Airtightness Tests at different wind conditions in a high building

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ABSTRACT

Because of temperature-based uplift within the building and the impact of wind on the building, airtightness measurements of high buildings are especially challenging. Temperature differentials between the building interior and the exterior with particularly high buildings can lead to excessively high baseline pressure differentials on the building envelope while the impact of wind can cause their extreme fluctuation, both of which may have a negative effect on the measurement.
This paper will present two airtightness measurements with a special test set-up in the same high-rise building at different times, i.e. under windy conditions and in calm weather. The first measurement was conducted at a wind force of 4 Beaufort. Two weeks later, a second airtightness measurement was conducted in calm conditions. This is highly interesting for the measuring practice of large buildings, because the testing date is usually set based on constructional and organizational aspects and only rarely takes into account optimal weather conditions. This presentation compares the test results of both airtightness measurements and in addition to sharing the experience from these measurements is also meant to prompt a discussion of the error of measurement with regard to the measuring standard EN 13829.

Fig. 1: Building view during the measurement in calm conditions (no wind). The measurements were conducted with a Minneapolis BlowerDoor Measuring System.

KEYWORDS

building airtightness, high building, airflow V_{50}, air change rate n_{50}

INTRODUCTION

The challenges when conducting airtightness measurements of tall buildings are as follows:
- How should we deal with the 5-Pascal limit for the baseline pressure differential according to German and European Industrial Standard DIN EN 13289?

- During the depressurization test it must be ensured that the entire building is depressurized.
- During the pressurization test it must be ensured that the entire building is pressurized.
- The pressure drop within the building must be controlled.

The first depressurization and pressurization measurement was conducted under relatively strong windy conditions (4 Beaufort). The testing team consequently asked itself how accurate the measurement was. Fortunately, the measurement could be repeated two weeks later under calm conditions and the measurement results could be compared.

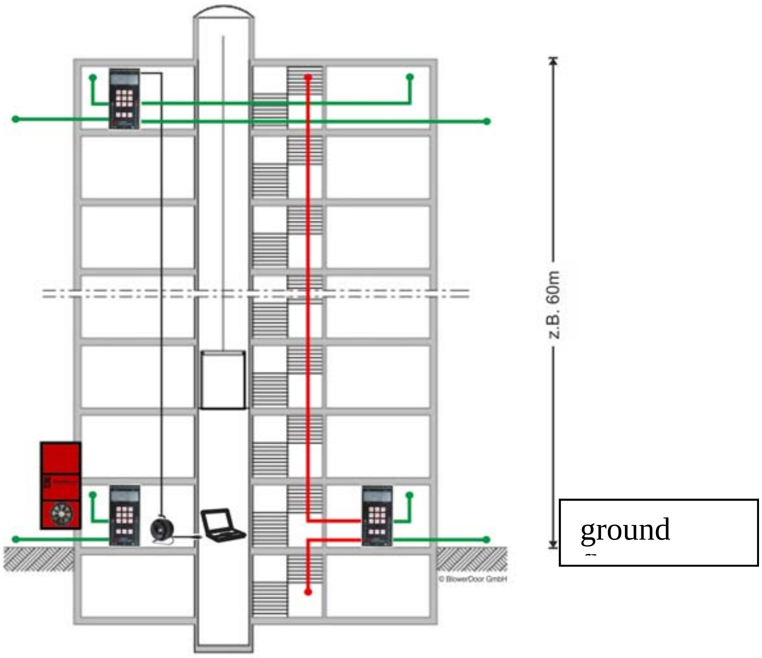

Fig. 2: Set-up of the measuring devices. The measuring data was recorded using the TECLOG software. Since the air flow rate to be measured was below 7,200 m³/h, one Minneapolis BlowerDoor Standard Measuring System (Model 4) sufficed to measure the 23,000 m³ tall building with an envelope area of 10,000 m².

The green lines in the diagram represent the tubes for determining the building pressure differential. On the ground floor, two measuring points have been marked. In reality, there were three. On the top floor, you have two measuring points, one on the upwind and one on the downwind side in order to cover the extremes. The red line represents the tube for determining the pressure differential within the building.
To prepare the building all interior doors were opened (approx. 250 doors), the flaps of the ventilation system and the stairwell smoke extraction were closed. The stairwell served as the re-flow path.

Summary of the results
The mean value V_{50} of the measurement under windy conditions is 4,893 m³/h. Under calm conditions (no wind), the mean value V_{50} was measured at 4,846 m³/h. This means more than 99 percent conformity of the results.

Airtightness measurement under windy conditions
The following graph shows the pressure curves of the first airtightness measurement under windy conditions. The wind force is estimated at 4 Beaufort. The inside temperature was 19°C, the outside temperature 10°C.

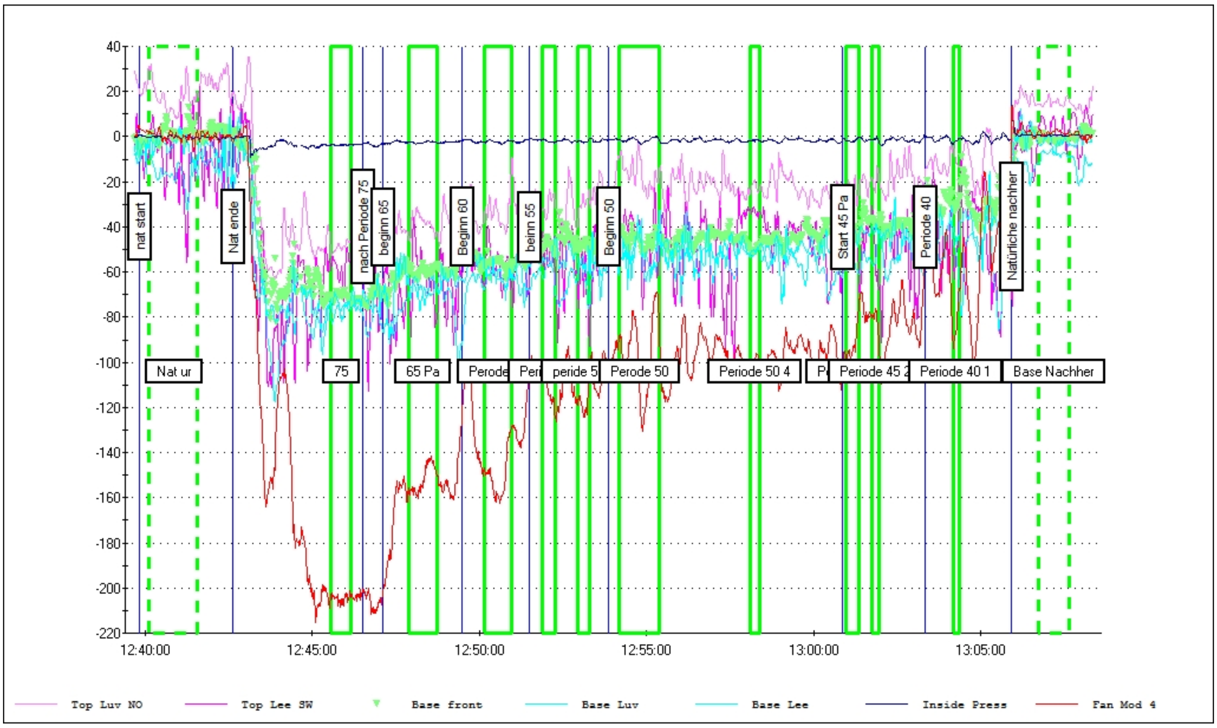

Fig. 3: Recording of the depressurization measurement under windy conditions on 5 February, 2011.

Explanations of the graph:
The curves “Top Luv No” [Top Upwind North] and “Top Lee SW” [Top Downwind Southwest] show the building pressure differentials measured on the top floor. “Base front”, “Base Luv” [Base Upwind], and “Base Lee” [Base Downwind] show the building pressure differentials measured on the ground floor. “Inside Pressure” is the pressure differential in the building. “Fan Model 4” shows the pressure at the Minneapolis BlowerDoor fan for determining the air-flow rate.
The pressure differential in the building (Inside Pressure) clearly was below 5 Pascal.

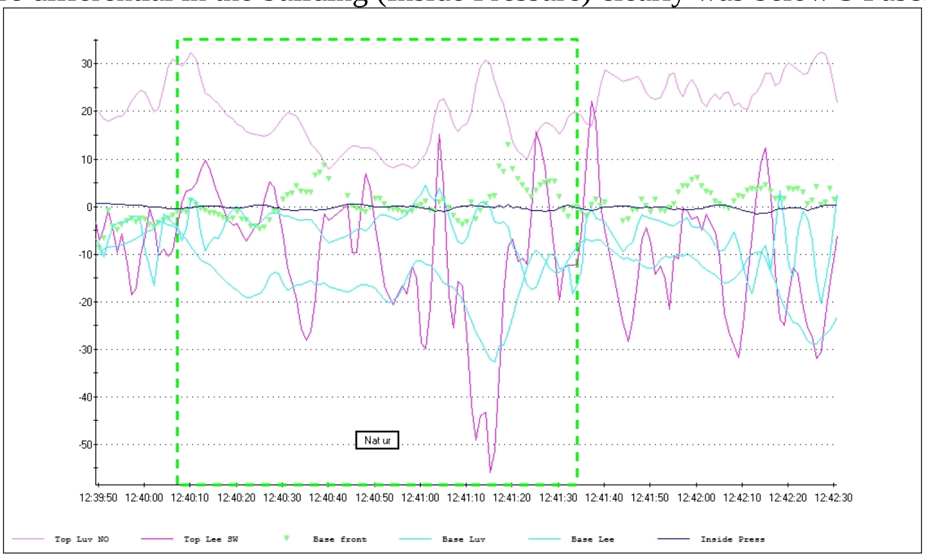

Fig. 4: Recording of the baseline pressure differentials before the measurement under windy conditions on 5 February, 2011.

The mean baseline pressure at the three measuring points on the ground floor before the measurement was -6.8 Pascal (measured over a period of 90 seconds). It ranges from -30 Pascal to +15 Pascal. On the top floor it is 30 Pascal on the upwind side and -55 Pascal on the downwind side. The baseline pressure differential after the measurement is -3.9 Pascal.

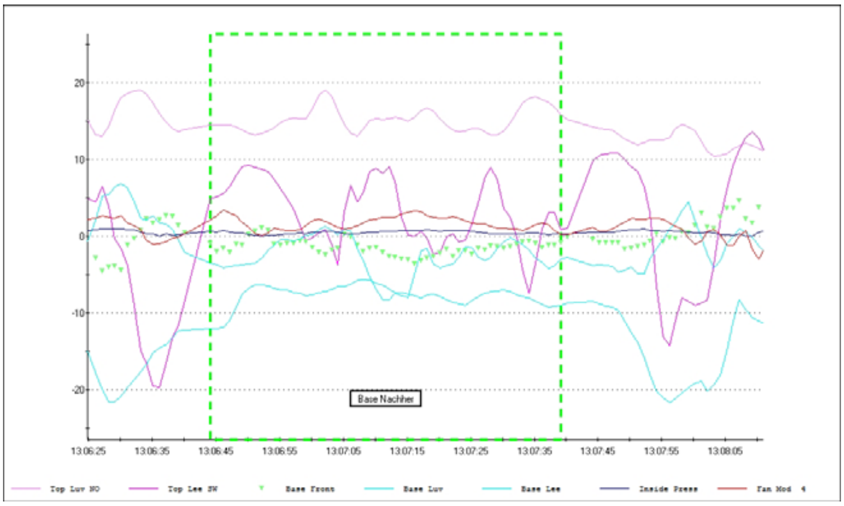

Fig. 5: Recording of the baseline pressure differential after the pressurization measurement under windy conditions on 5 February, 2011.

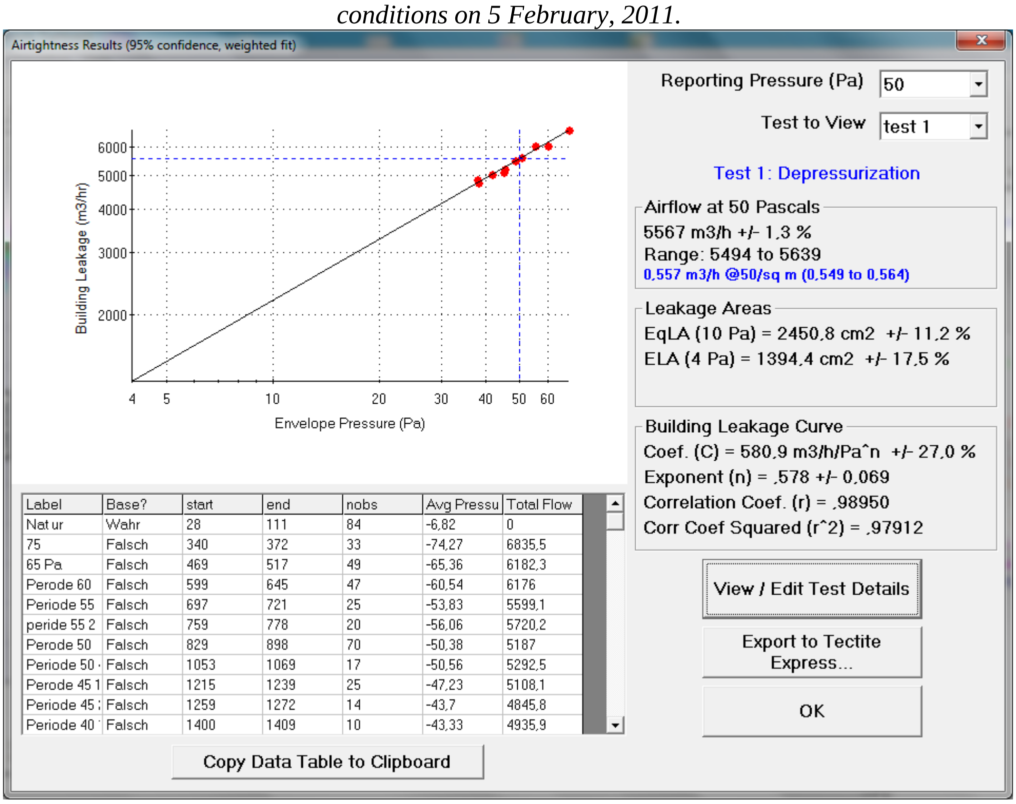

Fig. 6: Measuring result of the depressurization measurement under windy conditions (program window of the TECTITE Express 3.0 software).

The measuring curve in Fig. 3 shows that building pressure differentials from -75 Pascal to -40 Pascal were selected for the evaluation. These periods are marked by the fields edged in green. In total, 10 measuring periods were selected.
The recording of the measurement for the pressurization test can be seen in the following graph:

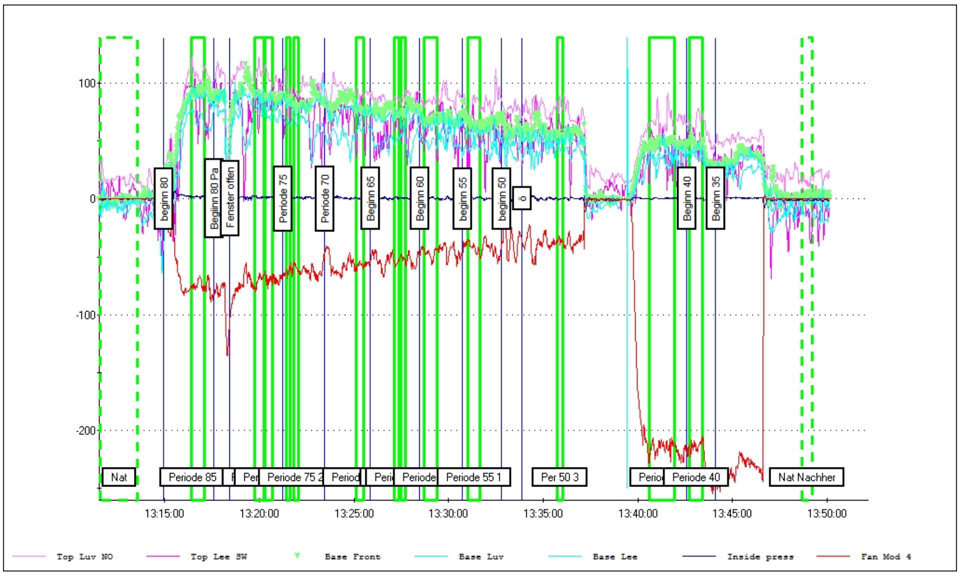

Fig. 7: Measuring curve for pressurization under windy conditions on 5 February, 2011.

The result of the depressurization test is V_{50} = 5,567 m³/h and of the pressurization test V_{50} = 4,219 m³/h. The mean value is V_{50} = 4,893 m³/h.

Measurement under calm conditions (no wind)

The measurement under calm conditions was conducted on 20 February, 2011 at a wind force of 1 to 2 Beaufort. The inside temperature was 17°C, the outside temperature 3°C.

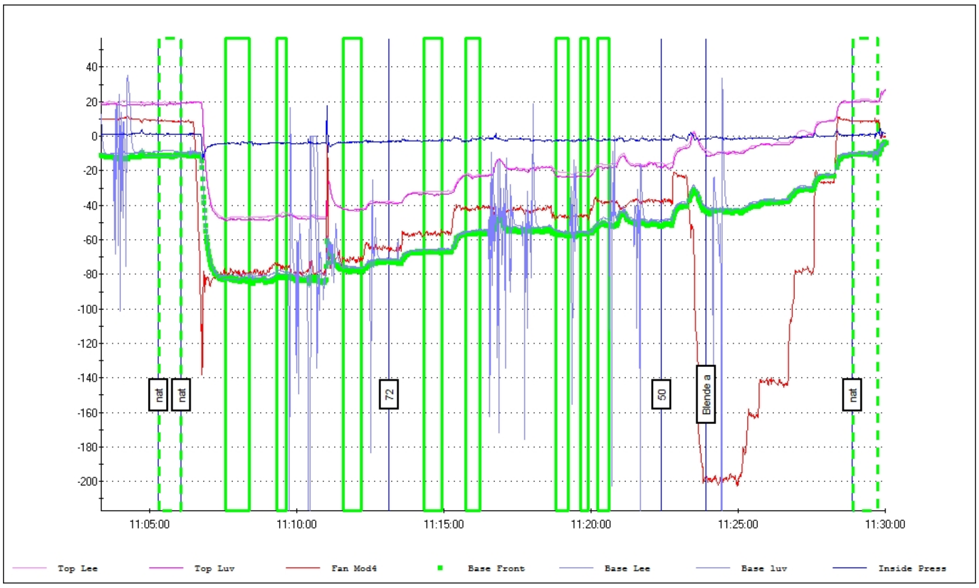

Fig. 8: Recording of the depressurization measurement under calm conditions (no wind) on 20 February, 2011.

Explanations of the graph:

The curves “Top Luv No” [Top Upwind North] and “Top Lee SW” [Top Downwind Southwest] show the building pressure differentials measured on the top floor. “Base front”, “Base Luv” [Base Upwind], and “Base Lee” [Base Downwind] show the building pressure differentials measured on the ground floor. “Inside Pressure” is the pressure differential in the building. “Fan Model 4” shows the pressure at the Minneapolis BlowerDoor fan for determining the air-flow rate.

The measuring curve in Fig. 3 shows that building pressure differentials from -75 Pascal to -40 Pascal were selected for the evaluation. These periods are marked by the fields edged in green. In total, 10 measuring periods were selected. This measurement also resulted in a building pressure differential inside the building (“Inside Pressure”) clearly below 5 Pascal.

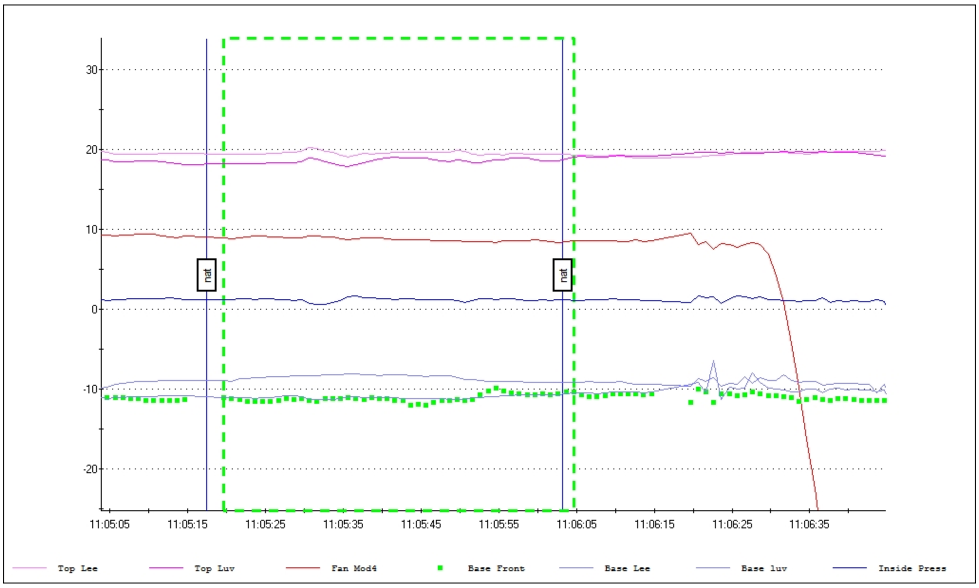

Fig. 9: Recording of the baseline pressure differentials before the measurement (under calm conditions) on 20 February, 2011.

In the recording of the baseline pressure differential before the measurement (Fig. 9) the difference of 30 Pascal between the ground floor and the top floor stands out. In the following graph (Fig. 10), the baseline pressure differential after the measurement is very similar to the previous one. The high pressure differentials stem from the high temperature difference between the inside and the outside.

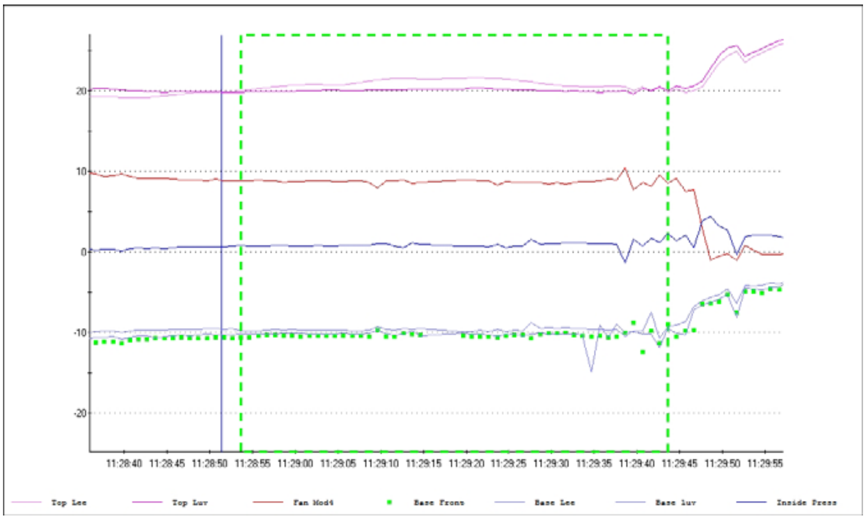

Fig. 10: Recording of the baseline pressure differential after the measurement (under calm conditions) on 20 February, 2011.

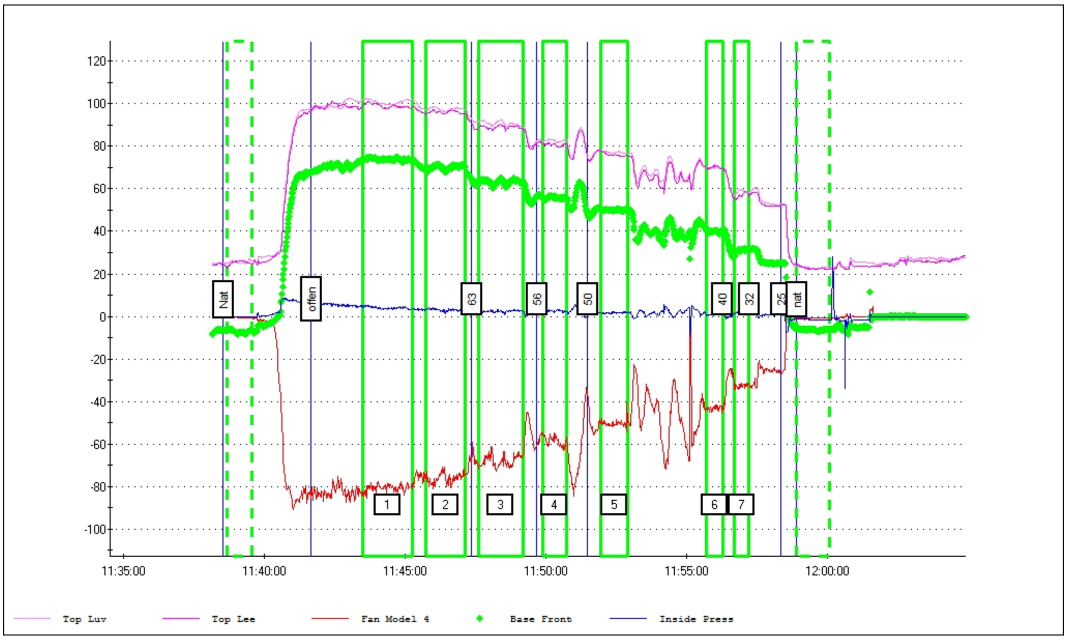

Fig. 11: Pressurization measurement under calm conditions (measurement on 20 February, 2011).

During the final pressurization measurement, the natural baseline differential on the ground floor could only be recorded at the fan ("Base Front"), because some floorers were working in the area of the tubes at the reference points Upside and Downside and frequently stepped on the tubes.

The pressurization on the top floor at all seven measuring stages (fields edged in green) was 25 Pascal higher than on the ground floor.

Overview of the measuring results:

1: Measurement under windy conditions					2: Measurement under calm conditions			
depressurization	5567	m^3/h			depressurization	4833	m^3/h	
pressurization	4219	m^3/h			pressurization	4859	m^3/h	
mean value	**4893**	**m^3/h**	**(under windy conditions)**		**mean value**	**4846**	**m^3/h**	**(under calm conditions**

The mean values of the measurement under windy conditions and under calm conditions in absolute terms differ by 47 m^3/h, i.e. by less than one percent.

Conclusion

With measurements at high and sometimes strongly fluctuating pressure conditions, a pressurization and depressurization test must be conducted. The measuring result is generated from the mean. By contrast, with a measurement according to German and European Industrial Standard DIN EN 13289 either a depressurization or a pressurization test is enough to get a measuring result.

When testing tall buildings, the extremes of the pressure conditions must be monitored in order to ensure, for example, that depressurization is achieved at all points of the building envelope when conducting a depressurization test.

Conclusion: This measurement is practical proof that the measuring method described above also allows for conducting sufficiently accurate measurements in conditions not according to standard. In order to confirm this, further theoretical considerations and practical experience must be taken into account. It must, for example, be analyzed to which extent the leakage distribution influences the measuring result.

Hypothesis: When conducting a depressurization and pressurization test as well as monitoring extreme pressures, the requirements of DIN EN 13289 with regard to the limits of the baseline pressure differential (±5Pascal) must not be observed.