Hochschule Aachen

I.F.I. Institut
für Industrieaerodynamik
GmbHInstitute at the
Aachen University of Applied
Sciences

Welkenrather Straße 120
D – 52074 Aachen
Germany

Tel.: +49 241/879708-0
Fax: +49 241/879708-10
E-Mail: info@ifi-aachen.de

Notified testing laboratory, inspection body and certification body no. 1368 according to the CPD

Client: SMAY Sp. z o.o.

Project no. DDS10-02

Report no.: DDS10-02-2

Test Report

Pressure Differential System SAFETY WAY®

This test report contains 12 pages, 3 annexes and a summary of test results.

Test Engineer: Dipl.-Ing. W. Mertens, M.Sc.

Aachen, August 29, 2010

Dipl.-Ing. B. Konrath

Dipl.-Ing. W. Mertens, M.Sc.

Contents

1 Mission statement

The pressure differential systems (DDS) will be tested in accordance with the revised edition of EN DIN 12101-6, which is expected to be published in 2010/2011. The test will establish the characteristic system specifications.

2 Results

Table 2.1 shows the basic test with the final result and the design values:

Performance class	$\dot{V}_N$ [m³/h]	$\dot{V}_L$ [m³/h]	Δp_N [Pa]	Δp_V [Pa]	Re_n [-]	A_T [m²]	Results
1	16,000	2,600	50	16	10,000	2.10	passed

Table 2.1 Results

$\dot{V}_N$ rated volumetric flow rate
$\dot{V}_L$ volumetric leakage flow rate
Δp_N nominal pressure differential
Δp_V pressure differential across exhaust flow
Re_n number of cycles in continuous test
A_T maximum door size for v = 2 m/s

3 Test philosophy

A pressure differential system consists of at least one device for volumetric flow supply coupled with a pressure controller. The volumetric flow supply is typically achieved with a fan; volumetric flow rate and pressure can be controlled in very different ways.

The system is designed to prevent smoke from entering a security area. Fresh air is supplied to the protected area through leaks and open doors in the direction of the fire room, thus pushing the smoke back into the fire zone. Typically, the security area is an anteroom to a staircase or an anteroom to an emergency lift. Pressure differential systems are therefore mostly installed in stairways. As specified by the standard, the pressure parameter between safety zone and fire zone with the door closed is derived from a maximum door opening force of 100 N. Door closing torque and door shape are also taken into consideration. The volumetric flow through the connecting door is based on the requirement of the standard for an average speed of 2 m/s through the door cross-section to the fire room. The leaks in a staircase add up to a volumetric leakage flow, which, when added to the volumetric flow through the

corridor, defines the total volumetric flow to be supplied by the fan. The establishment of the desired volumetric flow when the connecting door is opened, and the regulation of the pressure to the rated value as a function of door size when the connecting door is closed, must be completed within a pre-defined time period. In practice, the air flowing into the fire zone can be exhausted via the designated area and the facade or through a shaft; the exhaust flow may also be supported mechanically. The pressure loss, due to the flow along this route, affects the performance of the pressure controller and fan.

The test is carried out in the test room at the I.F.I. für Industrieaerodynamik GmbH, Institute at the University of Applied Sciences Aachen – called I.F.I. below. The volume of the test room is (5.25 x 4.55 x 4) m³. The layout of the test room is shown in Fig. 1.1.

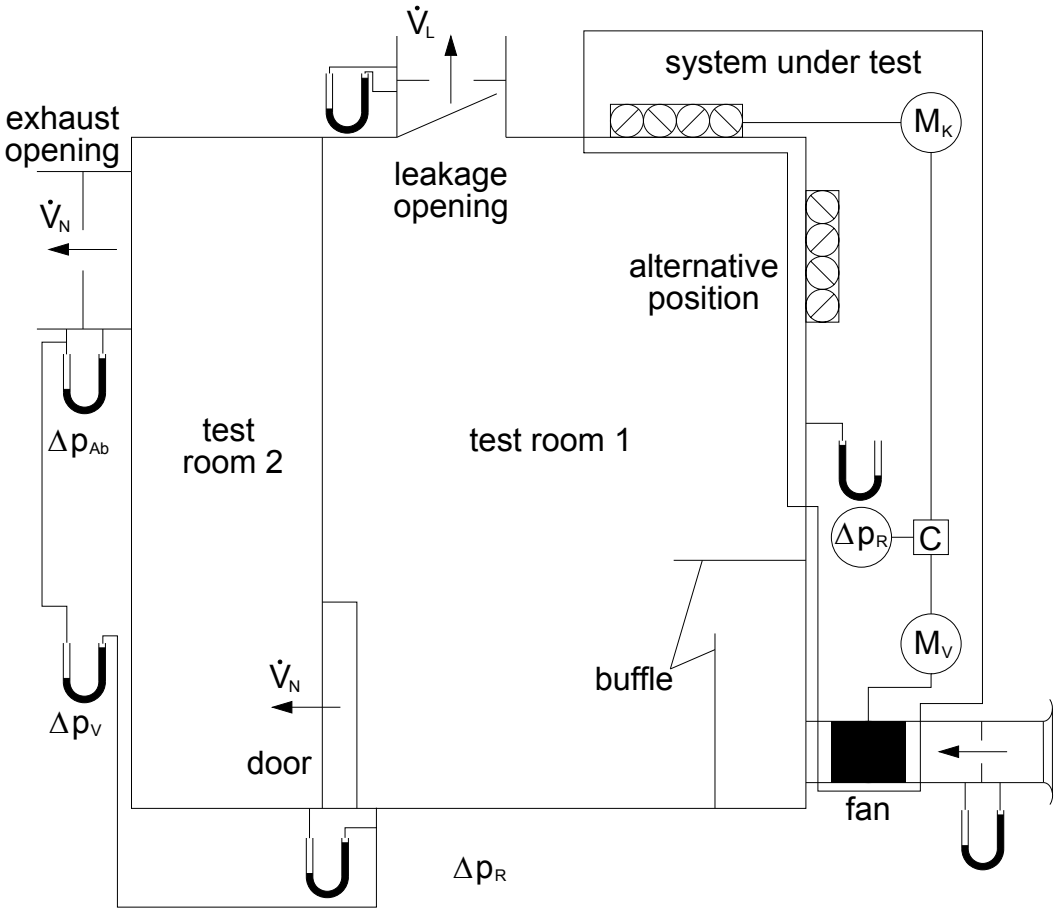

Fig. 1.1 Test room

3.1 Tests

The test comprises a number of subtests:

- functionality test, Fu
- reliability test, Re
- durability test, Du
- resonance test, Res
- dynamic behavior test, DB

3.1.1 Functionality test

In the functionality test (Fu) a door that has just been delivered is repeatedly opened and closed in the same manner to test the behavior of the DDS. The dynamic behavior test (DB) is run to test functionality. The functionality test is run before the continuous test.

3.1.2 Dynamic behavior test

The dynamic behavior test (DB) describes a repeated door operation. A door operation cycle is broken down into its constituent components and plotted against time (Fig. 2.1).

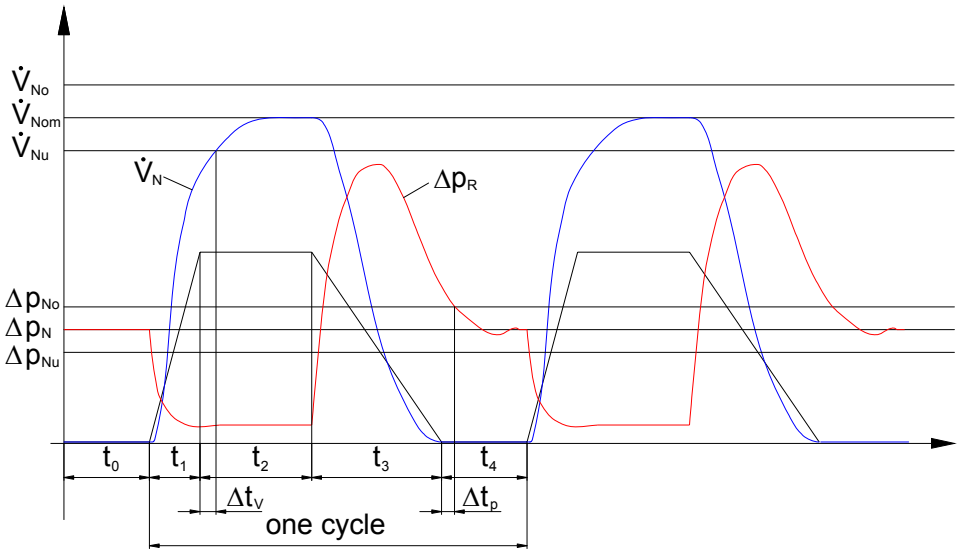

Fig. 2.1 DB cycle for functional test

t_0 start delay (occurs only once)
t_1 door opening time 1 s
t_2 time to establish volumetric flow 6 s
t_3 door closing time 3 s
t_4 pressure control delay time 6 s

The cycle t_1 to t_4 runs 20 times in the DB. Time to establish volumetric flow Δt_V and pressure regulation time Δt_p in every cycle are evaluated.

3.1.3 Reliability test

In the reliabilty test (Re) the cycle described in the previous section is run 10,000 times. Individual values are not measured and there is no evaluation during the cycles. The reliability test is passed when, after the test is complete, the DDS is able to deliver the rated volumetric flow into the fire storey through the opened door.

3.1.4 Certificate of stability

The durability test (Du) has the same functionality and sequencing as the dynamic behavior test; and it detects any deviation from the basic functionality of the system under investigation after the continuous test has been completed (impact of ageing).

3.1.5 Resonance test

The resonance test (Res) consists of a number of subtests. In this test the impact a door has on the control response, when the door is not fully closed between opening operations, is simulated. The subtests consist of 20 cycles with delay times t_2 and t_4 set to zero. The open period t_3 is adapted in each test and reduced from 3 s to 1 s in 0.5-second intervals. The establishment of volumetric flow and pressure control response are checked for each time combination after 20 cycles. The resonance test determines whether a control system tends to resonate. The resonance test is run after the reliability test; it may also be run before the reliability test, to determine any impacts due to ageing.

3.1.6 Testing procedure for modified performance classes

The dynamic behavior test and resonance test must be run again if a new set of performance classes are introduced for the same DDS. This is the case if one or more of the rating performance rated volumetric flow rate, rated pressure, volumetric leakage flow and exhaust pressure loss are altered.

3.2 Designations and definitions

The definitions below are used in the report:

Designation	Unit	Description
$\dot{V}_N$	m³/h	Rated volumetric flow delivered from test room 1 (staircase) to test room 2 (fire zone) with the door open
$\dot{V}_{Nom}$	m³/h	Rated volumetric flow delivered from test room 1 (staircase) to test room 2 (fire zone) with the door fully open
$\dot{V}_L$	m³/h	Volumetric leakage flow exhausted from the test room (test room, staircase) at nominal pressure differential with the corridor closed
$\dot{V}_{Nu}$	m³/h	Lower limit of rated volumetric flow – must be reached within time period Δt_p after the door has been opened – $\dot{V}_{Nu} = 0.9 * \dot{V}_N$
Δp_R	Pa	Pressure differential between test room and surrounding
Δp_N	Pa	Nominal pressure differential to be maintained by the DDS with the door closed
Δp_V	Pa	Pressure differential across the exhaust flow with the door open
Δp_{No}	Pa	Upper limit value of nominal pressure differential – the nominal pressure differential must drop below this limit value within the time period Δt_p after the door has been closed – $\Delta p_{No} = 1.2 * \Delta p_N$
Δp_{Nu}	Pa	Lower limit value of nominal pressure differential – the nominal pressure differential should not drop below this limit value in the regulated steady state with the door closed – $\Delta p_{No} = 0.8 * \Delta p_N$
Δp_{Ab}	s	Pressure differential across exhaust outlet
Δp_{In}	Pa	Local pressure differential at inlet opening to surrounding
Δp_{PR}	Pa	Local pressure differential at pressure release opening (staircase) to surrounding
t_A	s	Time when the corridor is fully opened
t_C	s	Time when the corridor is fully closed
t_D	s	Time when V_{Nu} is exceeded
t_E	s	Time when the pressure differential Δp_R is less than Δp_{No}
Δt_V	s	Time period needed to establish volumetric flow $t_D - t_A$
Δt_p	s	Pressure regulation time period $t_E - t_C$
$\Delta t_{V,i}$	s	Time to establish volumetric flow in DB cycle i
$\Delta t_{p,i}$	s	Pressure regulation time in DB cycle i
n	-	Number of cycles in DB – n = 20
A_T	m²	Maximum door size, which allows an average speed of 2 m/s with flow through the door at volumetric flow rate $\dot{V}_N$
Re_n	-	Number of test cycles in the continuous test

3.3 Test criteria

The test criterion to establish volumetric flow is said to be passed when the time period $\Delta t_{V,i}$ in DB, or the time period Δt_V in each subtest in the resonance test, is less than or equal to 3 s.

criterion for establishing volumetric flow DB $\Delta t_{V,i} \leq 3$ s (1)

criterion for establishing volumetric flow Res $\Delta t_V \leq 3$ s (2)

The pressure control criterion is said to be passed when the averaged time period $\Delta t_{p,i}$ in DB, or the time period Δt_p in each subtest in the resonance test, is less than or equal to 3 s. In the regulated state the pressure should not fall below 80% of the rated pressure.

pressure control criterion DB $\Delta t_{p,i} \leq 3$ s (3)

pressure control criterion Res $\Delta t_p \leq 3$ s (4)

lower pressure limit criterion $\Delta p_R \geq p_{Nu}$ (5)

4 Description of tested system

Manufacturer/supplier: SMAY Sp. z o.o – Krakow, Poland

System designation: SAFETY WAY®

4.1 Description

The system consists of two pressure/volumetric flow control units: one unit is installed at the inlet and one at the outlet to control the pressure inside the test room while the door is closed. Each unit consists of a fan with a louver damper fitted between fan and test room. The fan is driven by a frequency converter; the louver damper is actuated by a Belimo motor. The controller uses the local differential pressure signal between test room and ambient as a reference input variable to control the louver damper. The air intake pressure differential Δp_{Ein} (measured at the pressure side of the duct for the air-intake fan) to ambient is used as reference input variable to control the frequency inverter for air intake. The air release pressure differential Δp_{Fort} (measured at the inlet side of the duct for the exhaust fan) to ambient is used as reference input variable to control the frequency inverter for air

release. When the door in the test room is open air is released from the test room through this door only. Under these conditions the louver damper at the air release unit is fully closed.

The PDD-01-0001 system measures the pressure differential in the test room to ambient Δp_R not as an absolute variable, but measures the local pressure differentials Δp_{In} in the air inlet zone and Δp_{PR} at the inlet to the exhaust air fan. The rated pressure Δp_R in the test room is the mean value of the local measurements taken at the inlet and outlet. The pressure differentials at the inlet and outlet are established in the test room by throttling. The system was fully tested with a pressure differential of Δp_{In} = 60 Pa at the air inlet and Δp_{PR} = 40 Pa at the outlet. Another test was run with the settings Δp_{In} = 70 Pa/Δp_{PR} = 30 Pa. Annex A contains two system diagrams and the fan specifications. Annex B contains images of the test rig and components. Annex C contains the test diagrams.

4.2 Components

Fan for air-intake unit

Manufacturer	Venture Industries Sp. z o.o. – Kielpin, Poland
Type	AFC/4-800-400

Fan for exhaust-air unit

Manufacturer	Venture Industries Sp. z o.o. – Kielpin, Poland
Type	AFC/4-710-400

Louver damper (1x air-intake unit, 1x exhaust-air unit)

Manufacturer	SMAY Sp. z o.o
Type	PWII-S
Size	800x800 mm
Drive	Belimo NMQ24A-SRV-ST

Controller (1x air-intake unit, 1x exhaust-air unit)

Control panel	SMAY Sp. z o.o
Frequency inverter	Danfoss VLT®Automation Drive FC 302 – 4kW
Controller	URBS

URBS controller (1x controller for frequency inverter, 1x controller for motor louver damper) consists of:

Pressure sensor	Belimo VFP300
Controller	Belimo VRP-M

5 Analysis

In addition to the standard test a dynamic behavior test was run with the design parameters below:

Test	Performance class					
	$\dot{V}_N$ [m³/h]	$\dot{V}_L$ [m³/h]	Δp_{In} [Pa]	Δp_{PR} [Pa]	Δp_N [Pa]	Δp_V [Pa]
1 (performance class 1)	16,000	2,600	60	40	50	12
2 (performance class 1)	16,000	2,600	70	30	50	12

Table 5.1 Test variants

Figures 5.1 to 5.3 show the outline sketches of the functionality test and the durability for test 1 and the dynamic behaviour test in test 2. Tables 5.2 to 5.5 contain the test results and general data for each test.

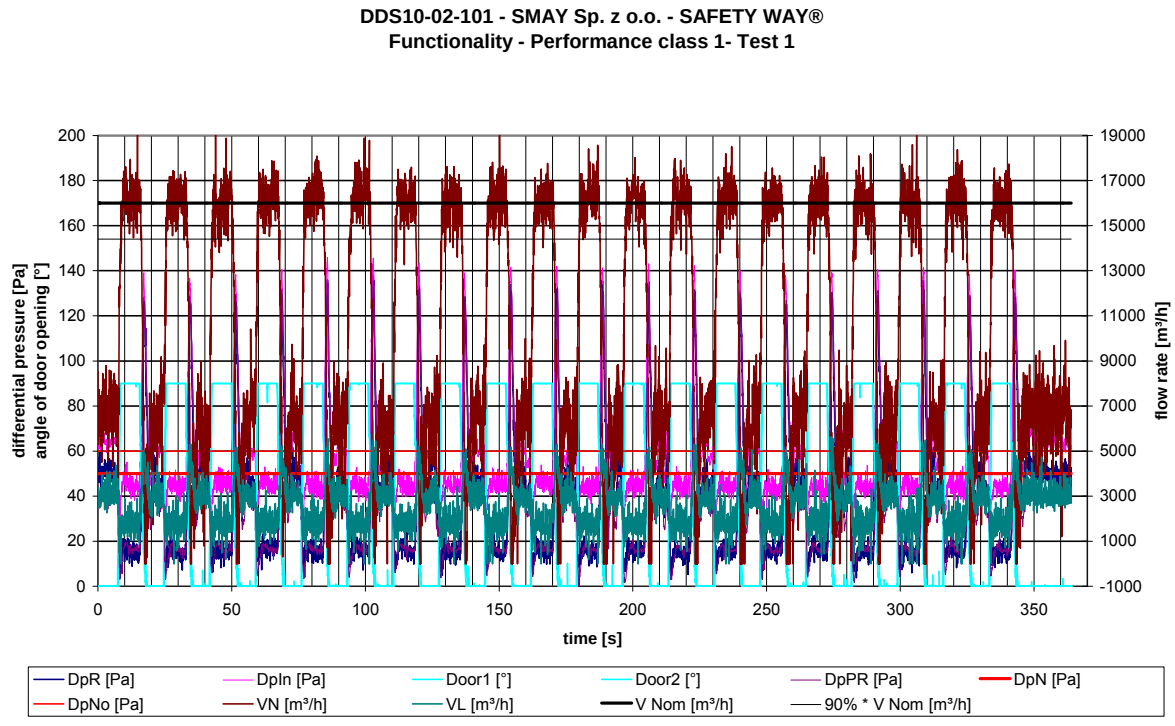

Fig. 5.1 Fu test 1

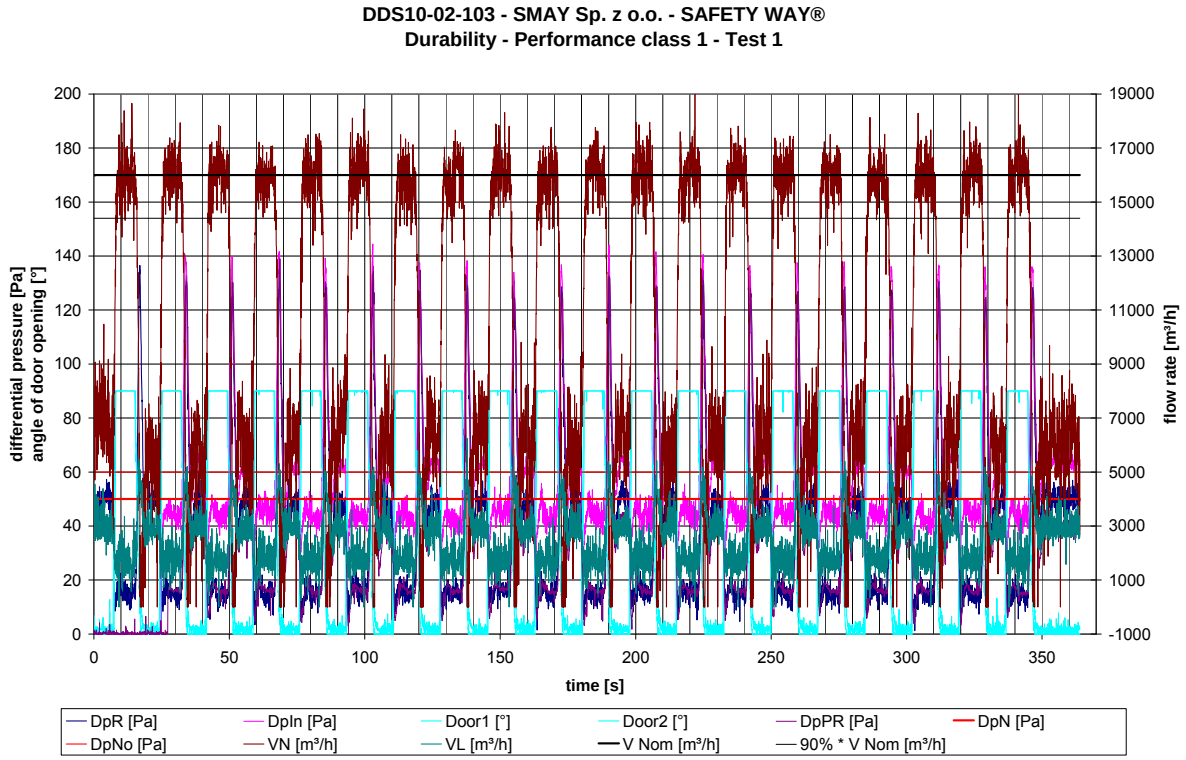

Fig. 5.2 Du test 1

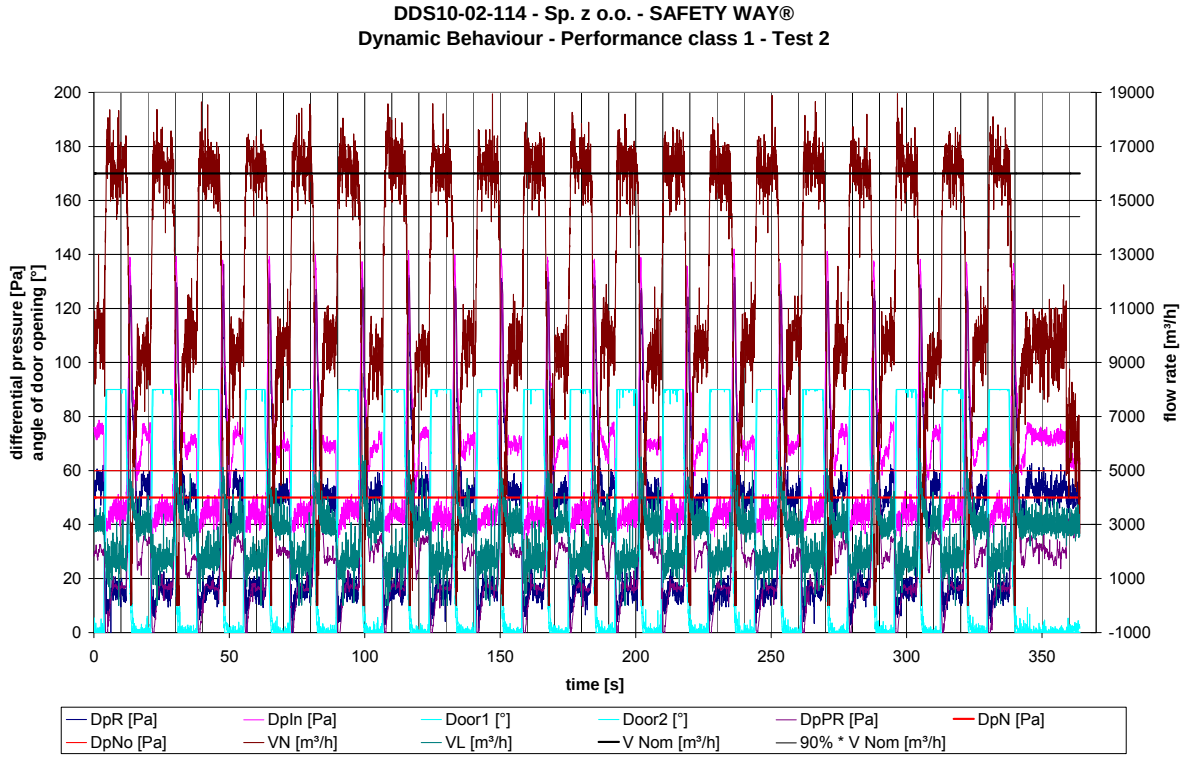

Fig 5.3 DB test 2

5.1 Analysis of test 1

SMAY Sp. z o.o. - SAFETY WAY®			
Performance class 1 - test 1			
V_N [m³/h]	**V_L [m³/h]**	**Δp_N [Pa]**	**Δp_V [Pa]**
16000	2650	50	16

Table 5.2 General data

SMAY Sp. z o.o. - SAFETY WAY®					
Table of results - performance class 1 - test 1					
Test	**t_3 [s]**	**Δp_{Nu} [Pa]**	**Δt_V [s]**	**Δt_p [s]**	**Results**
Fu		ok	1,4	0,3	**passed**
Rel					**passed**
Du		ok	1,0	0,2	**passed**
Res 1	3,0	ok		0,2	passed
Res 2	2,5			0,3	passed
Res 3	2,0	ok		0,3	passed
Res 4	1,5			0,2	passed
Res 5	1,0	ok		0,1	passed
Res 6	1,0		0		passed
Res 7	1,5	ok	0		passed
Res 8	2,0		1,8		passed
Res 9	2,5	ok	0,2		passed
Res 10	3,0		1,3		passed
Res					**passed**

Table 5.3 Test result

5.2 Analysis of test 2

SMAY Sp. z o.o. - SAFETY WAY®			
Performance class 1 - test 2			
V_N [m³/h]	**V_L [m³/h]**	**Δp_N [Pa]**	**Δp_V [Pa]**
16000	2650	50	16

Table 5.4 General data

SMAY Sp. z o.o. - SAFETY WAY®					
Table of results - performance class 1 - test 2					
Test	**t_3 [s]**	**Δp_{Nu} [Pa]**	**Δt_V [s]**	**Δt_p [s]**	**Results**
DB		ok	2,3	0,8	**passed**

Table 5.5 Test result

A n n e x A

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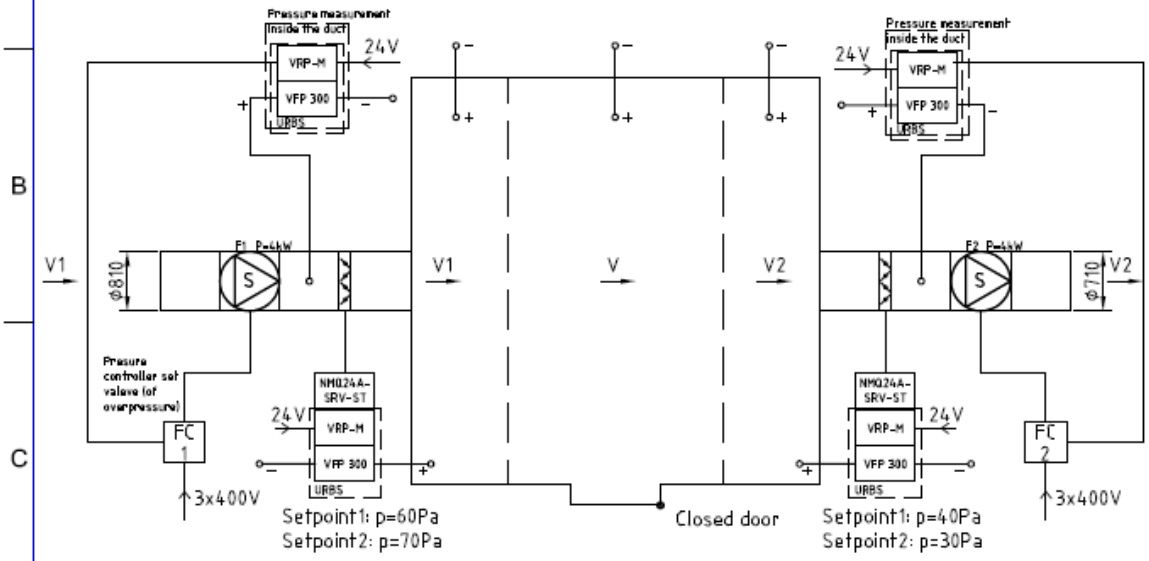
SMAY Sp. z o.o
Pressure differential system SAFETY WAY®

- Schematic diagrams -

Forced airflow mode

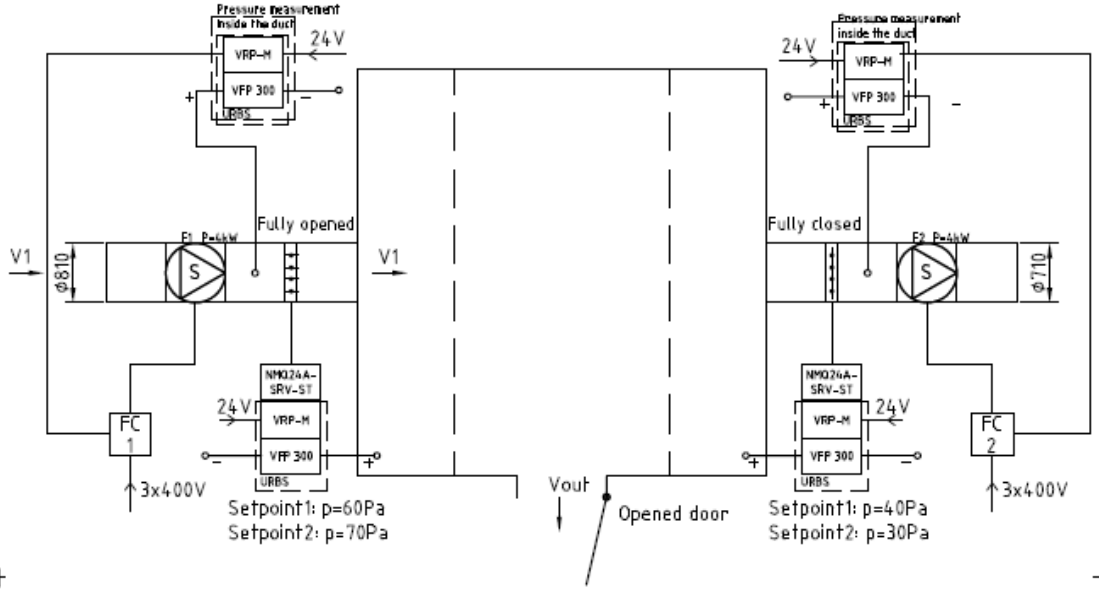


Specification:

- NMQ24A-SRV-ST – Actuator BELIMO NMQ24A-SRV-ST
- VRP-M – Pressure controller BELIMO VRP-M
- VFP 300 – Static differential pressure transducer BELIMO VFP 300
- S – Fan
- Multiblade damper
- F – Frequency converter

Projektował	R.Zapała	23.09.2010	SMAY Sp. z o.o. ul. Cieplownicza 29 31-587 Kraków	Plik	Safety Way - PID	Edycja 2
Sprawdził	P.Holewa			Zmiana	-	Arkusz 2/2
Zatwierdził	J.Wiche			SCALA	-	
Podziałka -	Format A4	Nazwa SWAY- PID - Schematic diagram - System 10			Nr rysunku 04.10.SWAY	

Forced airflow mode



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NMQ24A-SRV-ST – Actuator BELIMO NMQ24A-SRV-ST

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S – Fan

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F – Frequency converter

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Sprawdził	P.Holewa			Zmiana	-	Arkusz 1/2
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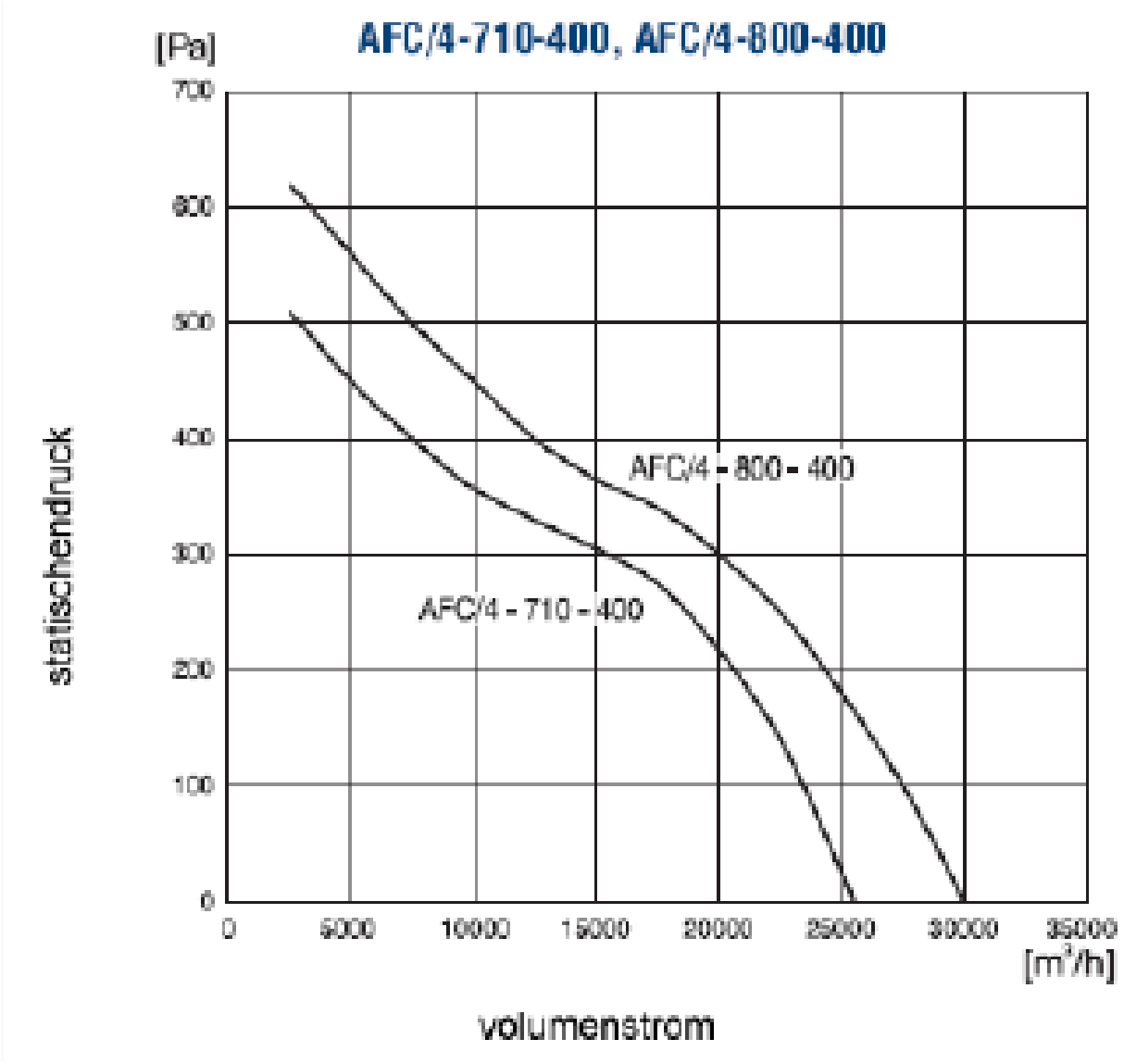
Podziałka -	Format A4	Nazwa SWAY- PID - Schematic diagram - System 10			Nr rysunku 04.10.SWAY	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[Pa]
700
600
500
400
300
200
100
0
statischendruck
AFC/4 - 800 - 400
AFC/4 - 710 - 400
0
5000
10000
15000
20000
25000
30000
35000
[m³/h]
volumenstrom

A n n e x B

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SMAY Sp. z o.o
Pressure differential system SAFETY WAY®

- System Images -

Fig. 1 Control unit, power supply and frequency converter for supply air and outlet air unit

Fig. 2 Pressure differential system SAFETY WAY® supply air unit with volumetric flow measurement system in front of test room

Fig. 3 Fan model plate of supply air

Fig. 5 SAFETY WAY® control components of supply air unit with louver damper SMAY PWII-S

Fig. 6 Belimo VFP300 pressure differential sensor

Fig. 7 Controller Belimo VRP-M

Fig. 8 Drive for louver damper Belimo NMQ24A-RV-ST

Fig. 9 SAFETY WAY® outlet air unit at test room

Fig. 10 Fan model plate of outlet air

Fig. 11 SAFETY WAY® control components of outlet air unit with louver damper SMAY PWII-S

A n n e x C

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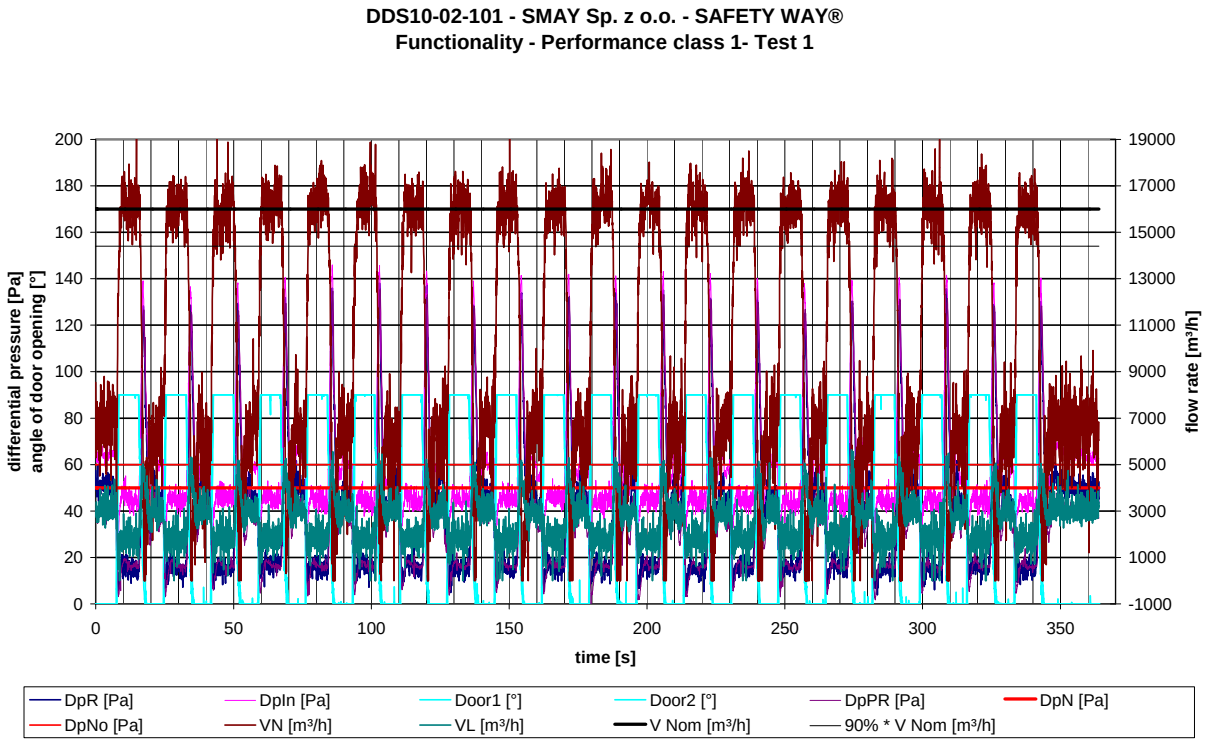
SMAY Sp. z o.o
Pressure differential system SAFETY WAY®

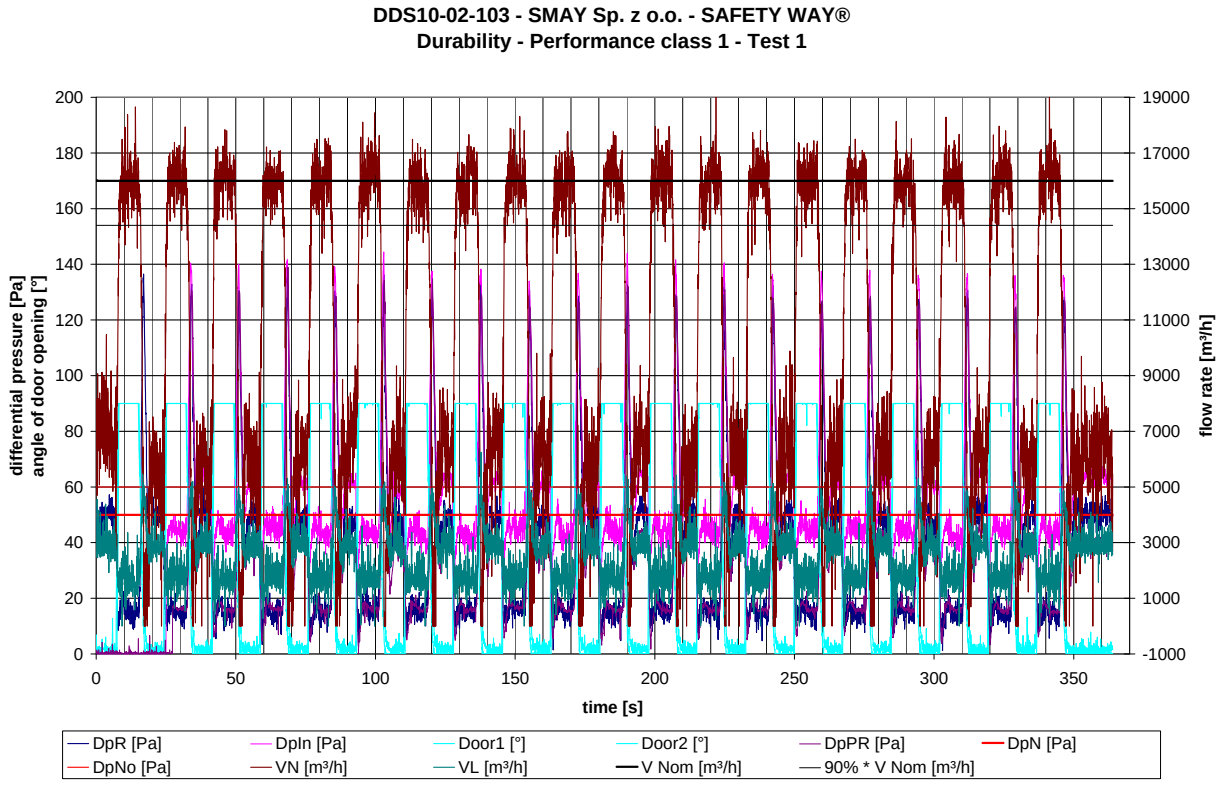
- Test Drawings -

Inhaltsverzeichnis

Performance Class 1 – Test 1 – Functionality

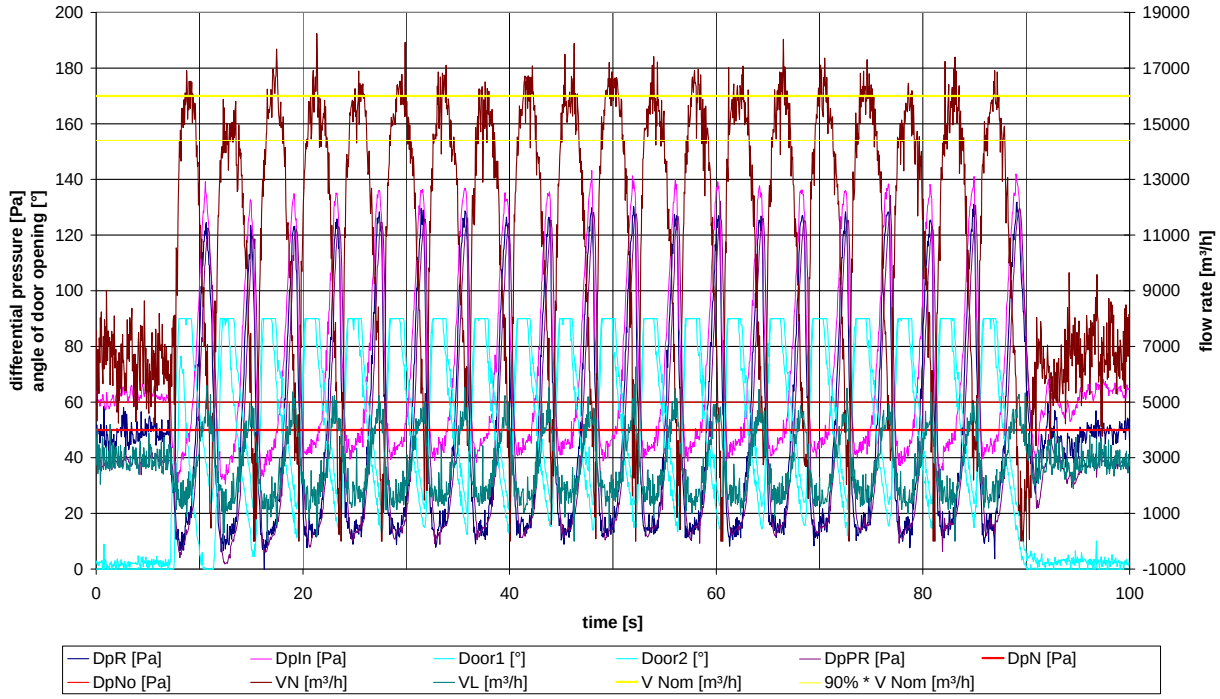


Performance Class 1 – Test 1 – Durability



Performance Class 1 – Test 1 – Resonance test

DDS10-02-104 - SMAY Sp. z o.o. - SAFETY WAY®
Resonance Test - t1=1s - t3=3s - Performance class 1 - Test 1



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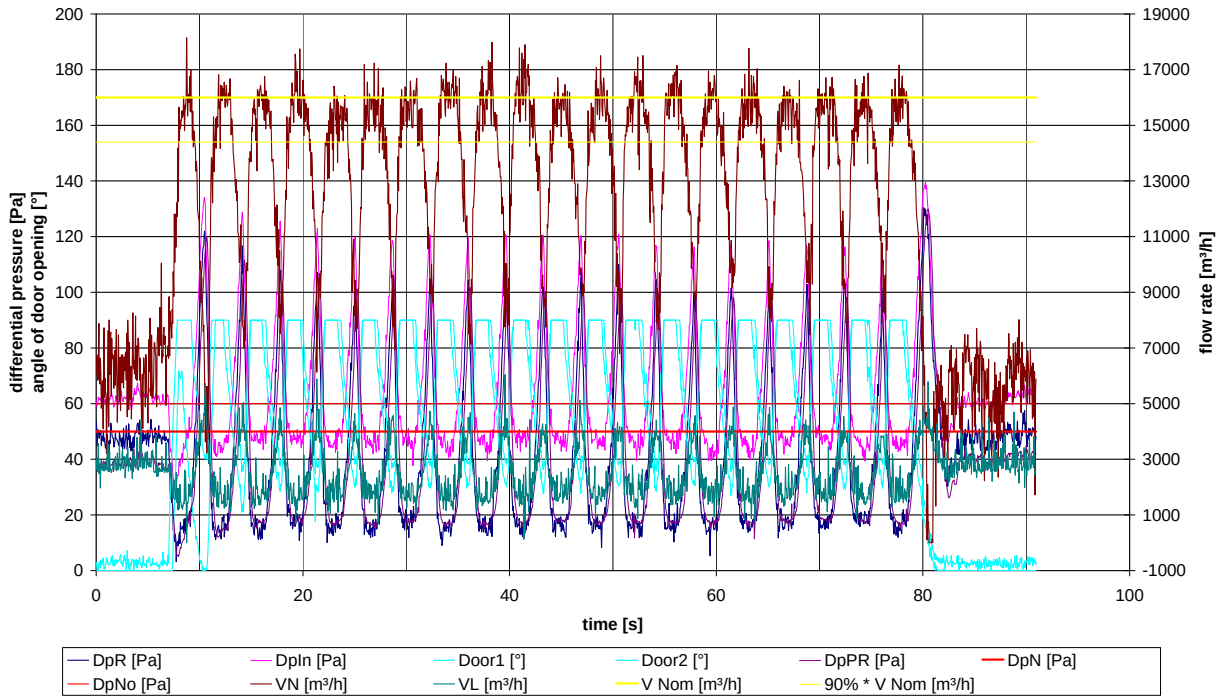
Resonance Test - t1=1s - t3=2,5s - Performance class 1 - Test 1



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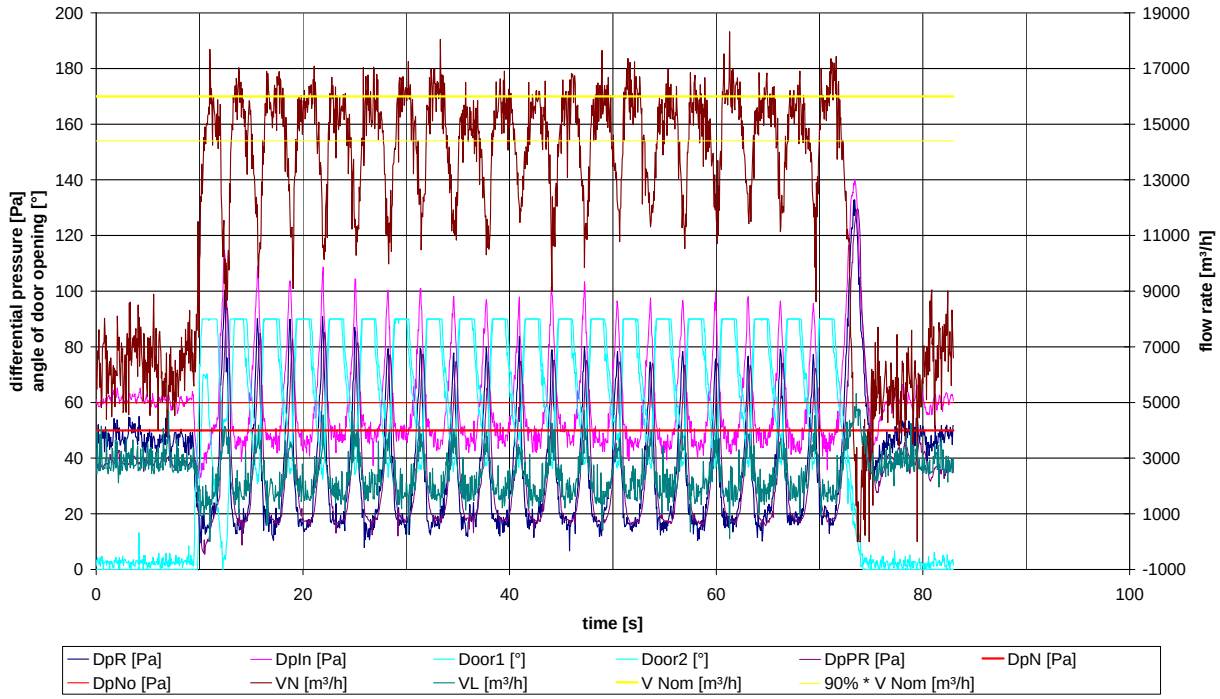
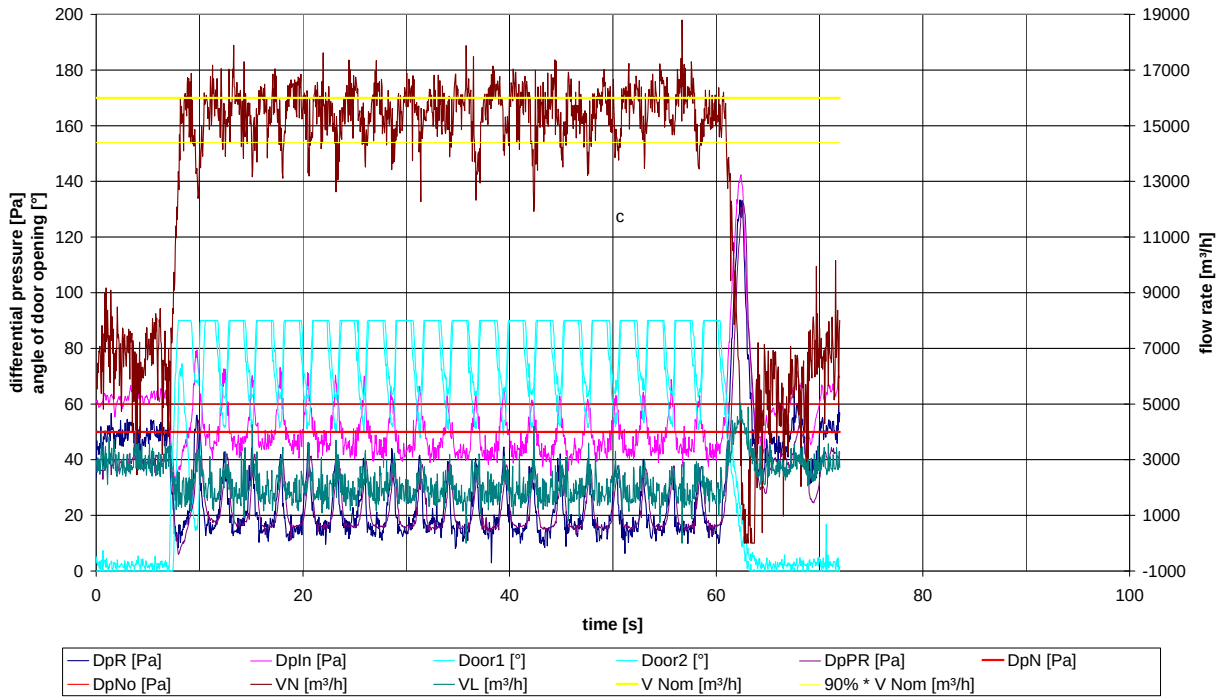
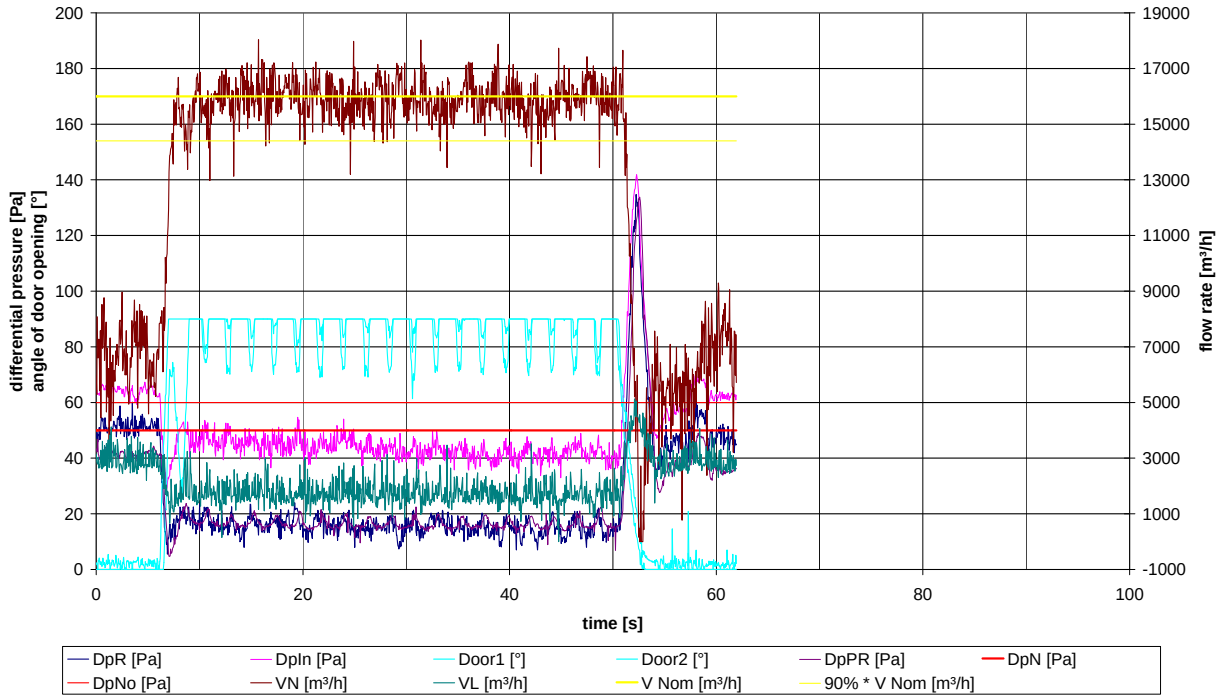
Resonance Test - t1=1s - t3=2s - Performance class 1 - Test 1



DDS10-02-107 - SMAY Sp. z o.o. - SAFETY WAY®
Resonance Test - t1=1s - t3=1,5s - Performance class 1 - Test 1



DDS10-02-109 - SMAY Sp. z o.o. - SAFETY WAY®
Resonance Test - t1=1s - t3=1s - Performance class 1 - Test 1



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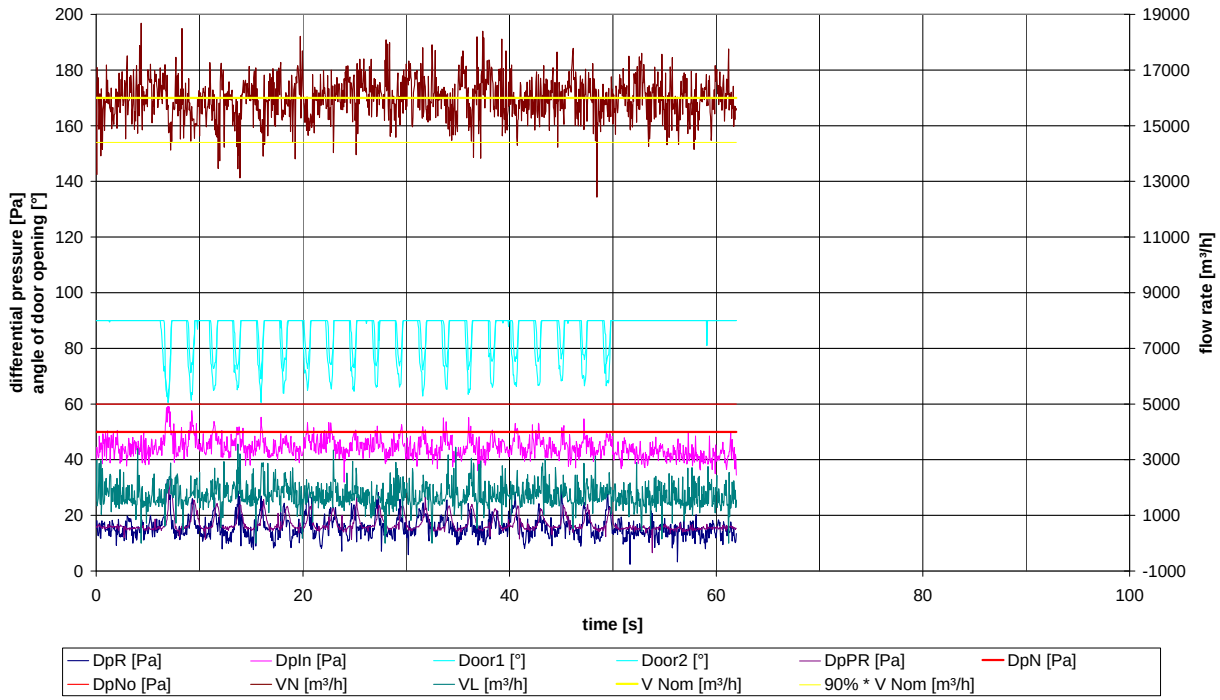
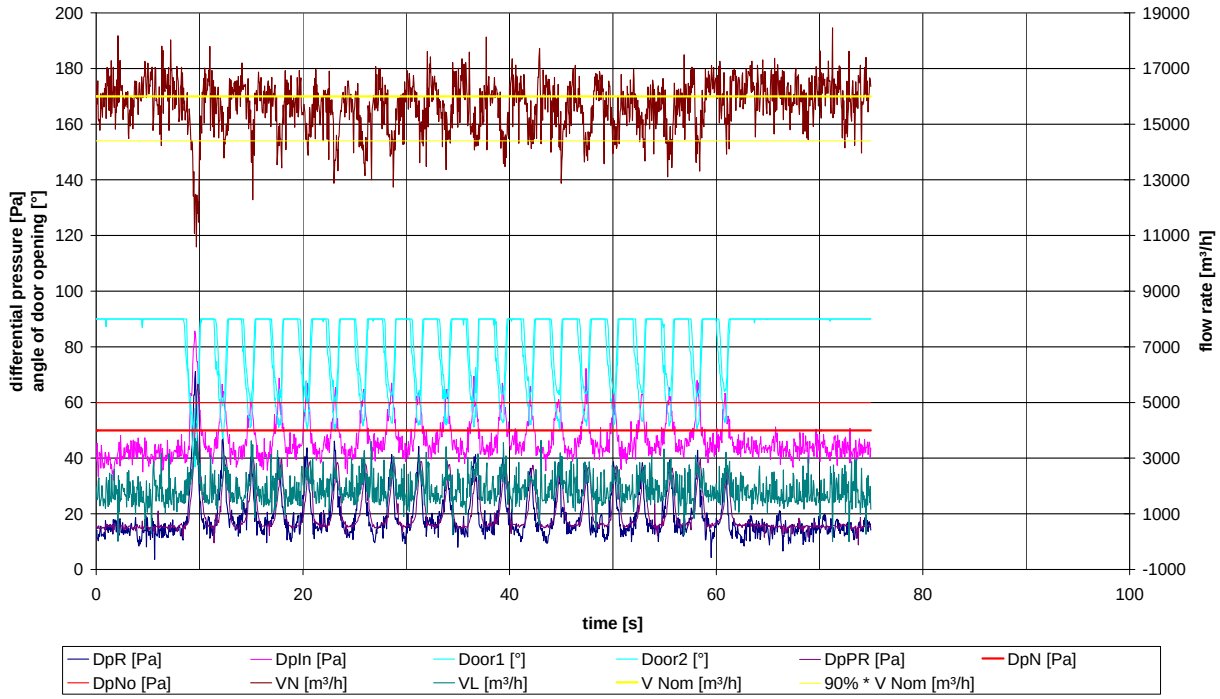
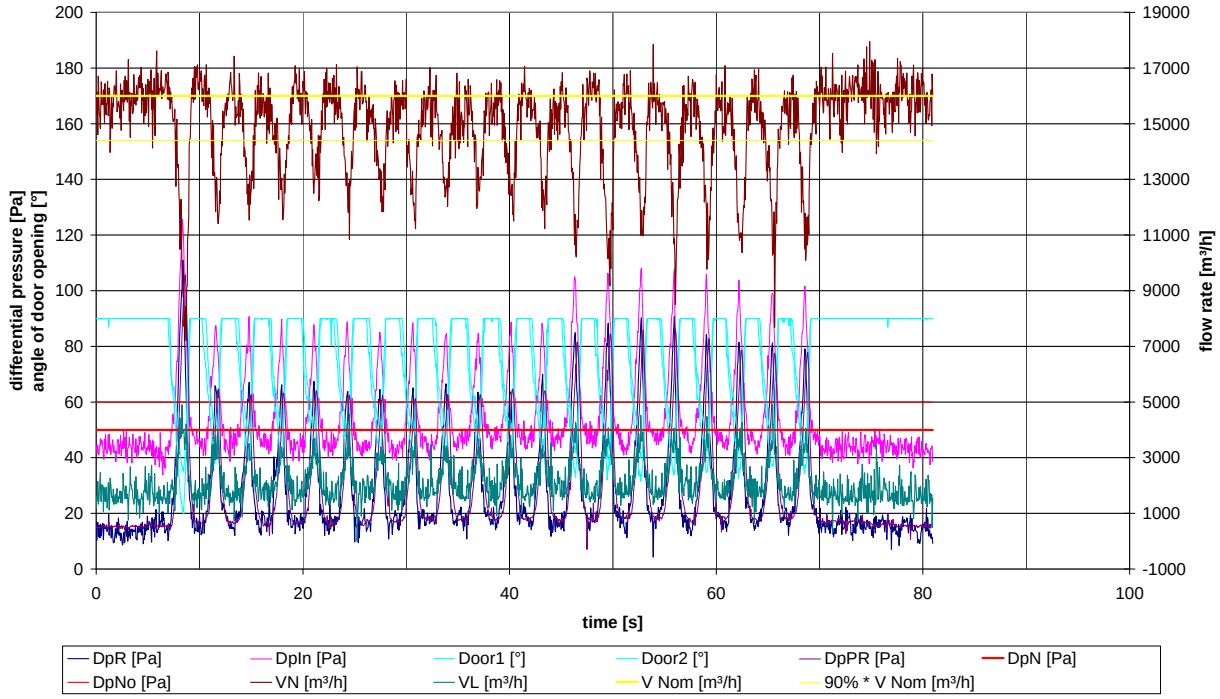
Resonance Test - t1=1s - t3=1s - Performance class 1 - Test 1



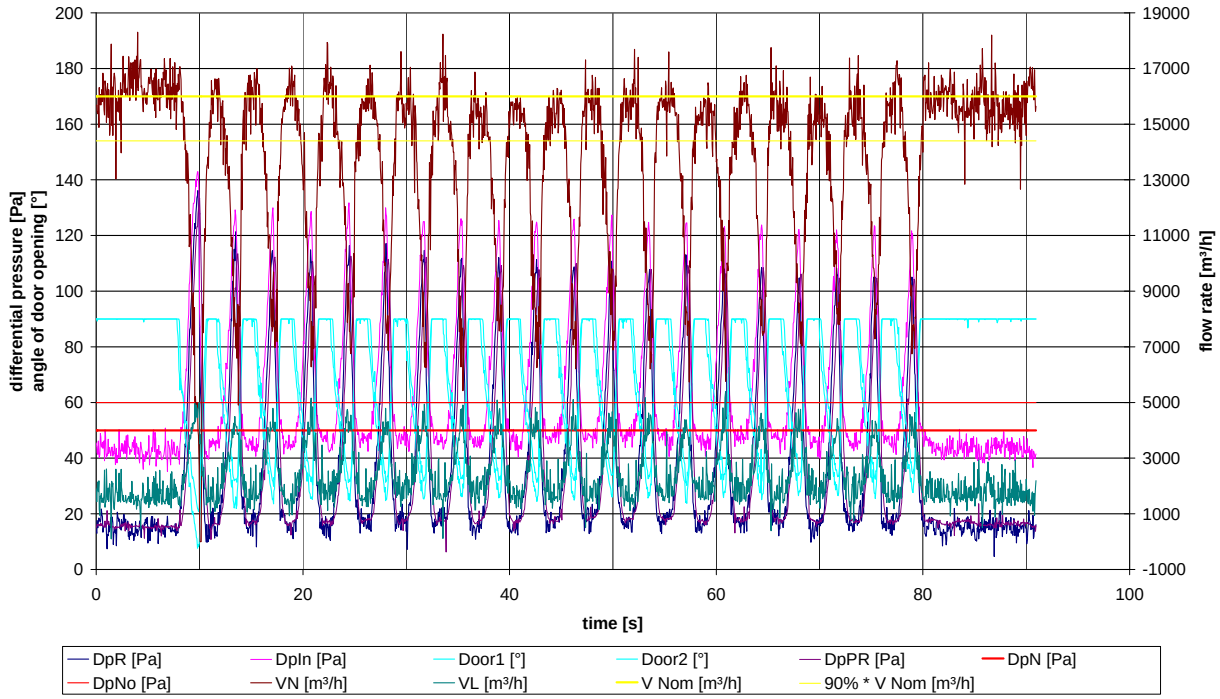
DDS10-02-110 - SMAY Sp. z o.o. - SAFETY WAY®
Resonance Test - t1=1s - t3=1,5s - Perfomance class 1 - Test 1



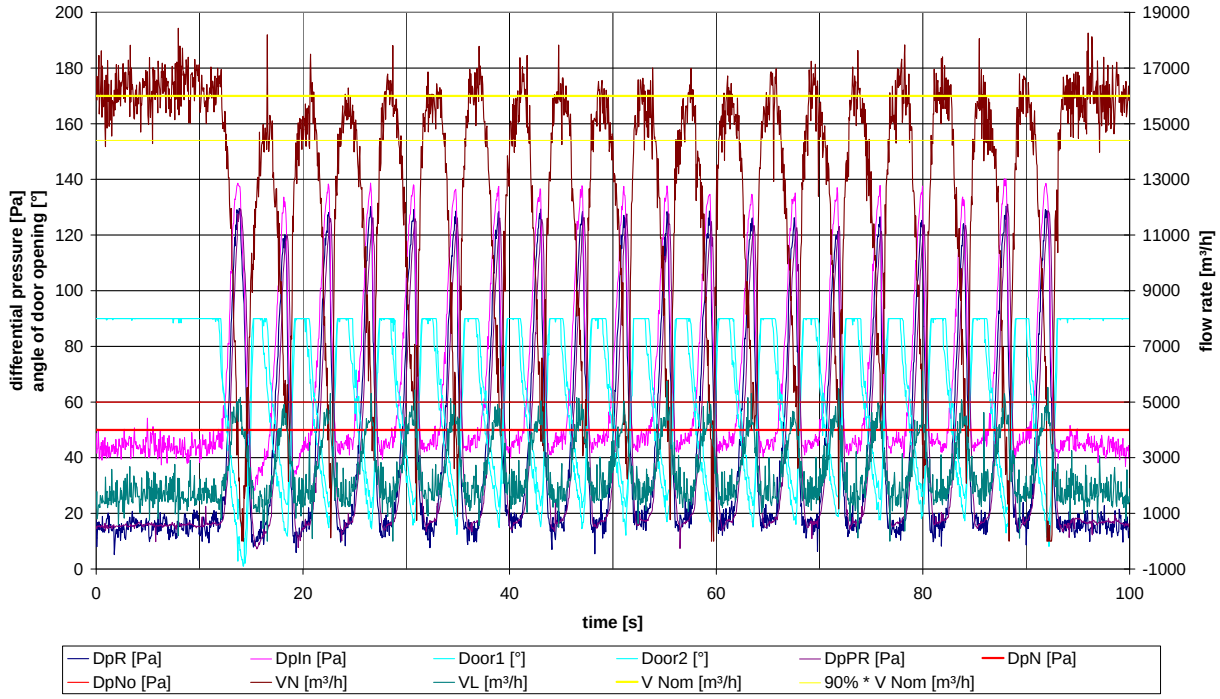
DDS10-02-111 - SMAY Sp. z o.o. - SAFETY WAY®
Resonance Test - t1=1s - t3=2s - Performance class 1 - Test 1



DDS10-02-112 - SMAY Sp. z o.o. - SAFETY WAY®
Resonance Test - t1=1s - t3=2,5s - Performance class 1- Test 1



DDS10-02-113 - SMAY Sp. z o.o. - SAFETY WAY®
Resonance Test - t1=1s - t3=3s - Performance class 1 - Test 1



Performance Class 1 – Test 2 – Dynamic Behaviour