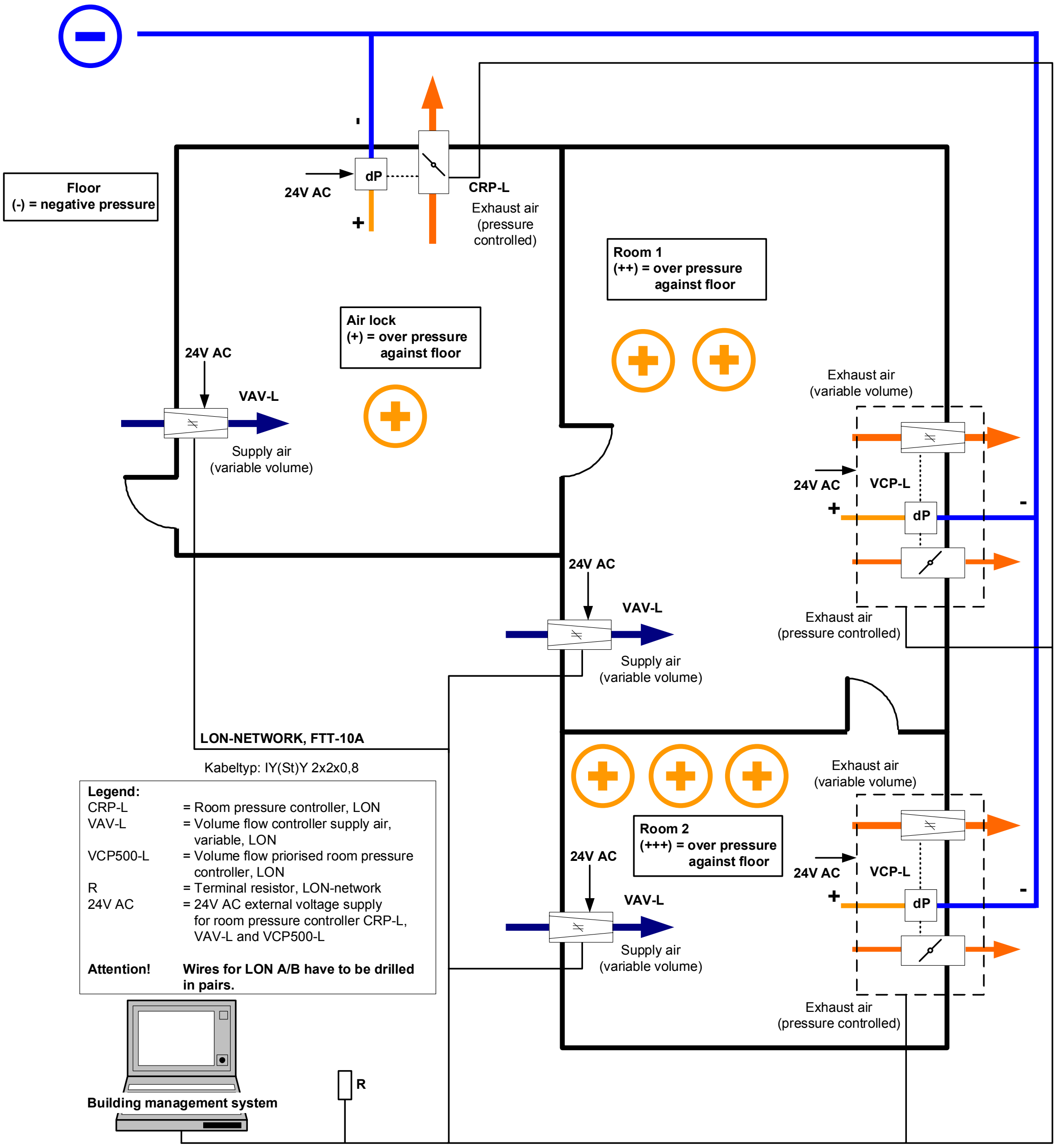
The CRP-L room pressure controller automatically regulates the programmed positive room pressure (+) for the non-critical room (air lock). However, the CRP should only be used when a correspondingly large room leakage area is available.

The VCP volume prioritised room pressure controller is used in rooms 1 and 2, because these have only a very small room leakage area (e.g. room leakage area 0.001 m ²) and a high rate of air exchange is required. The programmed values and the reference measurements of the differential pressure transmitter are shown in Table 7.5.

All CRP room pressure controllers and the VCP room pressure controllers are summarised on the negative pressure side (-) and measure against a common reference point, which must fulfil the conditions described in section 5.2.2 in order to ensure stable control.

In order to achieve variable room air change rates, completely variable volume flow controllers are used for this room plan. Thus, for example, for rooms in which animals are kept, 12 to 30 room air change rates are required, depending on how the room is used.

Figure 7.8: Room plan VCP room pressure control



In this plan, the usage-dependent volume flows (room air changes) and room pressure maintenance are predefined by the BMS via the LON network and the pressure controlled proportion of the room exhaust air is automatically regulated in order to maintain the required room pressure. Switchable room pressure maintenance (e.g. from 10 Pa to 25 Pa) is also possible.

Thanks to the control strategy of two control circuits that communicate with one another, SCHNEIDER's patented VCP volume flow prioritised room pressure controller can precisely and stably regulate the room pressure even at high air change rates and a very small room leakage area.

Both control circuits (volume flow and room pressure) are actuated by a common microprocessor in multitasking mode. They are calibrated with one another and automatically find the optimal control and operating area. Since both control circuits communicate with one another, conflicting control behaviour, as is usual with two separate, independent control circuits, is avoided. This novel concept very effectively prevents mutual oscillation and instable control behaviour.

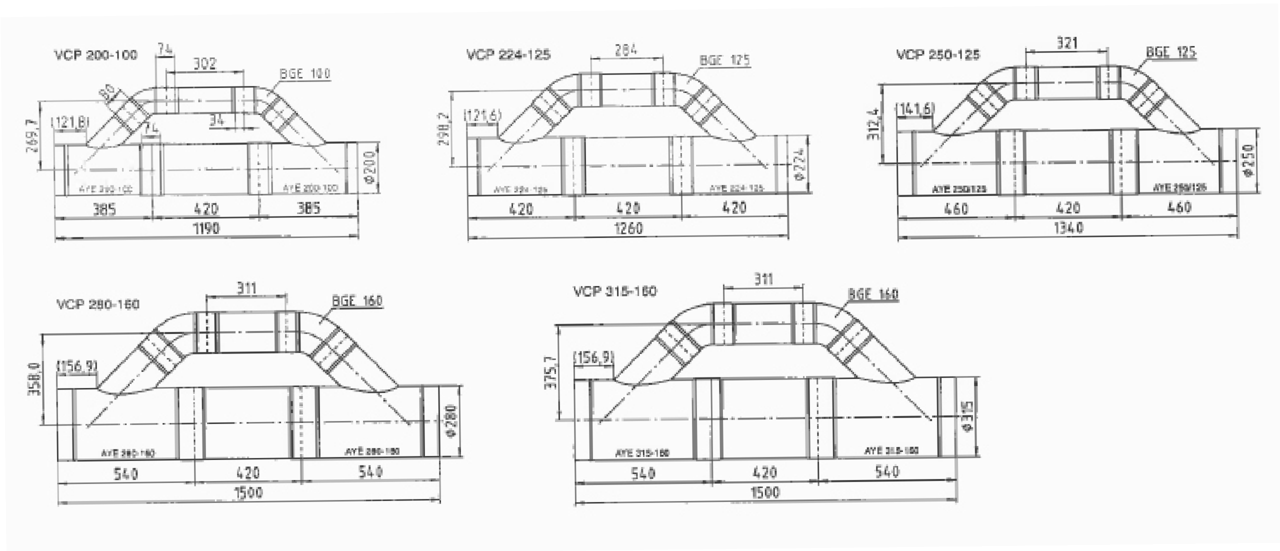
In this area of application SCHNEIDER has comprehensive know how and first class references.

Table 7.5: Sample values and reference measurements VCP room plan

Room	Reference measurement against a common reference	Programmed value [Pascal]	Differential pressure against corridor (atmosphere) [Pascal]
Air lock	Yes	+10	+10
Room 1	Yes	+20	+20
Room 2	Yes	+30	+30

Figure 7.9 shows various diameters of the VCP volume flow prioritised room pressure controller with mechanical dimensions. The volume flow controller (first control circuit) is on the main pipe and the room pressure controller (second control circuit) is on the bypass controller.

Figure 7.9: Mechanical dimensions of the VCP volume flow prioritised room pressure controller



8.1 PM100 room pressure monitor

For use as a room pressure monitor for rooms in which constant room pressure must be maintained. Clean rooms or laboratories must be maintained in a state of constant positive or negative pressure relative to neighbouring rooms (e.g. corridor). Depending on the area of application, the infiltration or leakage of contaminated or impure air with excess levels of dust is thus avoided.

PM100 is suitable for monitoring the required negative or positive room pressure and signals when the setpoint that is to be monitored is exceeded or underrun. The specification of setpoints is done via the digital inputs, by programming via the service module SVM100 or optionally via the field bus.

The following configurations are available:

- Differential pressure measurement with status display (red/green) and alarm acknowledgement as well as two potential-free contacts for threshold monitoring (optional)
- Differential pressure measurement with status display (red/green) and alarm acknowledgement as well as two potential-free contacts for threshold monitoring (optional)

In addition to the digital display, an external display can be connected as a secondary display.

PM100-L-1-W-2

DIS220

Figure 7.10: PM100 room pressure monitor with a secondary display (subsidiary display for a second room)

A high-speed control algorithm compares the setpoint value with the room pressure measured by the static differential pressure sensor and signals an alarm when the pressure is exceeded or underrun.

The setpoints that are to be monitored are freely programmable and are saved mains voltage failure-safe in the EEPROM.

This novel monitoring concept devised by SCHNEIDER reduces false alarms caused by external influences (doors, windows, etc.) and thus significantly increases operating safety.

The SCHNEIDER PM100 room pressure monitor can be used for redundant monitoring of an existing room pressure controller (e.g. the SCHNEIDER CRP/VCP room pressure controller). During threshold monitoring, the potential-free contacts signal the upper and lower thresholds.

The PM room pressure controller can be connected to the building services management (BSM) via the optional field bus interface, whereby all relevant data and information are available.

Alarm delay time

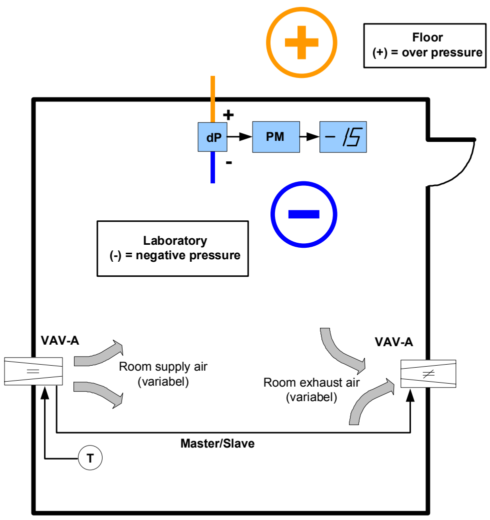
The alarm delay time is freely programmable from 0...240 s. The alarm status must be active for at least this pre-set time period in order for the alarm to be activated. This delay reduces false alarms, e.g. when the duct system is unstable.

Door contact recognition for the PM room pressure monitor, CRP room pressure controller and VCP volume flow prioritised room pressure controller

An additional internal delay period of 0...240 s is started when the differential pressure transmitter detects a sudden change in pressure (e.g. when a door or window is opened). Room pressure monitoring and control stops and is only started again after this delay period has elapsed.

This prevents false alarms or control caused by pressure changes when a room is entered. The time taken to open and close a door when a room is entered quickly is less than 10 s. This means that at a programmed PM/CRP/VCP delay time of e.g. 15 s, sudden changes in pressure are not controlled or an alarm is not signalled.

Figure 7.11: Room plan PM100 room pressure monitoring of a room regulated by a volume flow controller



9.1 VAV Volume flow controller

Microprocessor controlled, high-speed adaptive control system for variable control of room supply air and room exhaust air volume flows, particularly suitable for clean rooms and laboratories. A high-speed control algorithm compares the setpoint with the actual value measured by a differential pressure transmitter and regulates the flow quickly, precisely and steadily, independent of pressure fluctuations in the duct system. The minimum and maximum volume flow setpoint is freely programmable and is saved mains voltage failure-safe in the EEPROM.

Analogue or LON setpoint selection

The VAV variable volume flow controller is available in two versions, whereby the main difference is in the setpoint selection.

Table 7.6 shows the different product versions with the corresponding control mode.

Table 7.6:

	Product	
Control mode	**VAV-A**	**VAV-L**
Analogue 0(2)...10V	Yes	No
Digital (relay contact)	Yes	Yes
LON, FTT-10Ar	No	Yes

Operating modes and setpoint selection

The following control and operating modes are supported, depending on the model:

Table 7.7:

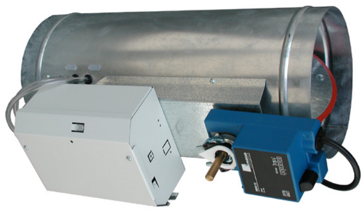
	Operating mode	
Control mode	**variable (VAV)**	**constant (CAV)**
Analogue 0(2)...10V	Yes	No
Digital (relay contact)	No	Yes (1-3 point)
LON, FT-X1 (FTT-10A)	Yes	Yes

All setpoints and actual values are available as analogue inputs or outputs 0(2)...10V DC (VAV-A model) or via the LON network (VAV-L model) as standard variables (SNVT). The LonMark specifications with the master list are complied with. The LON version VAV-L is described separately in the VAV-L technical documentation.

Models

The VAV-A and VAV-L volume flow controllers offered by SCHNEIDER are available as circular or rectangular models and are characterized by high-speed (control time ≤ 3 sec for a 90 ° angle) and stable control.

VAV-A-250-P-0-0-MM



VAV-A-250-S-0-0-

VAV-A-318-400-S0

9.1.1 Control speed of the VAV controller

During the entire planning of the system, the focus is on the protection of the personnel and the environment. Room pressure changes must be recognised quickly and regulated with the required supply or exhaust air; this is why SCHNEIDER consistently relies on high control speeds. The control time is < 3 sec. motor running time for an angle of 90° and is freely programmable from 3 s to 24 s (running time delay). Thus the stringent requirements of the user and the legal regulations can be fulfilled.

9.1.2 Control accuracy of the VAV controller

The control accuracy of a volume flow controller depends largely on the measuring system and the measuring accuracy of the static differential pressure sensor, as well as the positioning resolution of the servo motor.

SCHNEIDER always use the patented measuring tube and optionally the venturi tube as a measuring system. Both these measuring systems use the annulus measuring principle and capture the value that is to be measured via measuring holes situated in the air flow. This produces a very stable and reproducible measuring signal, whereby the volume flow can be regulated with a very high level of measuring accuracy.

The SCHNEIDER measuring system is self-cleaning and thus maintenance-free and not susceptible to poor inflow conditions.

In order to achieve a positioning resolution of < 0.5 °, SCHNEIDER consistently relies on direct actuation of the servo motor (Fast-Direct-Drive) by the control electronics. This achieves not only a good positioning resolution but also rapid and stable control behaviour.

Measuring volume flow with a static differential pressure transmitter

Using a suitable measuring device (venturi tube, measuring orifice, measuring tube or measuring cross) the differential pressure is determined by a static differential pressure transmitter. Measurement is very accurate and stable over the entire measuring range of 3...300 pa (optionally 8...800 pa), making it possible to regulate a volume flow range of 10:1.

Unlike the thermo-anemometric measuring principle, air does not flow through the static differential pressure transmitter and it is therefore particularly suitable for measuring in dusty or contaminated (corrosive) media (its suitability should be assessed in each individual case). The suitability of the thermo-anemometric measuring principle for such media is therefore very limited, as the sensor may become contaminated or damaged by the corrosive air and thus measurement can be very imprecise or faulty.

Setting the volume flows V_{MIN}, V_{MED}, V_{MAX}

Setting the volume flow (programming) is done via the SVM100 service module. The desired volume flow is entered as a numeric value in m3/h, whereby:

Notes on control dimensioning (dimensions and volume flow)

Due to the control accuracy, care must be taken to ensure that at minimum volume flow V_{MIN} the flow velocity in the volume flow controller does not fall below 2 m/s.

Due to noise radiation, in laboratory applications care must be taken to ensure that at maximum volume flow V_{MAX} the flow velocity in the volume flow controller does not exceed 7.5 m/s.

The volume flows V_{MIN}, V_{MED} and V_{MAX} are freely programmable within the range 50...25,000 m3/h, but care must be taken that the dimensions of the volume flow controller are appropriate in relation to the volume flow range while at the same time taking the flow velocity into account.

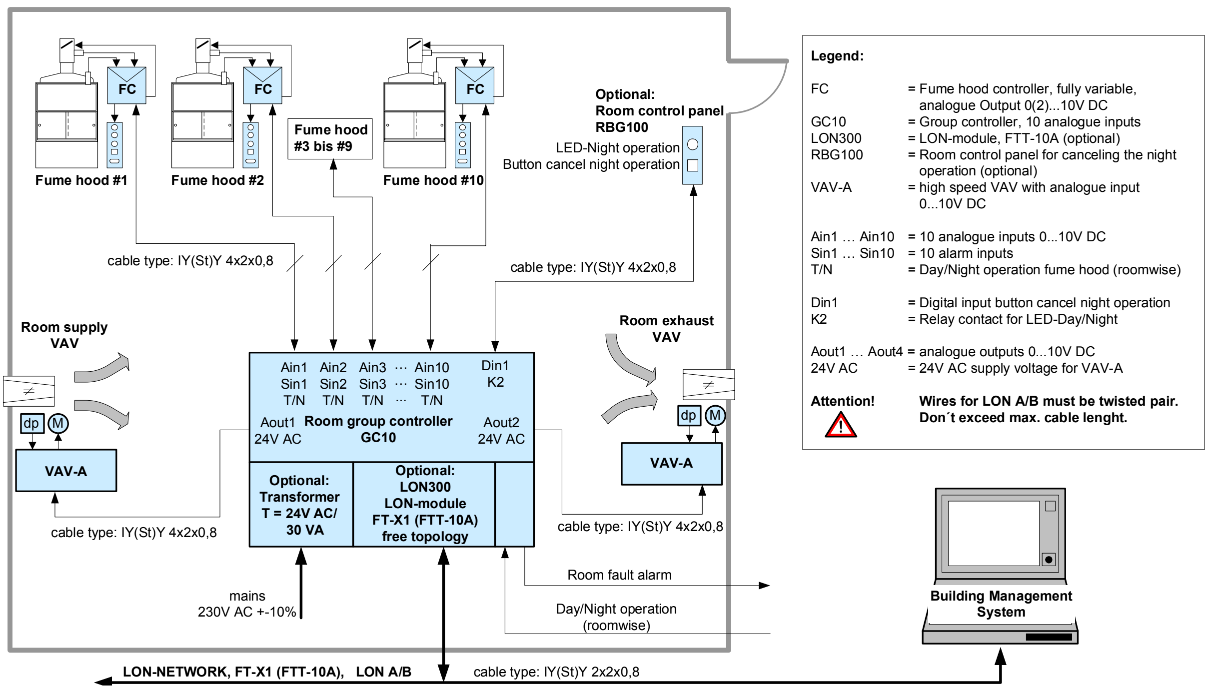
Forced control via digital inputs

Through appropriate wiring of the digital inputs Input 1 and Input 2 the functions $_{V}$MAX and Damper SHUT can be executed directly.

The wiring of the digital inputs is as follows:

0 = contact open (no current)
1 = contact closed (under current)

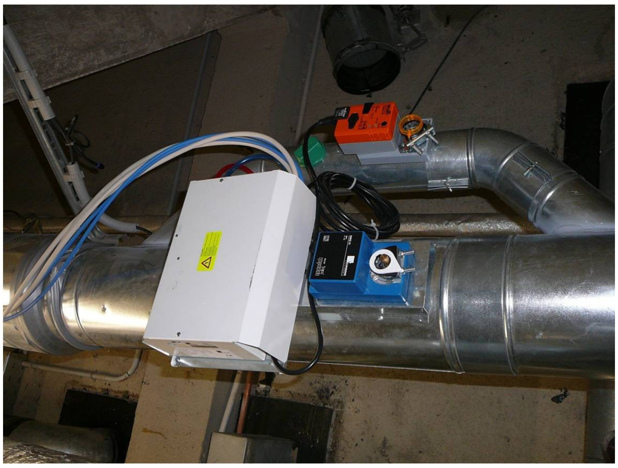
Figure 7.12: Room plan VAV-A with actuation via GC10 room group controller



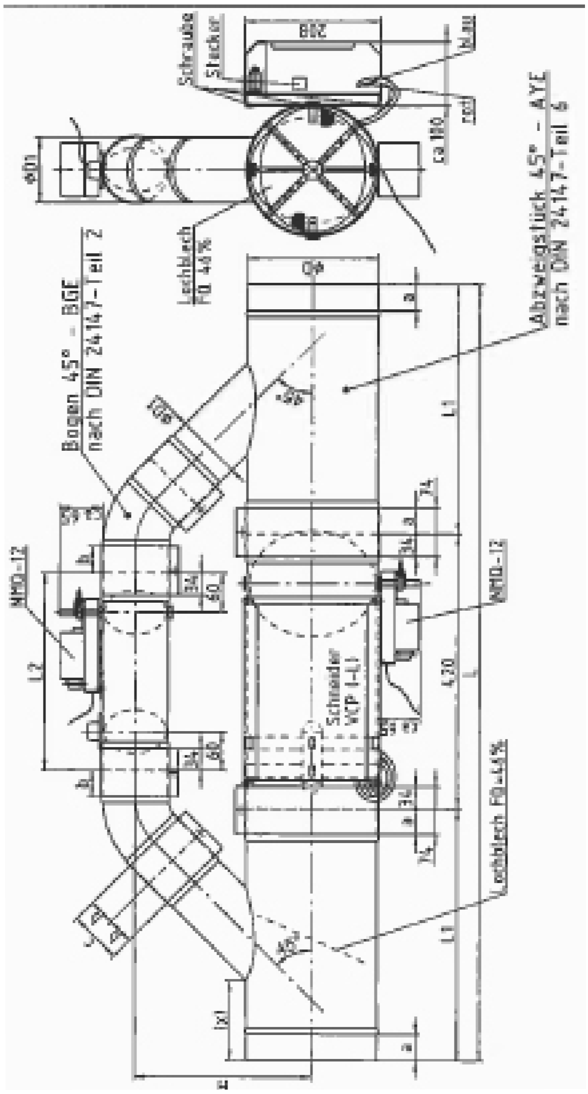
10.1 Performance features
CRP room pressure controller

- Microprocessor controlled room pressure controller
- Digital room pressure display in pascal (optional)
- Additional, external digital room pressure display in pascal (optional secondary display)
- External control panel with status display and alarm acknowledgement
- Integrated optional threshold monitoring of negative/ positive room pressure with acoustic alarm
- Freely programmable constant pressure maintenance
- All system data are saved mains voltage failure-safe in the EEPROM
- Servo motor running time <= 3s for 90°, running time delay freely programmable
- Free programming of system data via the service module SVM-100, such as control time, positive or negative pressure
- Retrieval of all actual values via the LON network (optional)
- Static differential pressure sensor with high long-term stability for continuous measurement of the actual value in the range 5 pa to 100 pa or ± 50 pa (external)
- High-speed, predictive control algorithm
- Rapid, stable, precise control through direct actuation of the servo motor with feedback potentiometer
- Closed loop
- Monitoring of the customer ventilation system
- Suitable as a room supply air or exhaust air controller
- Analogue actual value output 0(2)...10V DC/10mA
- Two digital inputs for up to three different room pressure setpoint specifications (e.g. air locks, daytime/nighttime operation)
- Relay contact 1 x A for monitoring the upper threshold
- Relay contact 1 x A for monitoring the lower threshold
- Programming plug on the circuit board
- External customer supply voltage 24V AC

10.2 Performance features VCP volume flow prioritised room pressure controller



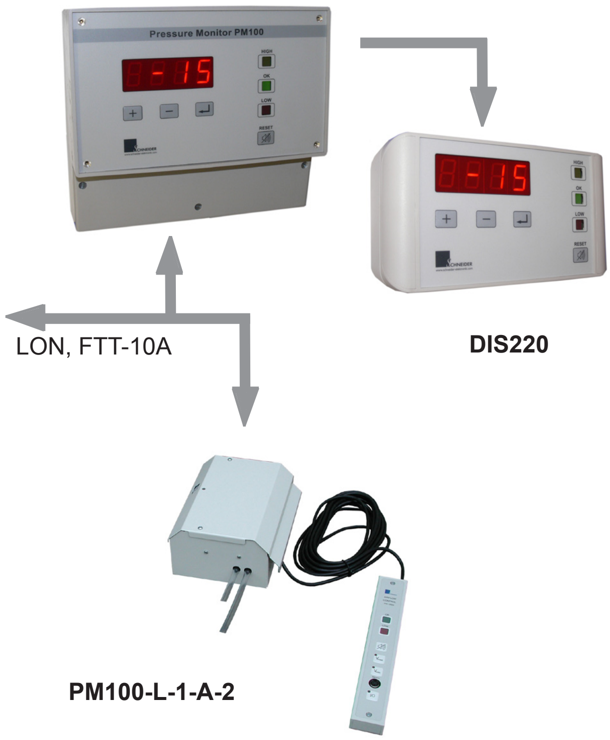
- Microprocessor controlled volume flow prioritised room pressure controller
- Optional digital room pressure display in Pa and volume flow display in m³/h
- Additional, external digital room pressure and volume flow display (optional secondary display)
- Optional external control panel with status display and alarm acknowledgement
- Integrated optional threshold monitoring of negative/ positive room pressure with acoustic alarm
- Freely programmable pressure maintenance and volume flow (room changes)
- All system data are saved mains voltage failure-safe in the EEPROM
- Running time of the servo motors <= 3s for 90°, running time delay freely programmable
- Free programming of system data via the service module SVM-100, such as control time, positive or negative pressure
- Retrieval of all actual values via the field bus module (optional)
- Static differential pressure sensor for room pressure control with high long-term stability for continuous measurement of the actual value in the range 5 Pa to 100 Pa or ± 50 Pa (external)
- Static differential pressure sensor for volume flow control with high long-term stability for continuous measurement of the actual value in the range 3 Pa to 300 Pa or 8 to 800 Pa (optional)
- High-speed, predictive control algorithm
- Rapid, stable and precise control through direct actuation of the servo motors with feedback potentiometer
- Two control circuits that communicate with one another in multitasking mode
- No mutual oscillation of the control circuits
- Two closed loop control circuits
- Monitoring of the customer ventilation system
- Suitable as a room supply air or exhaust air controller
- Analogue actual value output 0(2)...10V DC/10mA
- Two digital inputs for up to three different room pressure setpoint specifications (e.g. air locks, daytime/nighttime operation)
- Relay contact 1 x A for monitoring the upper threshold (volume flow, room pressure or volume flow and room pressure)
- Relay contact 1 x A for monitoring the lower threshold (volume flow, room pressure or volume flow and room pressure)
- Programming plug on the circuit board
- External customer supply voltage 24V AC
- Optional upgradeable field bus module for BACnet, LON and Modbus



10.3 Performance features PM100 room pressure monitor

- Microprocessor controlled monitoring system
- Digital room pressure display in pascal (optional)
- Additional, external digital room pressure display in pascal (optional secondary display
- Threshold monitoring of negative/positive room pressure with acoustic alarm and alarm acknowledgement button
- All system data are saved mains voltage failure-safe in the EEPROM
- Free programming of system data via the service module SVM-100, such as alarm delay time, negative/positive room pressure
- Retrieval of all actual values via the LON network (optional)
- Static differential pressure sensor with high long-term stability for continuous measurement of the actual value in the range 5 pa to 100 pa or ± 50 pa (external)
- Monitoring of the customer ventilation system
- Suitable as a redundant negative/positive room pressure controller
- Analogue actual value output 0(2)...10V DC/10mA
- Two digital inputs for setpoint switching
- Relay contact 1 x A for the upper threshold
- Relay contact 1 x A for the lower threshold
- Programming plug on the circuit board
- External customer supply voltage 24V AC
- Integrated power supply 230V AC (optional)

PM100-L-1-W-2



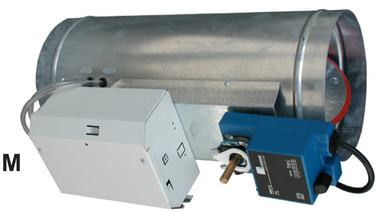
DIS220

PM100-L-1-A-2

10.4 Performance features VAV

- High-speed, adaptive control algorithm for precise and stable control
- Control time ≤ 3 sec for a 90 ° angle
- Suitable for supply air and exhaust air volume flow control in laboratories and clean rooms
- All system data are saved mains voltage failure-safe in the EEPROM
- Free programming of system data and retrieval of all actual values
- Monitoring of the customer ventilation system by integrated monitoring of the supply air/exhaust air setpoint that is to be regulated
- Closed loop
- Static differential pressure transmitter for continuous measurement of the actual value within the range 3...300 pa (optionally 8...800 pa) with high long-term stability
- Analogue setpoint input 0(2)...10V DC/1mA
- Analogue actual value output 0(2)...10V DC/10mA
- Rapid, stable, precise control through direct actuation of the servo motor with feedback potentiometer
- Control parameters are adaptively optimized online
- Response time and regulation of the exhaust air volume flow ≤ 3 sec
- Malfunction notification relay with potential-free contact
- Two digital inputs for BSK/RK contacts (fire/smoke damper) or forced control (e.g. damper shut, on/off)
- Direct forced control via digital inputs for the functions V_{MIN}, V_{MED}, V_{MAX} and damper = SHUT (CAV operation). Via V_{MIN} it is possible to implement, for example, night-time reduction (reduced operation).

VAV-A-250-P-0-0-MM



VAV-A-250-S-0-0-MM

VAV-A-318-400-S0

11.1 Product overview Room pressure controllers, Volume flow controllers, Room pressure controllers

The table shows an overview of the products available from SCHNEIDER in the product group Room pressure controllers, Room pressure monitors and Volume flow prioritised room pressure controllers.

See Chapter 1, Section 6.1 for the full LabSystem product overview.

Technical data sheets, further information and tender specifications for the **VAV, CAV, CRP, VCP** and **PM100** products are available for download on the Internet at **www.schneider-elektronik.de**.

Product group	Product	Short description	Chapter
High-speed room supply/exhaust air controller	**VAV**	Volume flow controller for laboratory supply and laboratory exhaust air, analogue input 0(2)...10V DC for setpoint, optional field bus module, control speed < 3 s	5.0 7.0
Mechanical automatic volume flow controller	**CAV**	Volume flow controller for floor extraction units and safety cabinets, mechanical, automatic, without auxiliary power	5.0
Fast running room pressure controller	**CRP**	Room pressure controller for untight rooms, analogue input 0(2)...10V DC for setpoint, optional field bus module, control speed < 3 s	7.0
	VCP	Volume flow prioritised room pressure controller for airtight rooms	7.0
Room pressure controller	**PM100**	Room pressure controller with internal static differential pressure transmitter 3...100 Pa or external sensor ± 50 Pa, -20...+80 Pa	7.0