BLOWER DOOR MEASUREMENT
OF LARGE BUILDINGS
- WITH ONE OR MORE BLOWER SYSTEMS

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ABSTRACT

This article describes five blower door measurements – each made with a different objective – carried out on large buildings. Proof of air tightness is required to guarantee the operational capability of ventilation systems or to enable fire protection by nitrogen gas inerting. Air tightness measurements of large buildings can be carried out without difficulty using a number of blower systems. With appropriate planning it is easy to achieve very good values, because of the low A/V ratio in these particular buildings – e.g. the level of air tightness required for passive houses (n_{50} > 0.6 h^{-1}) or even better.

KEYWORDS

Blower door, fire protection, energy, air tightness, ventilation systems, quality assurance

INTRODUCTION

The blower door system has been used to measure the air tightness of single-family houses in Germany since 1989. The applications and reasons for measuring air tightness are varied: quality assurance, production of expert reports and provision of energy advice, avoidance of convection-related building damage as well as protection against allergens in the home. Similar experience with apartment buildings (multiple dwellings) has been gained since 1991. Since the introduction of the Energy Saving Directive [EnEV 2002], the air tightness of large administration and industrial buildings is increasingly being checked too – and not just on energy-related grounds: quality assurance, sealing of clean rooms and fire protection are becoming more and more important.

DESCRIPTION OF THE BUILDINGS

The large buildings described here are distributed throughout the whole of Germany. A number of blower door systems had to be used for the measurement of each building.

Figure 1: External view of Building A, installation of 5 (out of 7) blower door systems: either 2 or 3 units were installed per external door opening using an aluminium frame and special panels (2 or 3-hole panels)

TABLE 1

Building data and photographs of the measured buildings

Building No.	Building data and installed number of blower doors	Photograph of the building
Building A	Care Centre in Karlsruhe, Baden-Württemberg, built 2004, proof of tightness required in accordance with [EnEV 2002] (building with ventilation system): $n_{50\ max.} \leq 1.5\ h^{-1}$ Volume (internal): 27,400 m³ 7 blower door systems installed	
Building B	Industrial building in Cloppenburg, Lower Saxony, built 2004, proof of tightness required to guarantee effective function of ventilation system: $n_{50\ max.} \leq 1.5\ h^{-1}$ Volume (internal): 17,100 m³ 3 blower door systems installed	
Building C	Office building in Hamm, North Rhine-Westphalia, built 2003, quality assurance of the air barrier at the construction phase: envisaged limit in accordance with [DIN 4108-7] (building with natural ventilation) $n_{50\ max.} \leq 3\ h^{-1}$ Volume (internal): 31,500 m³ 3 blower door systems installed	
Building D	Industrial building in Brunswick, Lower Saxony, built 2002, proof of tightness required in accordance with passive house standard ("zero emission building", with ventilation system): $n_{50\ max.} \leq 0.6\ h^{-1}$ Volume (internal): 46,500 m³ 4 blower door systems installed	
Building E	Industrial warehouse in Marl, North Rhine-Westphalia, built 2004, proof of tightness for fire prevention system (gas inerting by injection of nitrogen) required: $n_{50\ max.} \leq 0.02\ h^{-1}$ Volume (internal): 191,000 m³, 1 blower door installed	

METHODOLOGY

We were commissioned to carry out a blower door measurement each time in accordance with [EN 13829] and to determine the n_{50} (air change rate per hour at a 50 Pa pressure difference). The number of blower door systems required was determined as follows:

$$\text{Allowed air flow rate at 50 Pa} = \text{Volume V} \times n_{50\ max.}$$

$$\text{No. of blower systems} = \text{allowed air flow at 50 Pa / max. blower door capacity [TEC]}$$

If the building is leakier than planned, i.e. the $n_{50\ max.}$ figure is exceeded, the 50 Pa pressure difference cannot be created with the calculated number of fans.

Example – Building A (uncorrected volume advised by the client):

$$35{,}000\ m^3 \times 1.5\ h^{-1} = 52{,}500\ m^3/h$$

$$52{,}500\ m^3/h \ /\ 7200\ m^3/h \text{ at 50 Pa} = 7.3 \text{ blower systems}$$

Several blower units were installed per door opening. Airtight nylon panels with 2 or 3 fan holes are provided for this, with the panels installed in external door openings using adjustable aluminium frames. If internal doors create a pressure drop within the building, the blower systems have to be distributed around the building shell. The measurement then has to be carried out by a number of people who can communicate with each other by mobile phone. In other cases, the blower door systems can be installed at a single point and operated by just one person.

	
Figure 2: External view, installation of 3 blower door units in one external door	Figure 3: Internal view; aluminium frame with 2 middle cross bars; 3 blower door units (open, without reducing rings); APT 8 - Automated Performance Testing system in case; notebook with TECLOG and BlowerDoor plus

More people are needed to check the complete building envelope at approx. -50 Pa depressurization for large leakages and failings of temporarily sealed openings (preliminary check in accordance with [EN 13829], 5.3.1). By completion of the building preparation, some fans could gradually be switched off and covered on 2 of the buildings, e.g. on Building D, after fully closing and securing the sliding gates (2 of the 4 installed blower systems), on Building C after closing a number of windows that had opened under depressurization because they were not completely locked (2 of the 3 installed blower systems).

The readings (natural pressure difference, pressure difference sequence) were recorded with the TECLOG logging program and then analysed with the BlowerDoor-plus Excel worksheet and the test report prepared. [EN 13829].

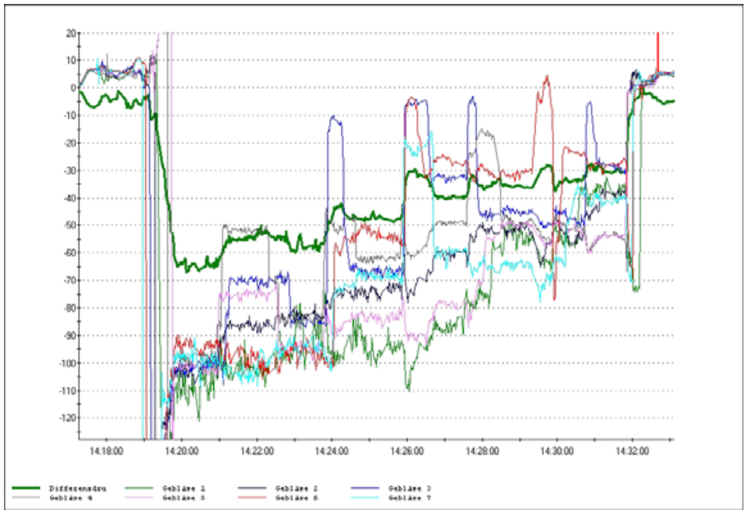

Figure 4: Building A, recording of the pressure difference sequence with TECLOG: natural pressure difference, applied pressure differences -65 to -30 Pa (green fat line), fan pressures of 7 fans

Blower door												
Number			1	2	3	4	5	6	7	8		
Model:	3 or 4		4	4	4	3	4	4	4			
Fan Configuration:	0, A, B, C, D, E		0	0	0	0	0	0	0			
Fan Configuration coefficient:	C [m³/hPa]		682.73	682.73	682.73	818.24	682.73	682.73	682.73			
Fan Configuration exponent:	n		0.4993	0.4993	0.4993	0.4947	0.4993	0.4993	0.4993			
Readings Building		**Readings BlowerDoor**									**Summary** V_{Fan}	Δp_{Fan}
zero flow Δp_0	-4.7	--	--	--	--	--	--	--	--	--	--	--
Δp_1 [Pa]	-64.4	$\Delta p_{Fan,i}$ [Pa]	108.6	102.4	102.0	98.1	101.5	94.0	98.0		--	--
	--	$V_{Fan,i}$ [m³/h]	7091.5	6886.4	6872.9	7909.7	6856.1	6598.3	6737.0		48952	5202.9
Δp_2 [Pa]	-53.7	$\Delta p_{Fan,i}$ [Pa]	102.1	86.4	70.5	52.3	74.9	99.2	101.9		--	--
	--	$V_{Fan,i}$ [m³/h]	6876.3	6326.3	5715.4	5794.6	5890.8	6778.1	6869.6		44251	4250.4
Δp_3 [Pa]	-57.1	$\Delta p_{Fan,i}$ [Pa]	89.1	82.9	85.3	84.5	94.3	97.1	94.4		--	--
	--	$V_{Fan,i}$ [m³/h]	6424.3	6197.0	6286.0	7346.8	6608.8	6706.1	6612.3		46181	4629.8
Δp_4 [Pa]	-47.5	$\Delta p_{Fan,i}$ [Pa]	93.9	74.0	66.6	61.6	83.4	52.8	68.4		--	--
	--	$V_{Fan,i}$ [m³/h]	6594.8	5855.4	5555.3	6283.3	6215.7	4947.2	5629.8		41081	3662.5
Δp_5 [Pa]	-35.7	$\Delta p_{Fan,i}$ [Pa]	54.4	51.3	45.0	47.4	49.9	31.3	64.3		--	--
	--	$V_{Fan,i}$ [m³/h]	5021.5	4876.5	4567.7	5519.4	4809.6	3810.4	5458.7		34064	2516.8
Δp_6 [Pa]		$\Delta p_{Fan,i}$ [Pa]									--	--
	--	$V_{Fan,i}$ [m³/h]									0	0.0
Δp_7 [Pa]		$\Delta p_{Fan,i}$ [Pa]									--	--
	--	$V_{Fan,i}$ [m³/h]									0	0.0
Δp_8 [Pa]		$\Delta p_{Fan,i}$ [Pa]									--	--
	--	$V_{Fan,i}$ [m³/h]									0	0.0
zero flow Δp_0	-4.5	--	--	--	--	--	--	--	--	--	--	--

Figure 5: Building A, entry of the depressurization readings in BlowerDoor-plus: difference pressures and fan pressures / air flow rate of the 7 BlowerDoor systems

RESULTS

Table 2
Number of blower door units used / air tightness results

Building	Number of blower door units installed/required	Measured air flow rate (m^3 / h)	Measured n_{50} (h^{-1})	Target value of n_{50} not to be exceeded (h^{-1})
Building A	7 / 7	45,111	1.6	1.5
Building B	3 / 3	22,260	1.3	1.5
Building C	3 / 1	6,742	0.21	1.5
Building D	4 / 2	10,089	0.22	0.6
Building E	1 / 1 (low flow ring A)	2,613	0.014	0.02

For an international comparison of the results, e.g. with the publications from GB [AIR 2004], [AIVC Prague 2004], the results of the air permeability q_{50} (per envelope area A_E) in addition would have been meaningful, but A_E values were not determined during these investigations.

DISCUSSION

Building A: proof of tightness in accordance with EnEV not achieved
The care centre was built using traditional methods of construction without special regard for air tightness. Because a ventilation system was installed and included in the heat requirement analysis, proof of air tightness is obligatory. The air tightness limit was just exceeded and remedial works were necessary. The measurement itself was very expensive as 7 blower door units had to be installed to deliver the required leakage flow. By installing 2x2 and 1x3 fans in parallel, the measurement could be carried out with 3 people.

Building B: securing effective operation of ventilation systems
The industrial building under test, located near Cloppenburg in Lower Saxony, has an internal volume of 17,100 m³ and is used for producing special cables. The building is equipped with an ultramodern ventilation system. The precondition for satisfactory operation of this ventilation system is a sufficiently airtight building envelope (in this case an air change rate of less than 1.5 h^{-1} at a building pressure difference of 50 Pa), to allow controlled air distribution . Using three blower door systems (maximum total capacity of around 24,000 m³/h) a air flow rate of 22,000 m³/h was measured under test conditions, corresponding to an air change rate of 1.3 h^{-1}. As a result, adequate air tightness of the building envelope – as the precondition for correct performance of the ventilation system - could be successfully proved.

Building C: quality assurance
The administration building in Hamm with an internal volume of 31,000 m³ could be measured with just one blower door unit (initial calculations indicated that four units would be required) and achieved excellent results – because there was a very good air tightness design concept. The air tightness constructional details were examined by the author at the design stage and suggestions for improvement were made.

Building D: high energy efficiency
An early blower door measurement (preliminary measurement of the air barrier) was carried out during the construction phase on the zero-emission industrial building (internal volume approx. 46.500 m³). This was necessary because, besides the thermal insulation, the air

tightness of the building is an essential factor in ensuring high energy efficiency. The planned controlled ventilation with heat recovery can only achieve its aim if the air exchange for provision of the required clean, fresh air actually takes place via the heat exchanger and not through joints and cracks. Following remedial works, two of the four blower door units could be switched off during the course of the measurement – the final measurement was carried out with just two blower door systems.

Building E: fire protection

The industrial warehouse in Marl with an internal volume of around 190,000 m³ is protected by a fire prevention system (gas inerting). By injecting nitrogen, this system reduces the oxygen content in the warehouse to such an extent that a fire is no longer possible. As a result, no sprinkler system is required. Instead, extremely demanding requirements are imposed with regard to air tightness: under the terms of the contract, the facade – made from mineral fibre sandwich panels – must not exceed an air change rate of 0.02 h^{-1} at 50 Pa (n_{50}). Once again here - because of the tightness of the building envelope– this meant that a single blower door system was adequate for the required proof: 2,613 m³/h were delivered with low flow ring A, an air flow rate specified as standard for multiple-dwellings in the [EnEV 2002].

CONCLUSION

The measurement results show that - with a good air tightness design concept - the cost of the measurement is low and the capacity of one blower door system (7800 m³/h) is often sufficient. Where there is no real design concept and the buildings are very large and leaky, air tightness measurements are carried out with up to eight systems. For the measurements, up to three blower door units can be installed in the sturdy aluminium frame per door opening, or they can be distributed individually over the openings in the facade (ground floor), according to the characteristic properties of the building.

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