FLOODSTAND Integrated Flooding Control and Standard for Stability and Crises Management

FP7-RTD- 218532

FLOODSTAND-deliverable:

Experiments with leaking and collapsing structures

Authors	Piotr Jakubowski, Norbert Bieniek
Organisation	CTO S.A.
Revision	1.6
Deliverable No.	D 2.1b
Date	08.10.2010

Document identification sheet		
FLOODSTAND	**Integrated Flooding Control and Standard for Stability and Crises Management**	FP7-RTD- 218532

Title: Experiments with leaking and collapsing structures	**Other report identifications:** CTO S.A. RK No. RK - 2010/T - 052 /E CTO reference: 5.167.01.221
Investigating partners: CTO, STX,MW **Author: Norbert Bieniek,** **Piotr Jakubowski** **Reviewed by**: **Mateusz Weryk**	
[ ] **Outline** [ ] **Draft** [x] **Final** **Version number:** 1.6 **Revision date:** 08.10.2010 **Next version due:** **Number of pages: 280**	[x] **A deliverable** [ ] **Part of a deliverable** [ ] **Cover document for a part of a deliverable** [ ] **Deliverable cover document** [ ] **Other** **Deliverable number**: CTO **Work Package**: WP2 **Deliverable due at month**: 15
Accessibility: [x] **Public** [ ] **Restricted** [ ] **Confidential (consortium only)** [ ] **Internal (accessibility defined for the final version)**	**Available from**: CTO **Distributed to**: **Disclosees when restricted:** **Comments:** Report accessibility for Consortium, Steering Committee and Advisory Committee.
Abstract: The report contains the results of tests in test tank, which is used for laboratory testing the strength of ship's structural elements: doors, windows, partition walls and others.	

Acknowledgements
The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 218532. The financial support is gratefully appreciated.

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EXECUTIVE SUMMARY (public)

The report contains the results of the flooding tests performed with a use of the test tank in a scale 1:1. The idea was to perform controlled flooding tests and simultaneously record some key parameters such as pressure, displacement and flow-rate. As a result of this test one get the information what is the realistic behavior of such structures with real loading conditions.
The testing procedure is described in Chapter 3. The main idea is to flow the water into the mock-up every 0.5 m water height and record all parameters mentioned above. This procedure is being repeated until the test object is damaged or water flow rate value exceeds critical value ~90 l/s or critical pressure above 220kPa. There were 20 object tested such as:
A-60 double leaf hinged marine fire, B class joiner door – hinged, Steelframes for B-wall and cabin wall, Steelframes for cabin wall, Cool Room sliding door, SWT door – sliding Steelframes, Cross flooding hatch, Sliding door and Hinged door.
During the test, 13 test objects have been damaged, 6 reached a critical flow, and 1 test object achieved critical pressure of 228 kPa.
In Chapter 5 “SUMMARY” one can find a table Tab. 5.1 Test end status and parameters maximum values (displacement, leak or pressure) which summarize all tests performed.

All tests were video recorded using both normal camera and high speed camera in order to record leakage and collapse phenomena. Special laser system was developed for displacement measurements.

As a result of this report one can find:
- flooding test results with all corresponding measured parameters (leakage, pressure, displacement)
- test procedure with test specimens list

Progress beyond state of the knowledge:
A special mock-up test stand was developed as a unique measurement tool used for leakage phenomena investigation. With a use of this laboratory device one has tested different kinds of ship’s partition. For the first time real scale leakage effect was investigated and precisely analysed.

CENTRUM TECHNIKI OKRĘTOWEJ S.A.
SHIP DESIGN AND RESEARCH CENTRE S.A.
CTO S.A.

SHIP STRUCTURES DIVISION

Address :
Al. Rzeczypospolitej 8
80-369 G D A Ń S K, POLAND

Phone: (48-58) 51-16-258
Fax: (48-58) 51-16-250
e-mail: rk@cto.gda.pl

TECHNICAL REPORT

No. RK - 2010/T - 052 /E

Title: Experiments with leaking and collapsing structures

Page 3
Number of pages 280
Copy No. …

Prepared by: Norbert Bieniek, Piotr Jakubowski

Approved by: Mateusz Weryk

Accepted by:

Gdańsk, 06.09.2010

GENERAL INFORMATION

Customer: European Commission, Research Directorate – General

Acronym: FLOODSTAND

Project Title: Integrated flooding and standard for stability and crises management

Project no.: FP7-RTD- 218532

CTO reference: 5.167.01.221

Work Package no 2: Flooding progression modeling

Task no 2.1: Experiments with leaking and collapsing structures.

Subtask no 2.1.2: Experiments

Subject of report
This report contains results of the flooding tests performed on ship's partition samples such as windows, door and walls.

Keywords:

……
……

Distribution of the Report:

Consortium: ……. copies
CTO S.A.: …. copies

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1. EXECUTIVE SUMMARY

The report contains the results of the flooding tests performed with a use of the test tank in a scale 1:1. The idea was to perform controlled flooding tests and simultaneously record some key parameters such as pressure, displacement and flow-rate. As a result of this test one get the information what is the realistic behavior of such structures with real loading conditions. The testing procedure is described in Chapter 3. The main idea is to flow the water into the mock-up every 0.5 m water height and record all parameters mentioned above. This procedure is being repeated until the test object is damaged or water flow rate value exceeds critical value ~90 l/s or critical pressure above 220kPa. There were 20 object tested such as:
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2. INTRODUCTION

Thru past few years a growth of size of passenger ships was observed. Simultaneously much more passengers are transported at once. Such concentrated large amount of passengers on decks leads to increase of risk of safety. Aspect of safety on sea becomes more meaningful and should be considered more widely than before. It is not sufficient just to fulfil the requirements of classification companies. Its necessary to predict potential danger in areas, where now they do not occur.
One of innovational ideas is a new look on stability and unsinkability of passenger ships, which is flooding of ship problem. It is necessary to study this process, because as many examples show, the time of flooding of vessel in similar conditions can be diametrically opposed to other vessel. The idea of this research is numerical simulation of flooding and its effects of doors and adjacent construction.
Specimens used in this Project were design and tested according to procedure mentioned in Delivery D2.1a.

3. STAND FOR EXPERIMENTAL STUDIES

Test specimens were provided by the STX and Mayer Werft shipyard and represent typical structures in a modern passenger ship. Also the installing was done with the same methods and practices as in the real ships.
For the purpose of conducting experiments, special mock-up test stand were design and consists of:

- Testing tank – volume ~3m^3 (Fig.1)
- water supply system (Fig.1, Fig.2)
- specimen mounting window (Fig.3)
- measurement system (Fig.4)

Fig. 1. Tank with source water from pump.

Water supply system (with leakage measurement) scheme is presented on Fig.2

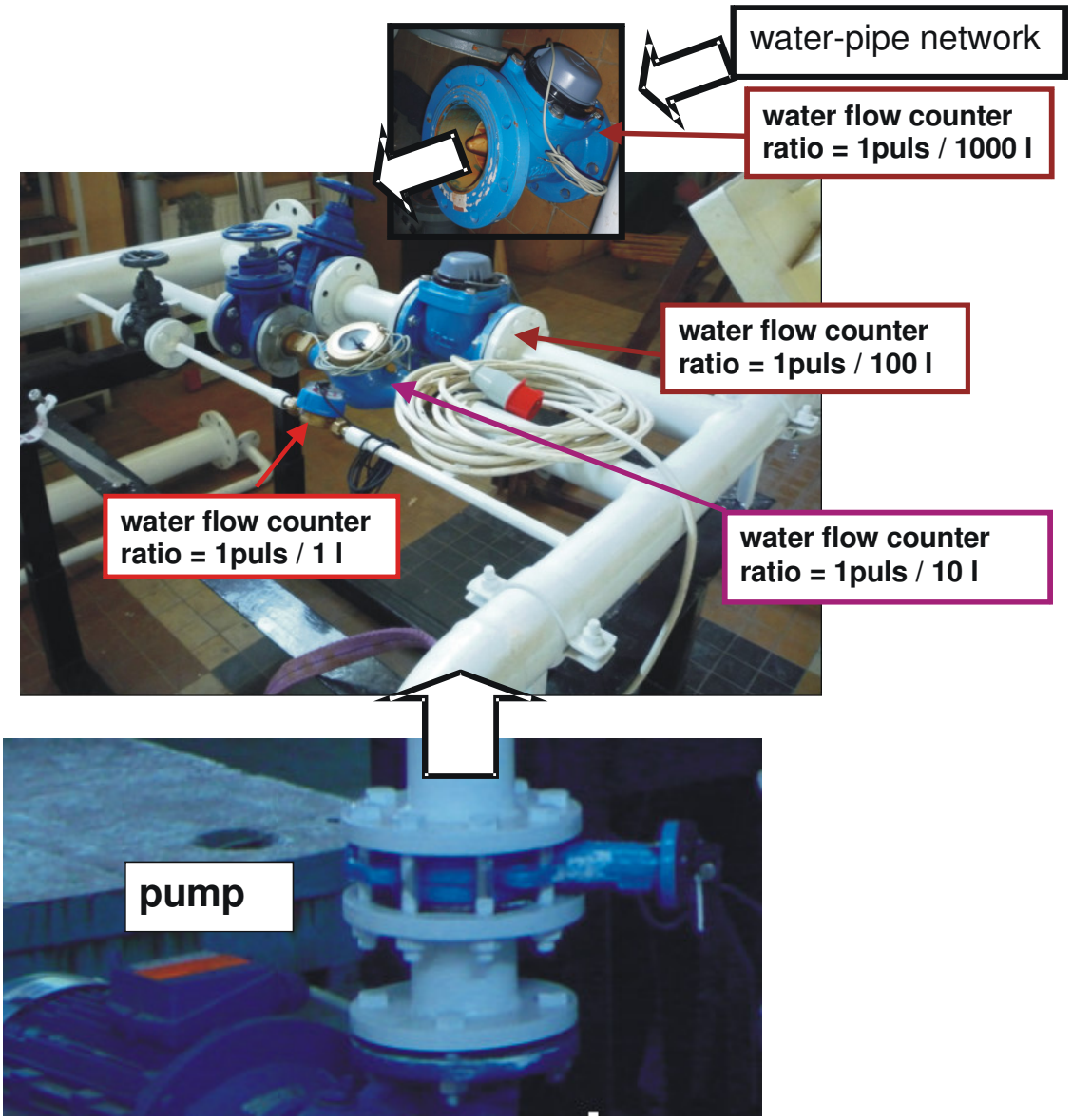


Fig. 2. Water supply system (with leakage measurement)

In this measurement system four water-flow meters were used with different resolution:

- 1 impulse / 1 litre
- 1 impulse / 10 litres
- 1 impulse / 100 litres
- 1 impulse / 1000 litres

Measurement system counts all impulses coming from all flow-meters simultaneously. The sum of counted impulses with proper multiplier in given time unit let one calculate water volume supplied to mock up test stand. Leakage measurement is done when there is constant flow, i.e. where pressure is constant (water supply volume => water leakage).

Fig. 3. Stand with installed test object.

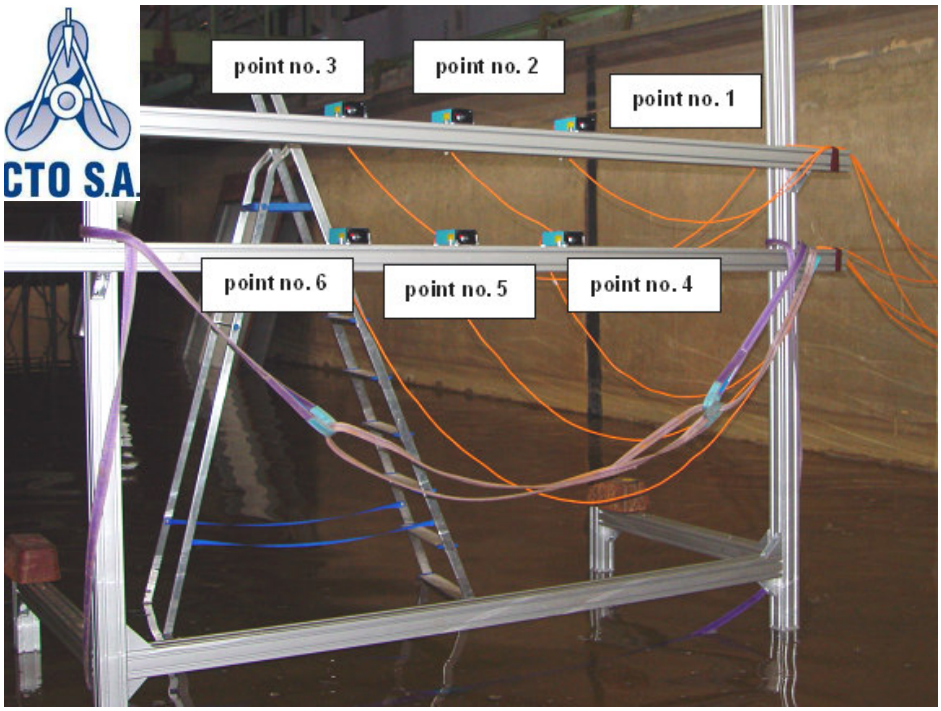


Fig. 4. Laser displacement measurement system.

DT500 Displacement sensor, model A311 presentation on Fig. 4 and Fig. 5.

Fig. 5. DT500 Displacement sensor, model A311

Technical data		DT500-	A311	A411	A323	A423
Measuring range		0.2 ... 7 m [1]				
		6 ... 90 % remission				
Reproducibility [2]		1 mm				
Accuracy		±3 mm				
Temperature drift		Typ. 0.05 mm/K				
Measured value output		150 ms				
Light spot diameter		10 mm at 7 m				
Resolution		0.1 mm				
Light source [3], **light type**		Laser diode, red light				
Laser class		2 (EN 60825/21 CFR 1040)				
Supply voltage V_S [4]		10 ... 30 V DC [5]				
Residual ripple [6]		5 V_{PP}				
Power consumption typ.	without heating	3 W				
	with heating	22 W				
External Teach ET	MF < 450 ms	Teach: > 12 V				
Laser off	MF > 450 ms	Free-running > 12 V				
No false triggering on power-up		Typ. 500 ms				
Current output		0 ... 20 mA/4 ... 20 mA				
Interface		CAN				
VDE protection class [7]		⧈				
Device connection		M12, 8-pin				
		M12, 5-pin				
CAN (CANopen Features)		20 ... 1000 kbit/s				
CAN Address		11 bits in size				
Enclosure rating		IP 65				
Ambient temperature	without heating	Operation –10 °C ... +50 °C				
	with heating	Operation –40 °C ... +50 °C [4]				
		Storage –25 °C ... +75 °C				
Weight		Approx. 1000 g				
Initialisation period		Typ. 500 ms				
EMC		EN 61000-6-2, EN 55011				
		EN 60947-5-7:2003-09				
Mechanical load		Shock: EN 600 86-2-27/-2-29				
		Sine: EN 600 68-2-6				
		Noise: EN 600 68-2-64				

1) Accurate to 7 m only
2) Statistical error 1 σ, environmental conditions constant
3) Average service life 50,000 h at T_A = +25 °C
4) Reverse-polarity protected
5) V_S ≥ 24 V DC for DT500-A4xx with heating
6) May not exceed or fall short of V_S tolerances

Fig. 6. Technical data the laser distance sensor.

Pressure sensor type: 8251 75 2517 17 (range 0-2,5 bar) presentation on Fig. 7.

MAIN CHARACTERISTICS

- Sensor: Thin film on steel
- Measuring range: 0...2.5 to 0...600 bar /0...30 to 0...7500 psi
- Signal output: 4...20 mA
  0...5 VDC
  1...6 VDC
  0...10 VDC
- NLH (BSL through 0): ± 0.3 % FS typ.

TYPE:	Industrial Pressure Transmitter						**8251**
RANGE: [psi]	Nominal pressure:	0...30	Overpressure:	70	Burst pressure:	720	**G5**
		0...50		115		860	**G6**
		0...100		170		1450	**G7**
		0...150		290		2900	**G8**
		0...250		464		2900	**G9**
		0...400		725		4350	**H0**
		0...500		1160		4350	**H1**
		0...1000		1740		5800	**H2**
		0...1500		2900		7250	**H3**
		0...2000		4640		10850	**H5**
		0...3000		7250		14500	**G4**
		0...5000		11600		21750	**H4**
		0...7500		14500		29000	**H6**
	[bar]	0...2.5		5		50	**75**
		0...4.0		8		80	**76**
		0...6.0		12		100	**77**
		0... 10		20		200	**78**
		0... 16		32		200	**79**
		0... 25		50		300	**80**
		0... 40		80		300	**81**
		0... 60		120		400	**82**
		0...100		200		500	**83**
		0...160		320		750	**85**
		0...250		500		1000	**74**
		0...400		800		1500	**84**
		0...600		1000		2000	**86**
		customized ranges on request e.g.:				−1 ... +4 bar	**XX**
SENSOR:	Relative pressure						**25**
	Absolute pressure						**45**
PRESSURE CONNECTION:	G1/4"	male	O-Ring				**17**
	1/4"NPT	male					**30**
	7/16"-20UNF	male		(only for relative pressure measurement)			***18**
	7/16"-20UNF	female	(valve opener)	(only for relative pressure measurement)			***24**
	*max. allowable pressure range: 40 bar/500psi; for relative pressure only						
EXECUTION:	Male electrical plug:	industrial standard (contact distance 9.4mm)				Material.: PBT	**01**
		M12x1 / 4-pole				Material.: PBT	**32**
		M12x1 / 5-pole				Material.: PBT	**35**
				150			
OUTPUT:		load resistance		I_{supply}			
	4...20mA	(U_{supply} -9V)/20mA					**19**
	0... 5 VDC	≥2.0kΩ		≤10mA			**14**
	1... 6 VDC	≥2.0kΩ		≤10mA			**16**
	0... 10 VDC	≥5.0kΩ		≤10mA			**17**
ACCESSORIES:	Female electrical connector:	M12x1 / 5-pole		(for execution 32 + 35)			**33**
		industrial standard					**34**
	Pressure peak damping element:	(only for pressure connection Nr. 17+30)			hole:	ø 1.0mm	**40**
						ø 0.3mm	**43**
						ø 0.5mm	**45**
	Special electrical connection:						**96**
	(only for execution male electrical plug No.: 32/ for output No.: 14/16/17						

Fig. 7. Pressure sensor technical data.

Pressure sensor type: 8251 75 2517 17 – photo.

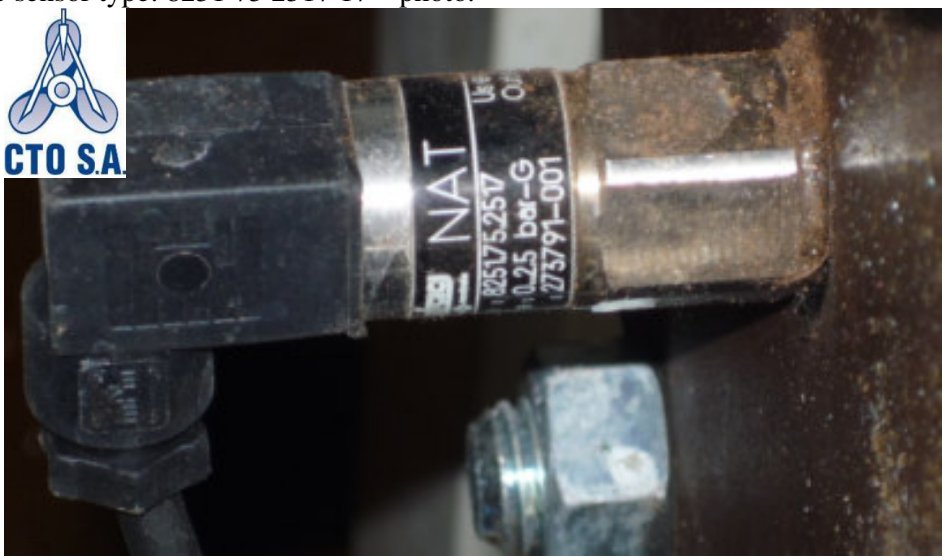


Fig. 8. Pressure sensor – photo.

Recording computer with software presentation on Fig. 9.

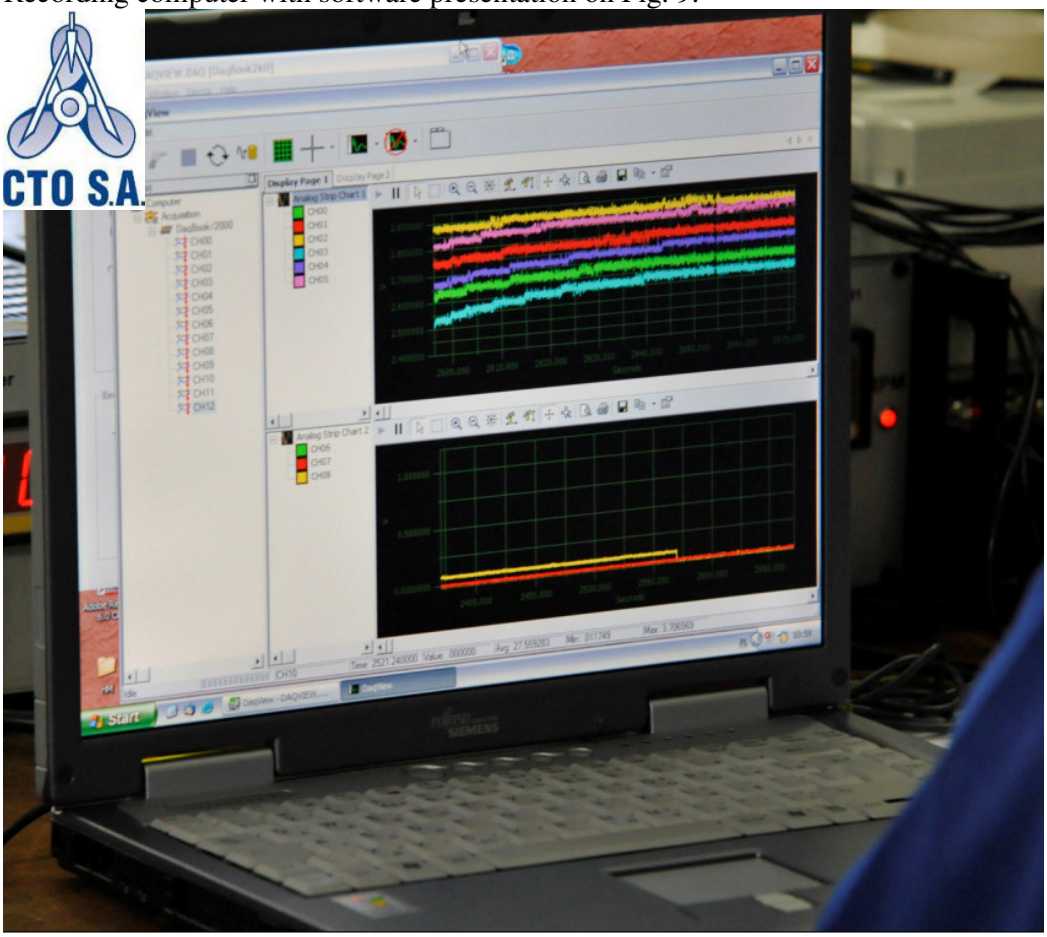


Fig. 9. Recording computer.

Pressure was evaluated according the rule presented in Fig. 10.:

$$1\ [\text{m } H_2O] = 0{,}1\ [\text{bar}] = 10\ [\text{kPa}]$$

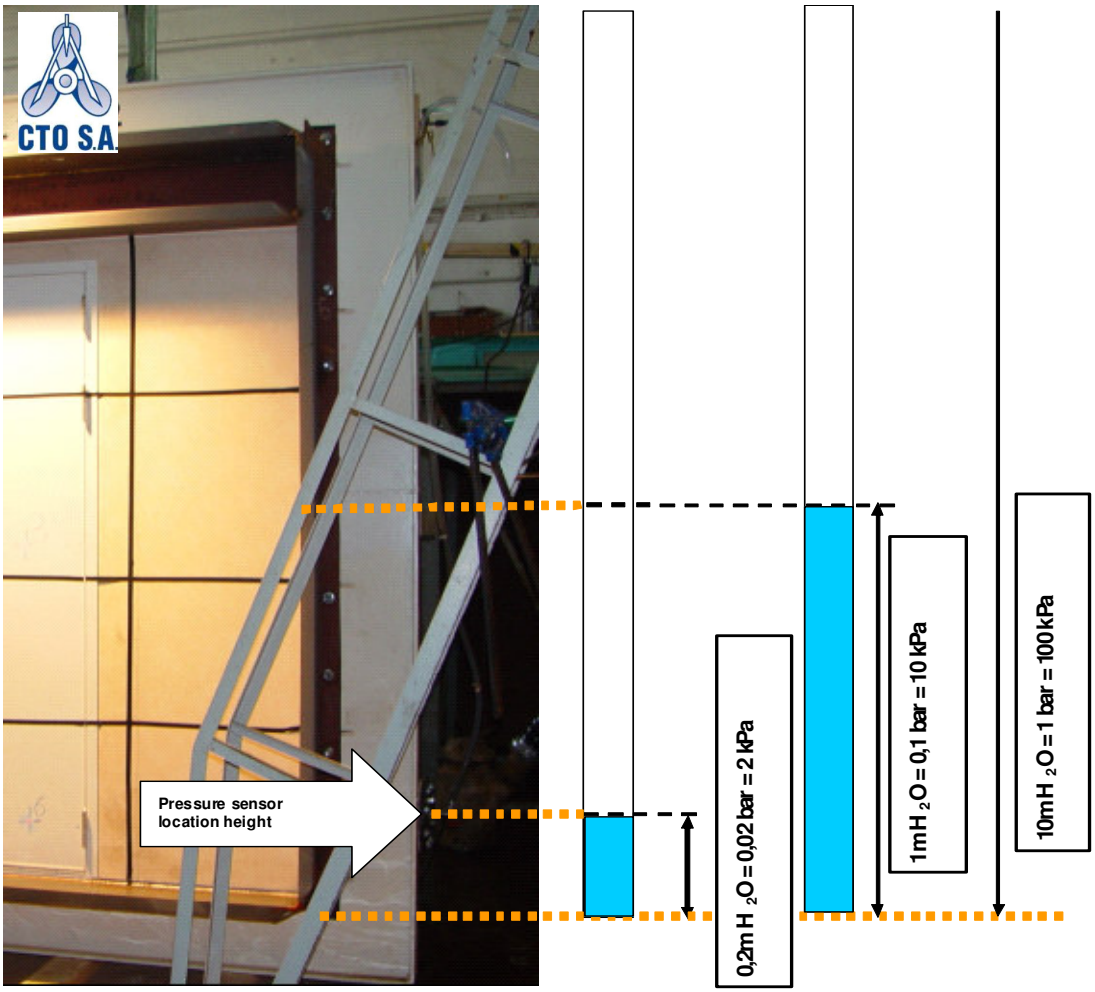


Fig. 10. Pressure conversion between [m H_2O] , [bar] and [kPa] in relation to tank's bottom.

Water density in function of temperature is presented in below table

Tab. 1. Water density

Temp. (°C)	Density (kg/m^{-3})	Temp. (°C)	Density (kg/m^{-3})	Temp. (°C)	Density (kg/m^{-3})	Temp. (°C)	Density (kg/m^{-3})
0	999,84	8	999,85	16	998,94	50	988,04
1	999,90	9	999,78	17	998,77	60	983,21
2	999,94	10	999,70	18	998,59	70	977,78
3	999,96	11	999,60	19	998,40	80	971,80
4	999,97	12	999,49	20	998,20	90	965,31
5	999,96	13	999,37	25	997,04	100	958,35
6	999,94	14	999,24	30	995,64		
7	999,90	15	999,10	40	992,21		

During testing, water temperature was in a range between 14-15 °C (mean value14,5 °C), therefore water density was 999,24 – 999,10 kg/m^{-3} (mean value 999,17 kg/m^{-3})

TEST PROCEDURE

In order to test it:

- Mount the test object on the tank (Fig. 2),
- Determine the measurement points,
- Set the laser sensors on specific points,
- Programming the sensor measuring range according to the rule: the distance to the point L_0, L_0 + 0.10 m and L_0 - 0.20 m,
- Connect the pressure sensor and laser sensors to (filters, optical isolation card + measurement card),
- Recording start (displacement, pressure, leakage, video recording),
- Pump system start,
- Pumping the water to a pressure p=5kPa and for steady leakage conditions water flow (leakage) is recorded [l / s],
- Procedure repeat in steps of 5kPa up to: sample damage or leakage excess or critical pressure above p=220kPa,
- Recorded files digitally filtered,
- Measurement results presented in forms of graphs and tables.

Test is executed properly when test object is damaged or water flow rate value exceeds critical value ~90 l/s or critical pressure above 220kPa.

4. RESULTS OF THE MEASUREMENTS

4.1 ELEMENTS: TYPE B2, A class fire door

a) Model no. 1.1; Sliding door; test no 15628, (direction: "INTO the door frame")

Test No. 15628, tested object no. 1.1 - Sliding door – Pressuring in the way of "into the door frame".

Dimensioning of measurements points of the element no 1.1.

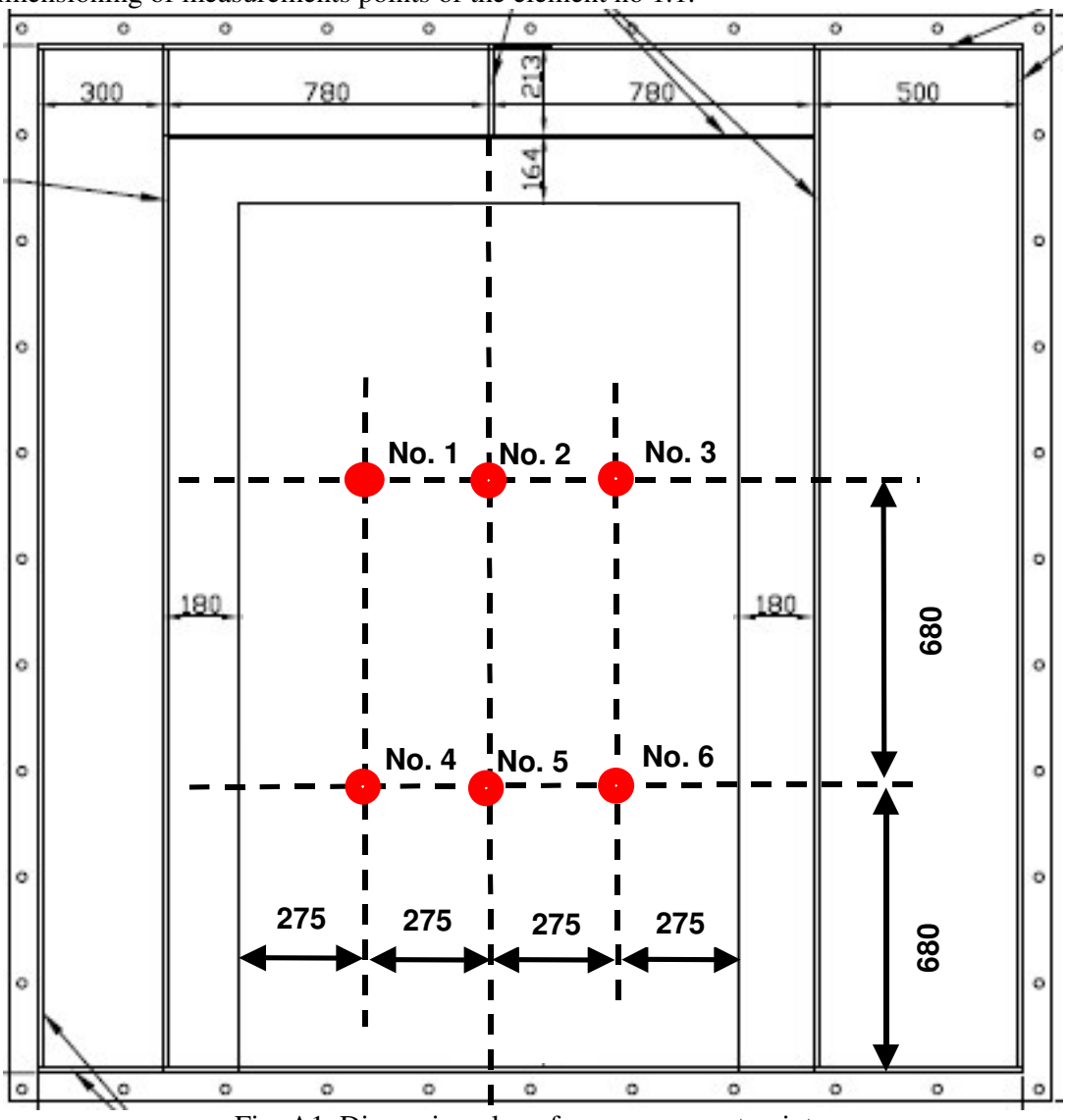


Fig. A1. Dimension plan of a measurement points.

Stand with installed test object no 1.1.

Fig. A2. Stand with installed object test.

Fig. A3. Measuring points location.

Results of the test are presented on Fig. A4 to Fig. A7.

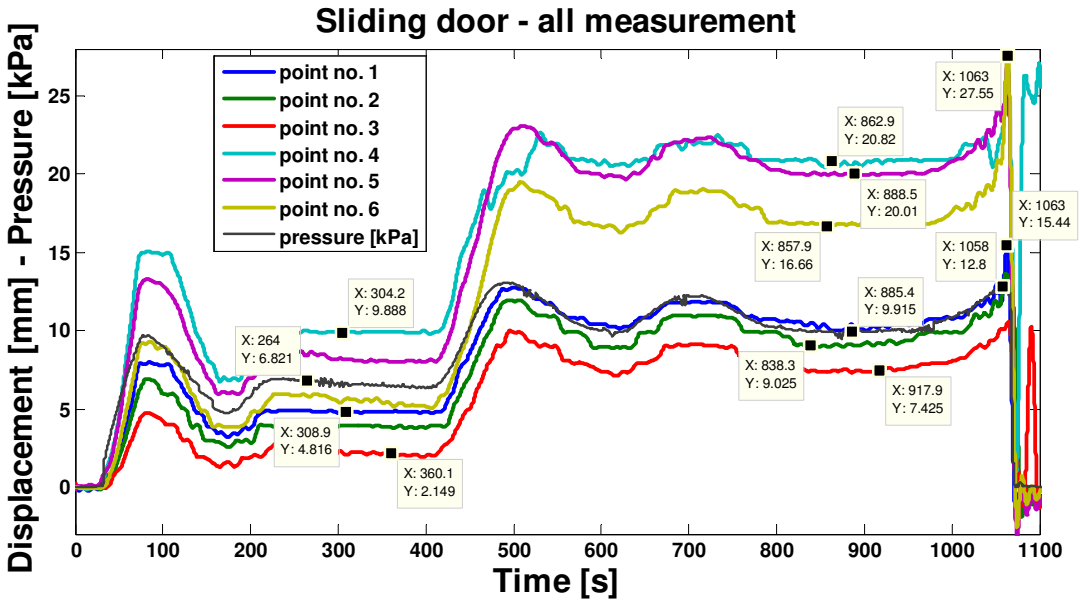


Fig. A4. Measurement results (full time history).

1th phase – tank filling up, presentation on Fig. A5.

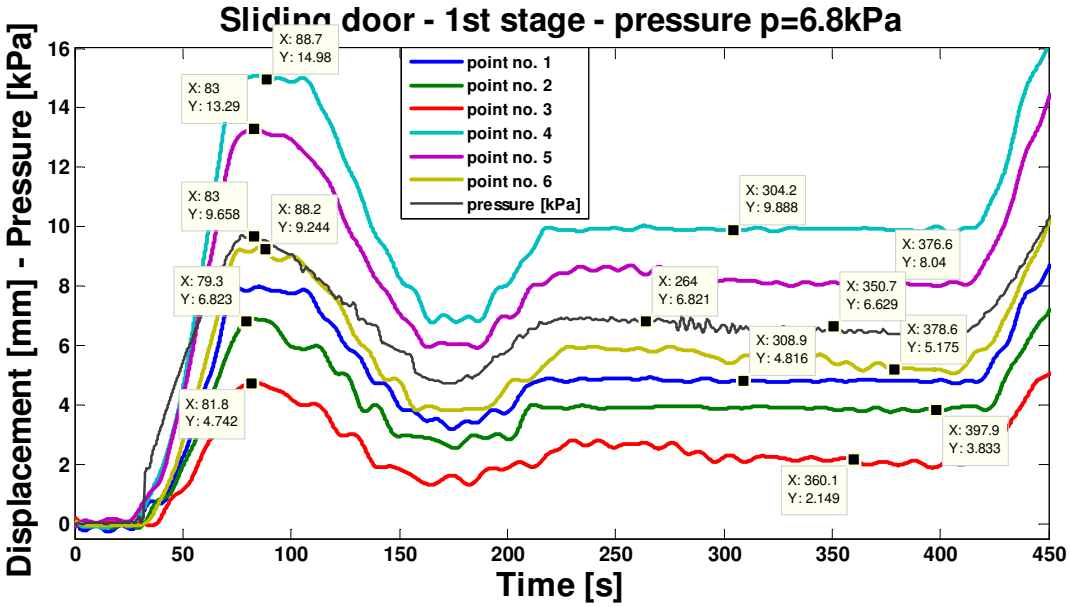


Fig. A5. Pressure – 6.8 kPa.

2nd phase – pressure level p=9.9 kPa, presentation on Fig. A6.

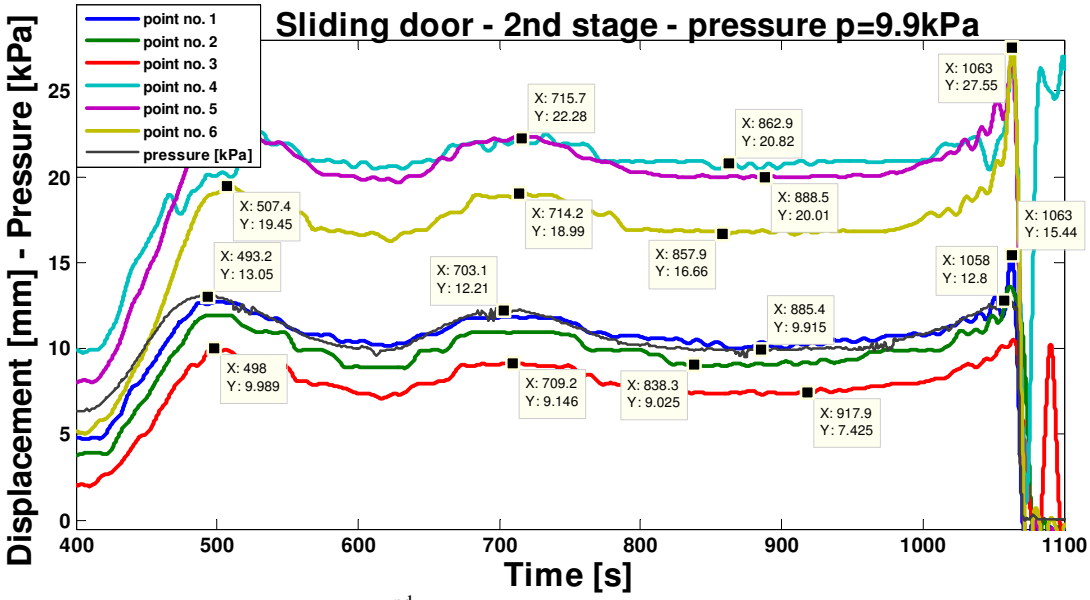


Fig. A6. 2nd phase – pressure level p=9.9 kPa.

3rd stage – finish.

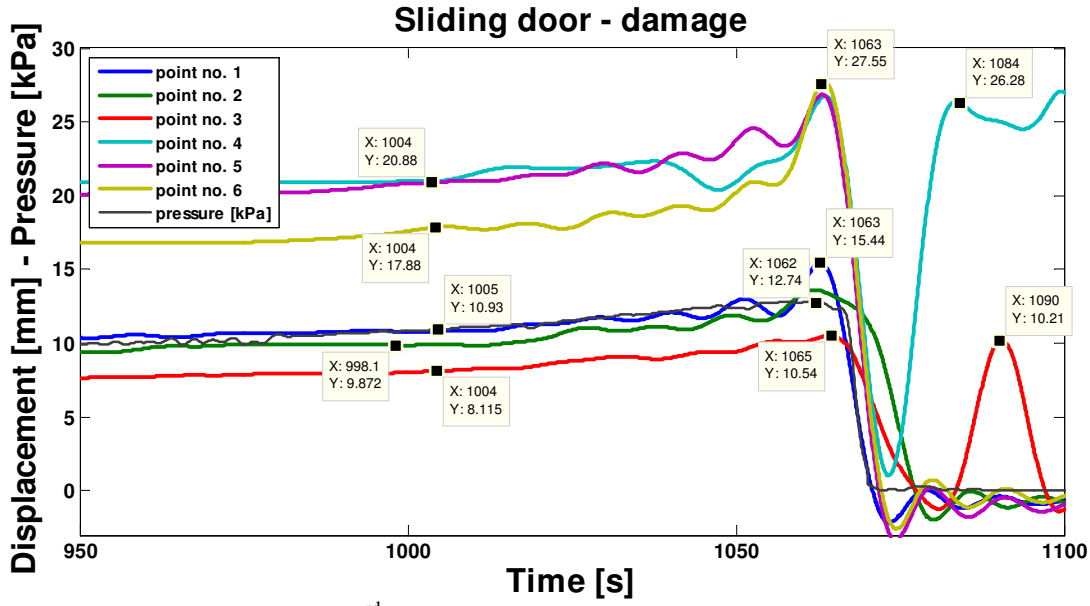


Fig. A7. 3rd stage – finish, pressure level 12.7 kPa.

Table TA.1. Displacement, leakage and pressure test results.

Tab. TA.1	Test results object no. 1,1, test number 15628							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	6,7	4,82	3,90	2,25	9,89	8,23	5,81	8,1
2	10,0	10,54	9,00	7,42	20,94	20,01	16,67	49,4
3	12,8	damage	damage	damage	damage	damage	damage	------

Test photos.

Test object no. 1.1. damage

Fig. A8. Door damage.

Fig. A9. Door damage.

Fig. A10. Door damage.

Fig. A11. Door damage – the upper right corner.

Fig. A12. Door damage – the bottom left corner.

Fig. A13. Mounting bracket.

Fig. A14. Mounting bracket.

Fig. A15. Door lock.

Fig. A16. Door damage – the bottom right corner.

Fig. A17. Door damage – the upper right corner – view from inside the tank.

Fig. A18. Door damage – the upper light corner – view from inside the tank.

Fig. A19. Door damage – the bottom left corner – view from inside the tank.

Fig. A20. Door lock – view from inside the tank.

Fig. A21. Damage the wall from the door lock.

Fig. A22. Damage the wall the lower left corner.

Fig. A23. Damage the wall the upper right corner.

b) Model no. 1.2; Sliding door; test no 15630, (direction: "OUT the door frame")

Stand with installed test object no. 1.2, test no 15630.

Fig. B1. Stand with installed object test.

Dimensioning of measurements points of the element no. 1.2.

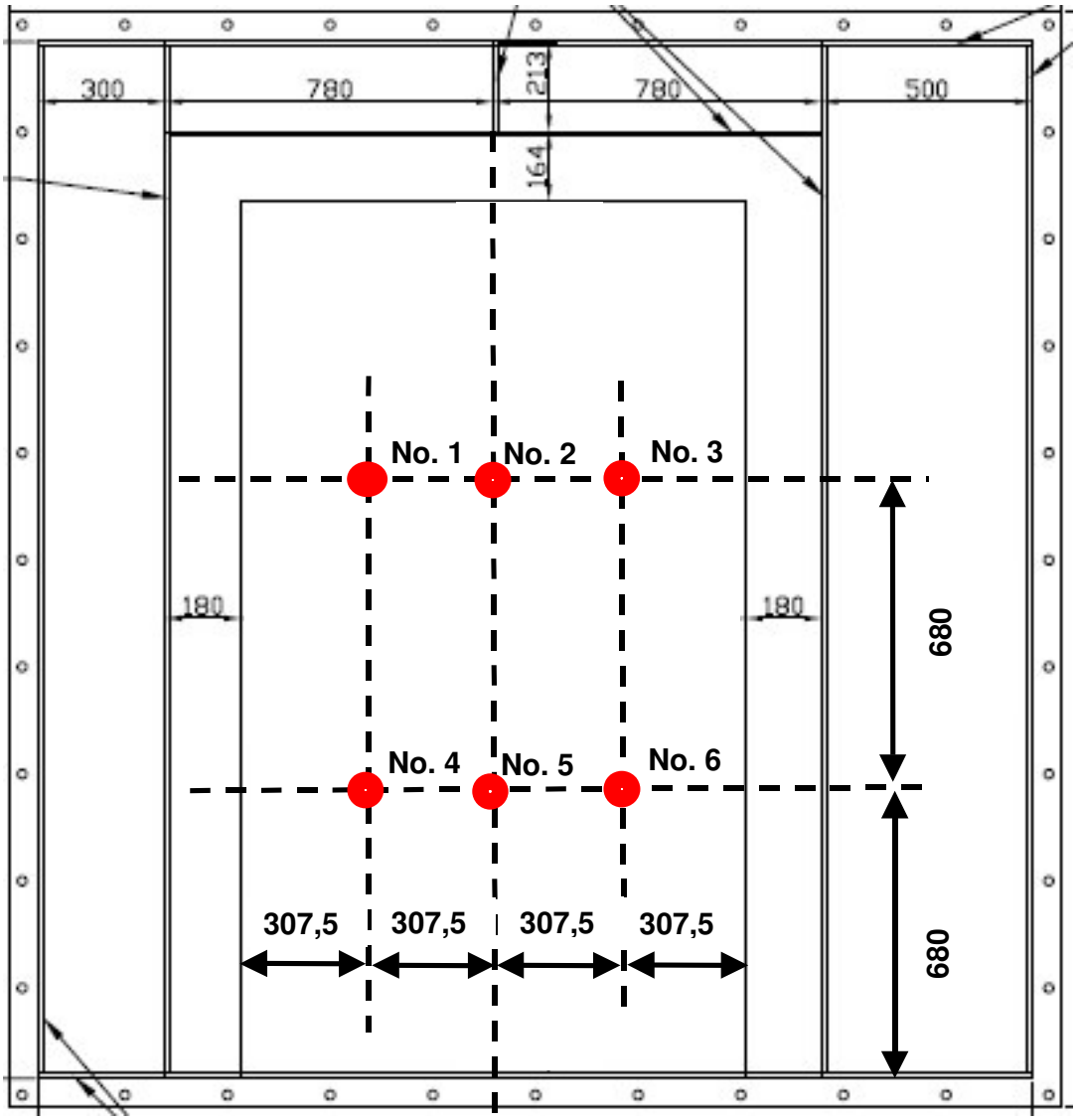


Fig. B2. Dimension plan of a measurement points.

Results of the test are presented on Fig. B3 to Fig. B6.

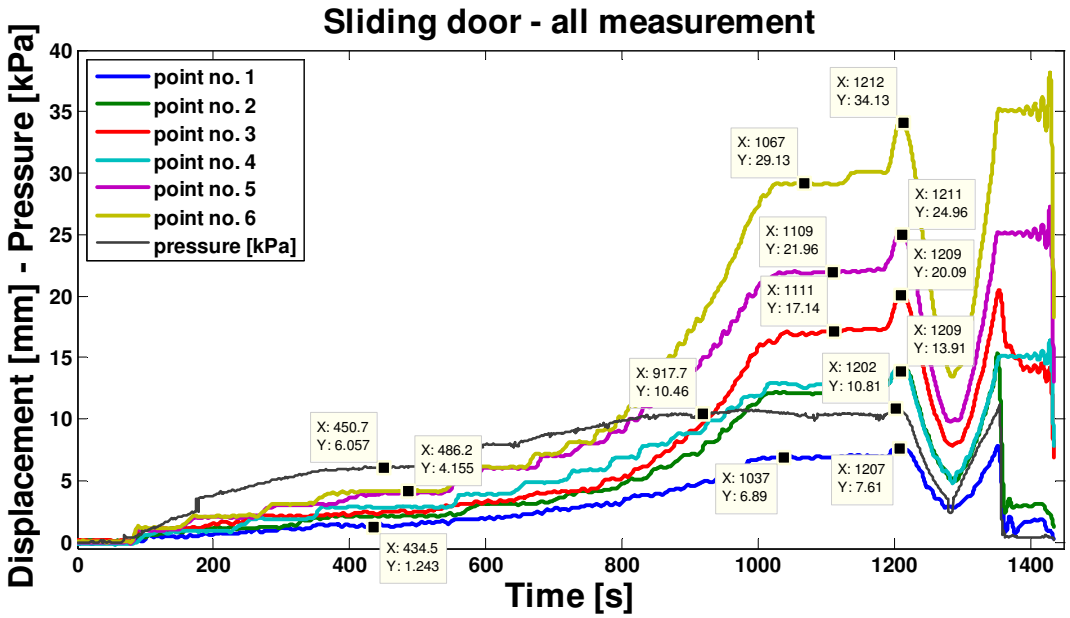


Fig. B3. Measurement results (full time history).

1th phase – tank filling up

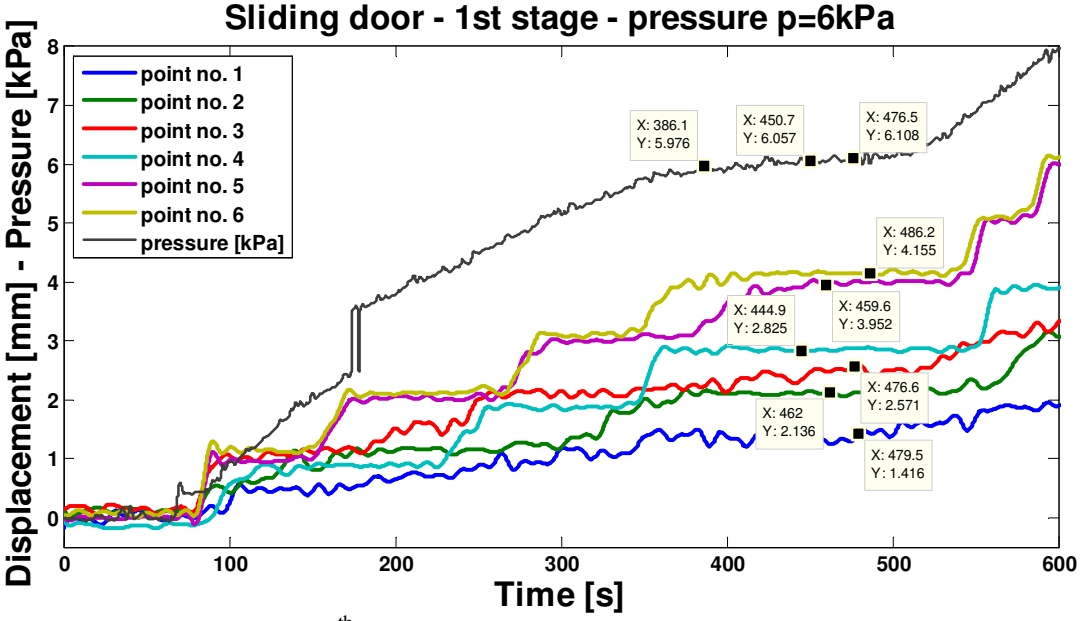


Fig. B4. 1th phase – tank filling up - pressure p=6kPa.

2nd phase – pressure p=10 kP

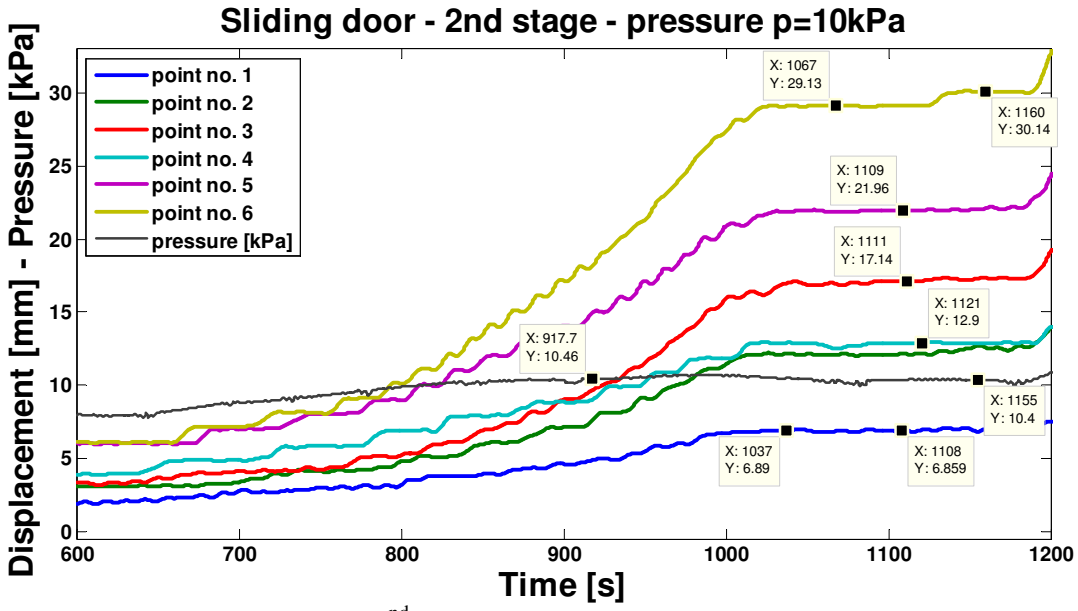


Fig. B5. 2nd phase – pressure level p=10 kPa.

3rd phase – finish

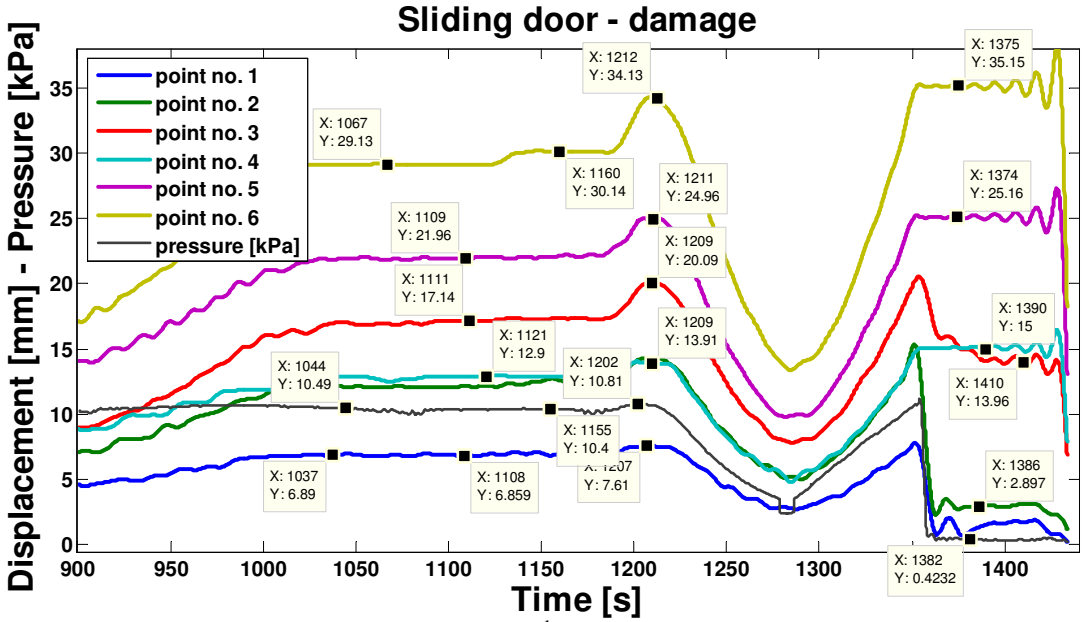


Fig. B6. 3rd phase – finish.

Table TB.1. Displacement, leakage and pressure test results.

Tab. TB.1	Test results object no. 1,2 test number 15630							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	6,0	1,41	2,15	2,25	2,91	3,10	4,02	44,8
2	10,6	6,80	12,07	17,00	12,91	21,90	29,11	48,7
3	10,8	damage	damage	damage	damage	damage	damage	------

Test photos.

Fig. B7. Leak at pressure p=6 kPa.

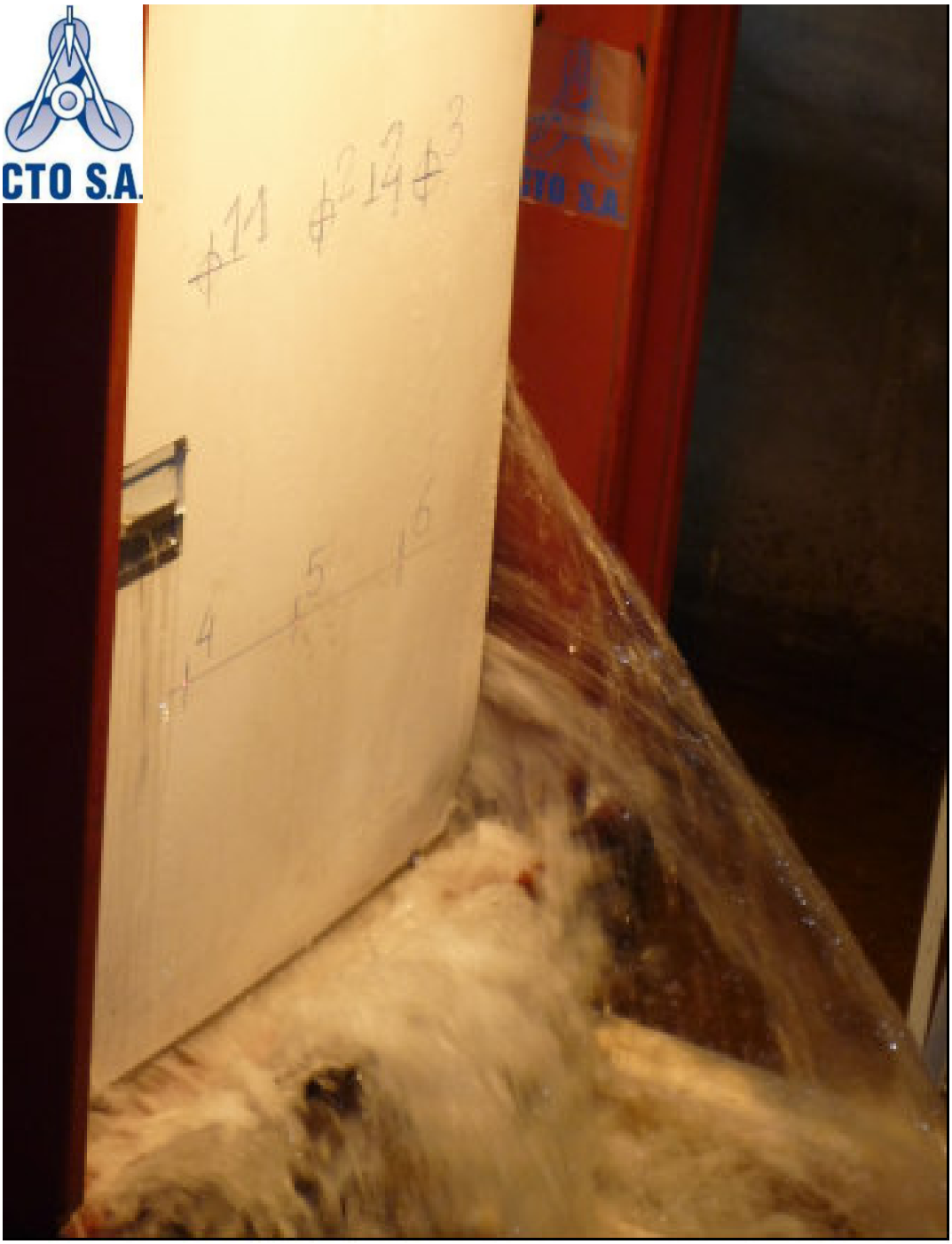


Fig. B8. Leak at pressure p=10 kPa.

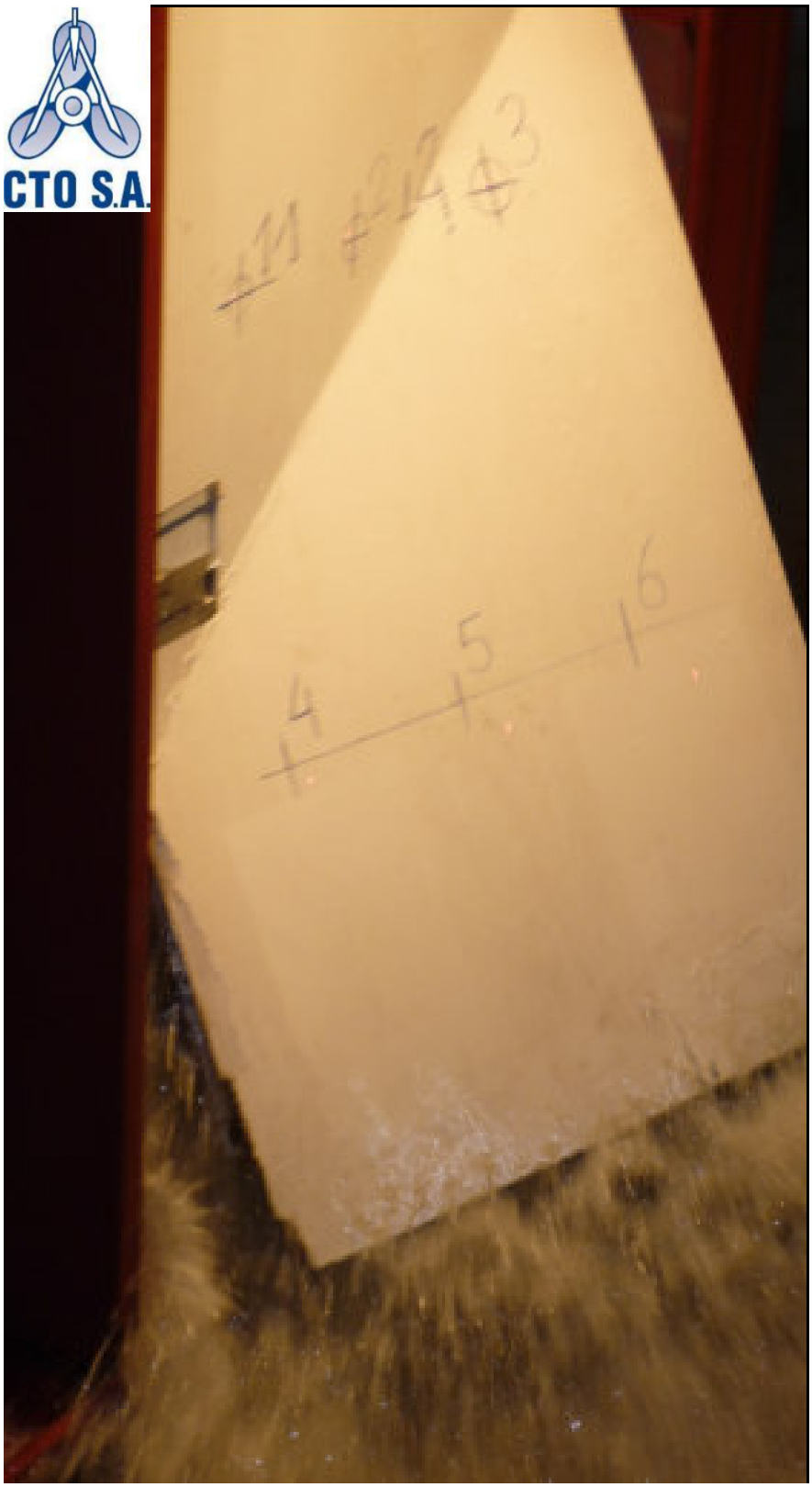


Fig. B9. Door damage.

Fig. B10. Door damage.

Fig. B11. Door damage.

Fig. B12. Door damage.

Fig. B13. Door damage.

Fig. B14. Door damage.

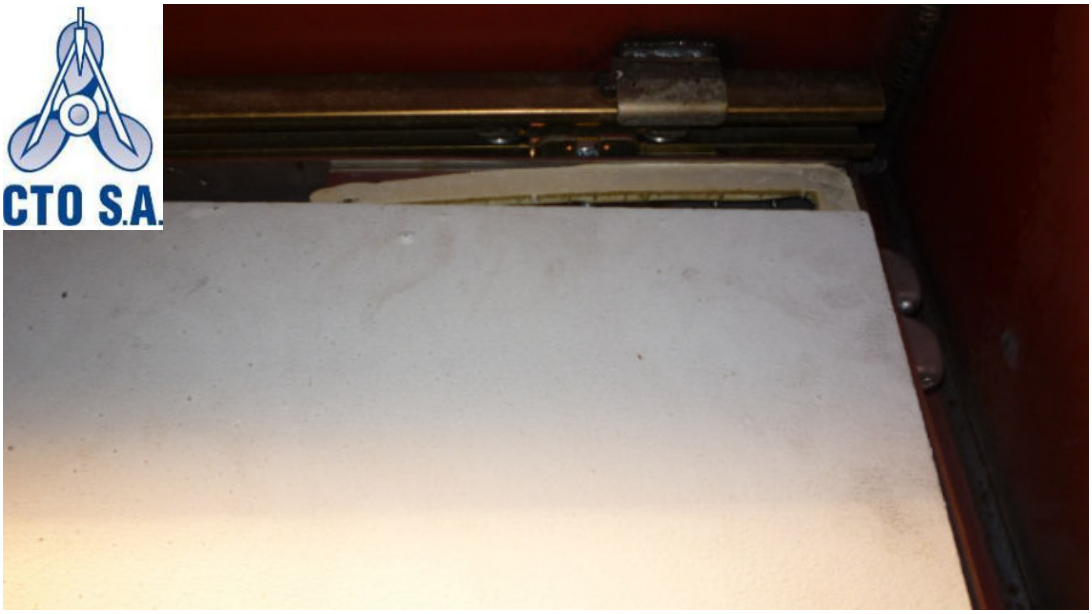


Fig. B15. Door damage.

Fig. B16. Door damage.

Fig. B17. Door damage.

c) Model no. 2.1; Hinged door; test no 15634, (direction: "INTO the door frame")

Test No. 15634, tested object no. 2.1.

Fig. C1. Stand with installed object test.

Dimensioning of measurements points of the element no. 2.1.

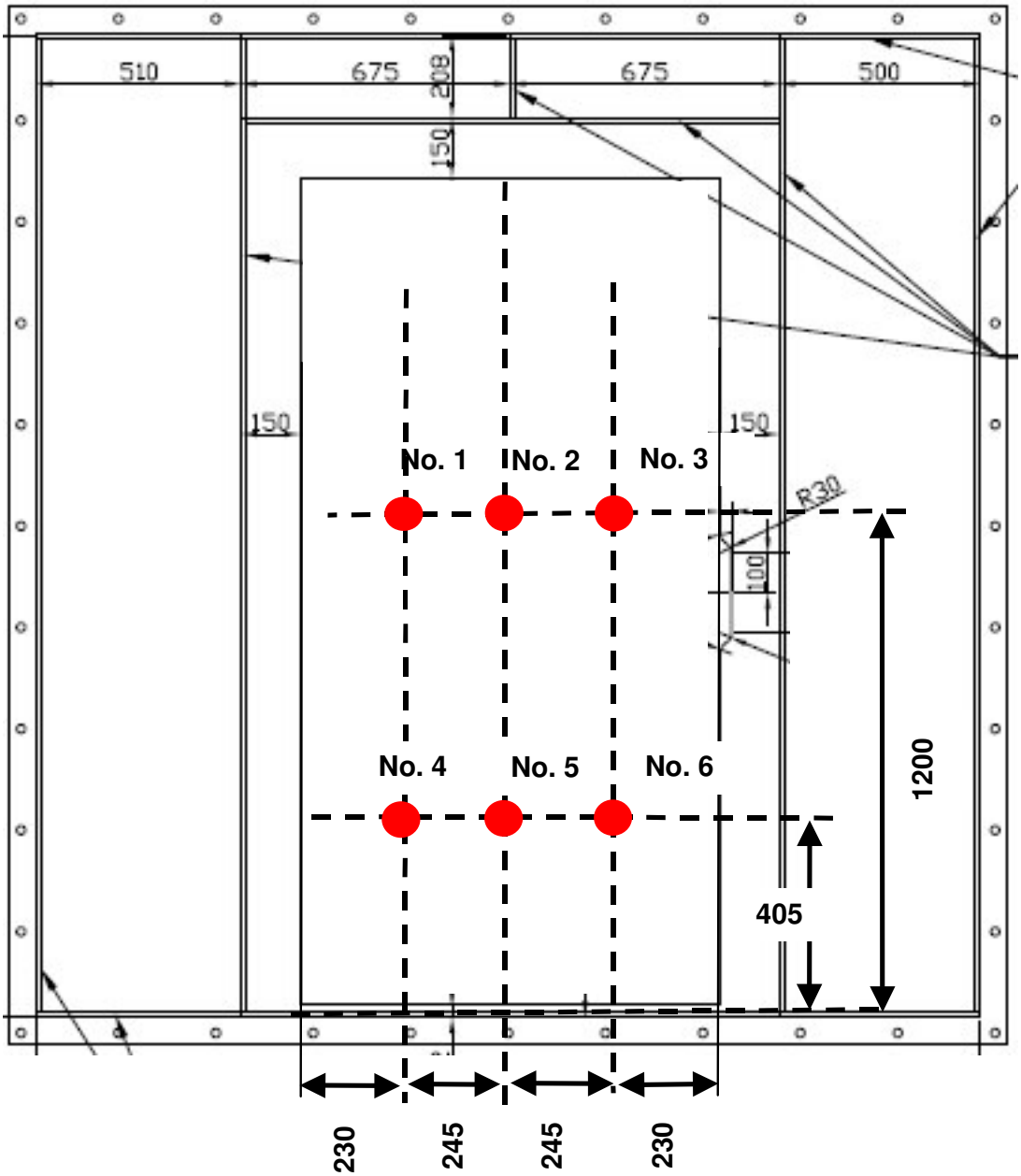


Fig. C2. Dimension plan of a measurement points.

Results of the test are presented on Fig. C3 to Fig. C9.

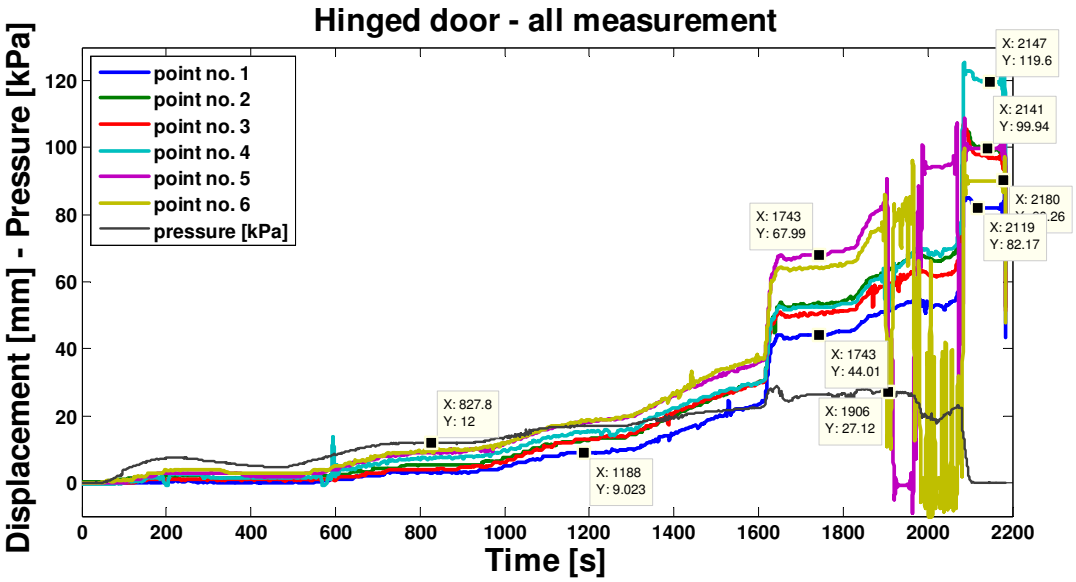


Fig. C3 Measurement results (full time history).

1th phase – pressure p=7kPa.

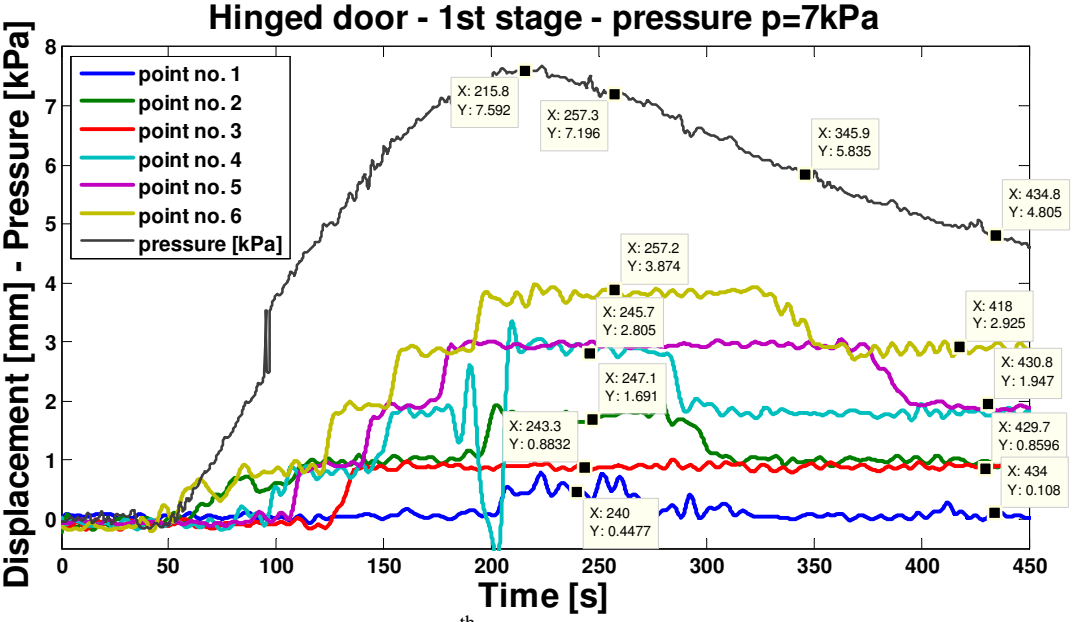


Fig. C4. 1th phase – pressure p=7kPa.

2nd phase – pressure p=12 kPa,

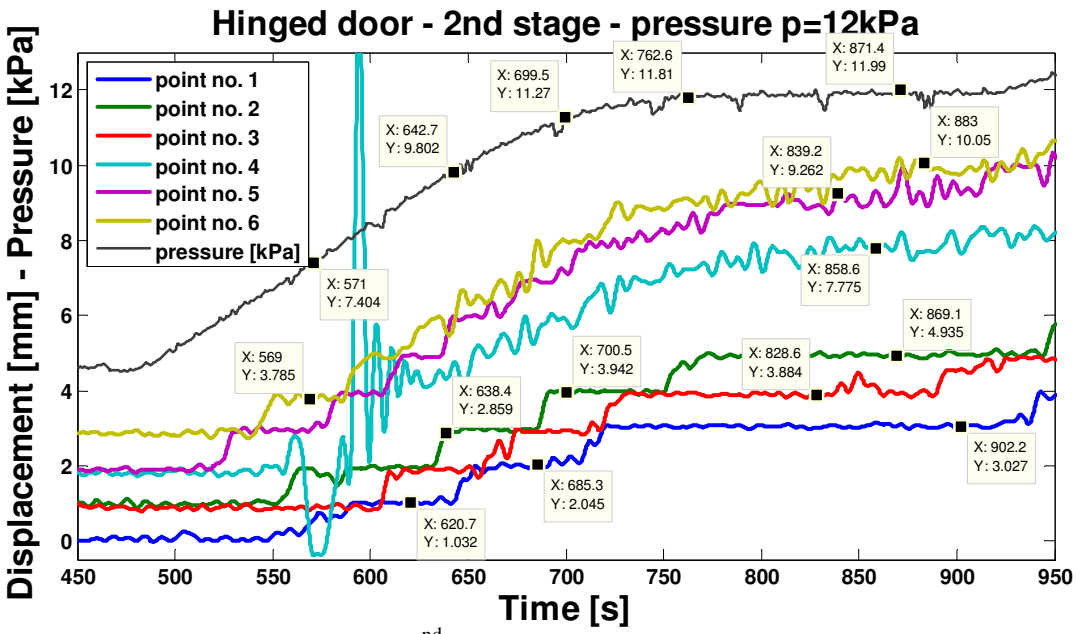


Fig. C5. 2nd phase – pressure p=12 kPa.

3rd phase – pressure p=17 kPa

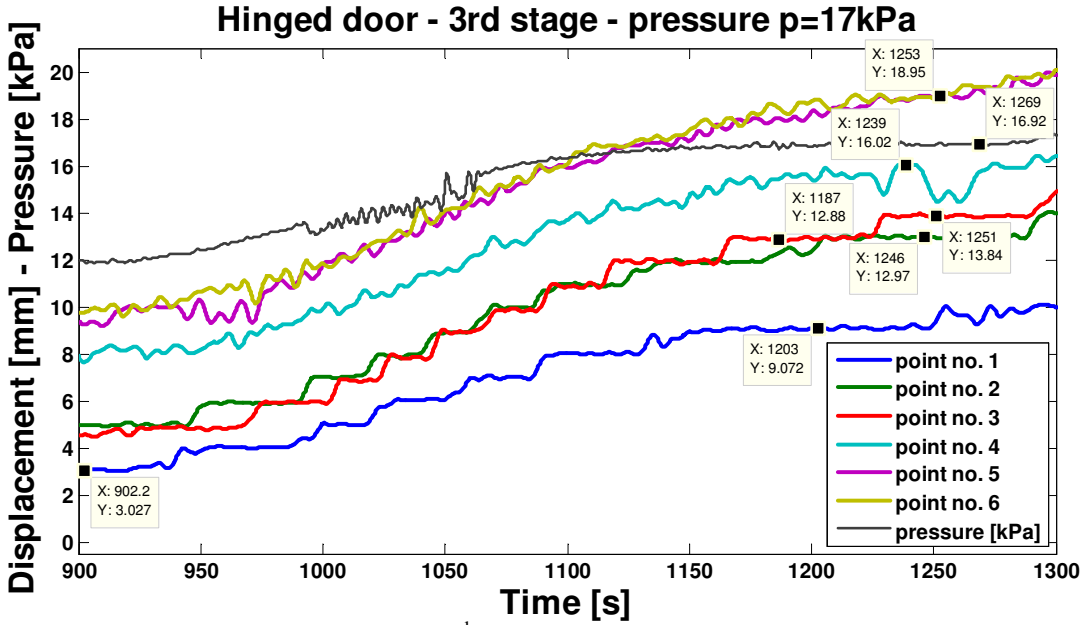


Fig. C6. 3rd phase – pressure p=17 kPa.

4nd phase – pressure p=22 kPa

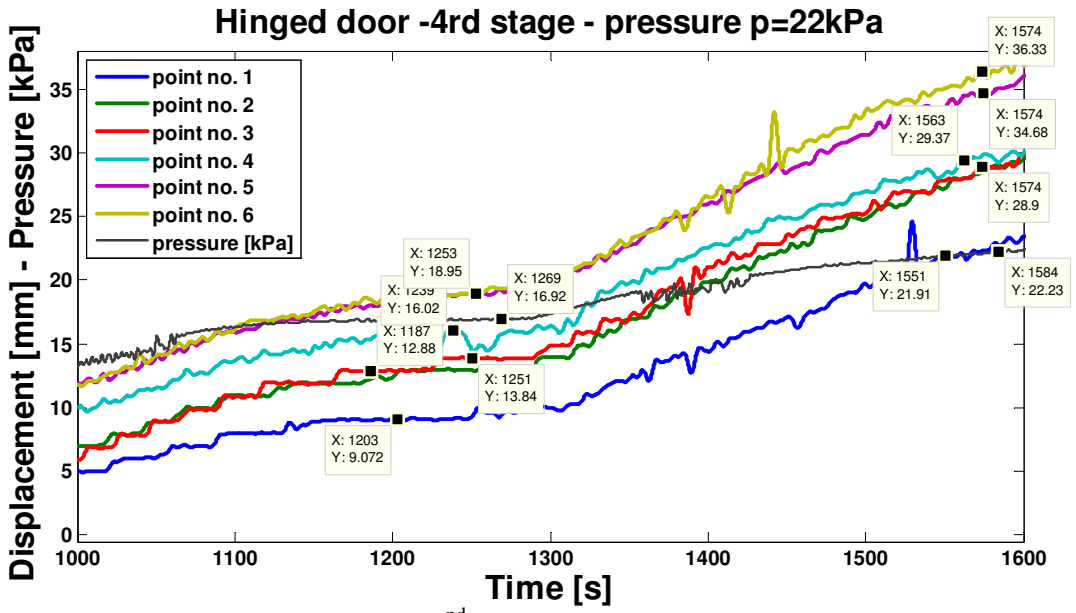


Fig. C7. 4nd phase – pressure p=22 kPa.

5nd phase – pressure p=27 kPa

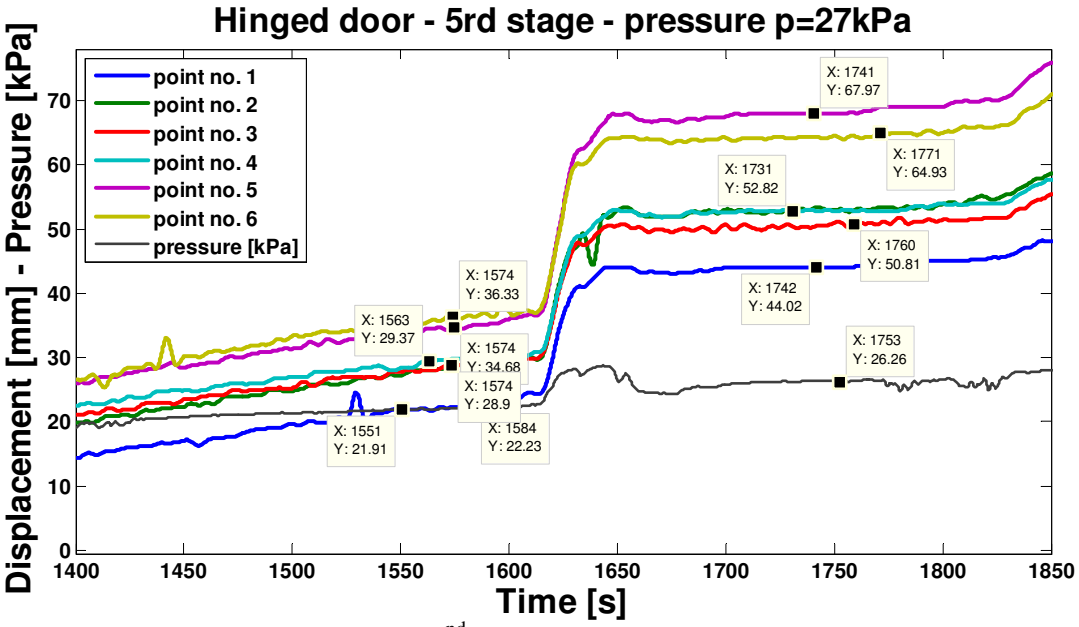


Fig. C8. 5nd phase – pressure p=27 kPa.

6nd phase – finished

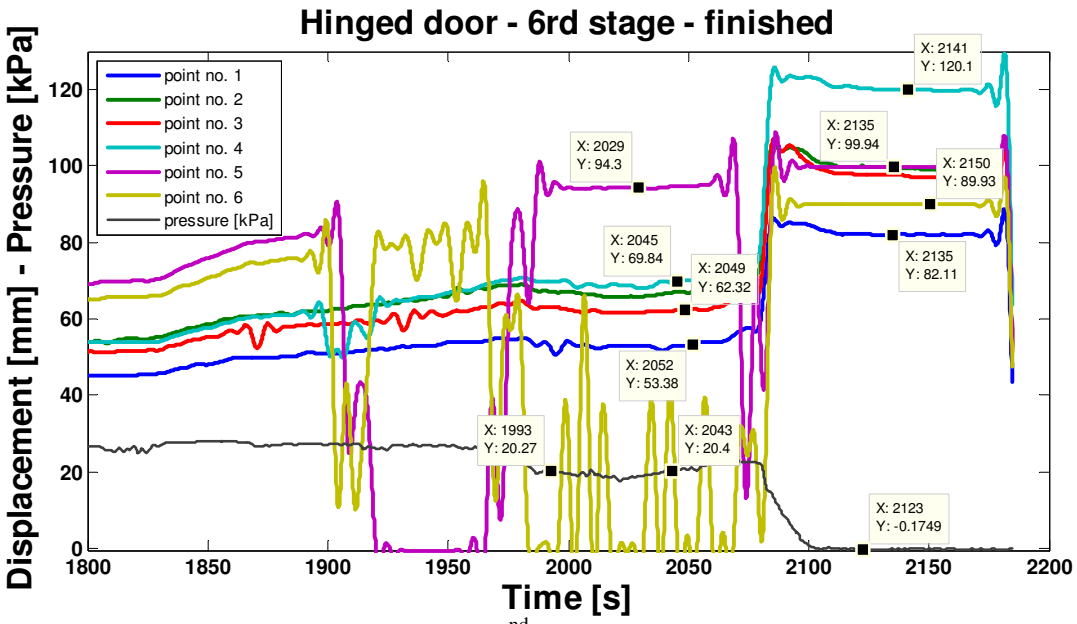


Fig. C9. 6nd phase – finished.

Table TC.1. Displacement, leakage and pressure test results.

Tab. TC.1	Test results object no. 2,1, test number 15634							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,1	0,11	1,01	0,89	1,78	1,93	2,84	2,6
2	12,0	2,98	4,97	3,88	7,78	9,07	10,05	7,2
3	16,9	9,02	13,00	13,84	15,93	19,73	19,62	14,4
4	21,9	22,23	28,81	28,39	29,80	34,68	36,33	17,8
5	26,3	44,02	53,27	50,81	52,82	67,97	64,93	19,1
6	22,7	damage	damage	damage	damage	damage	damage	------

Test photos.

Fig. C10. Leak at pressure p=16 kPa.

Fig. C11. Leak at pressure p=16 kPa.

Fig. N12. Leak at pressure p=22 kPa.

Fig. C13. Leak at pressure p=26 kPa.

Fig. C14. Door damage.

Fig. C15. Door damage.

Fig. C16. Door damage.

Fig. C17. Door damage.

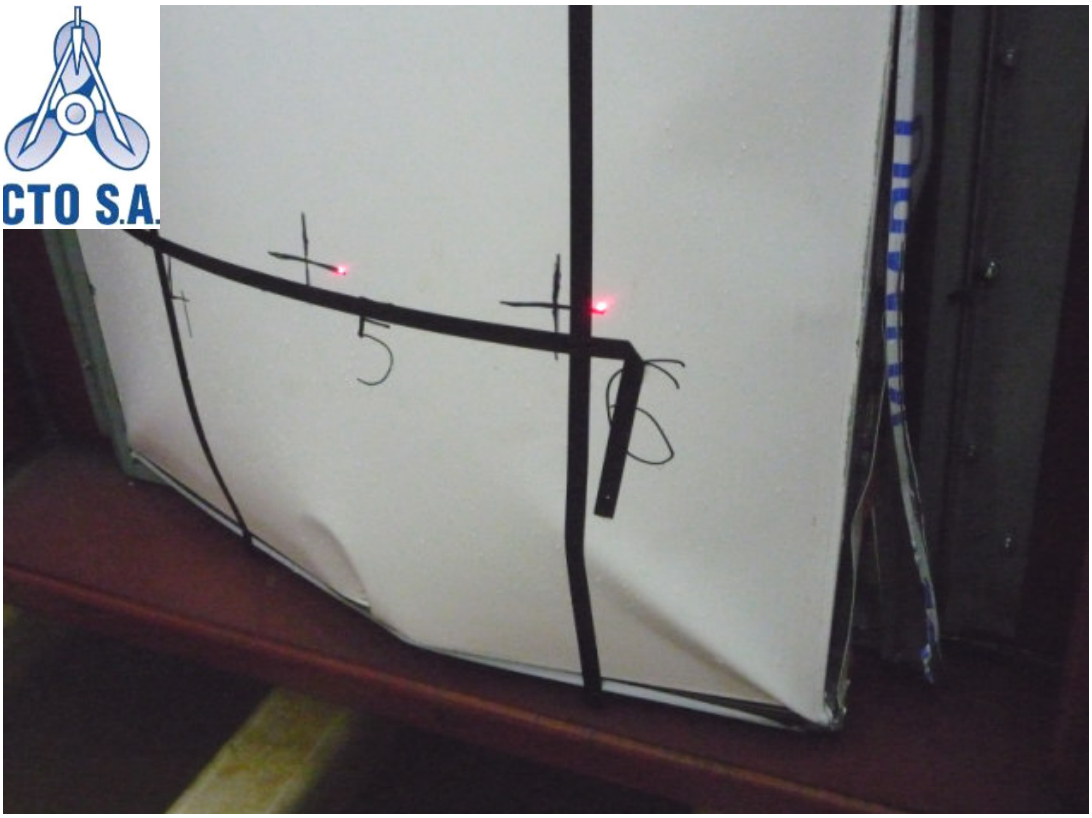


Fig. C18. Door damage.

Fig. C19. Door damage.

d) Model no. 2.2; Hinged door; test no 15639, (direction: "INTO the door frame")

Stand with installed object test no. 2.2. test no 15639.

Fig. D1. Stand with installed object test.

Dimensioning of measurements points of the element no 2.2.

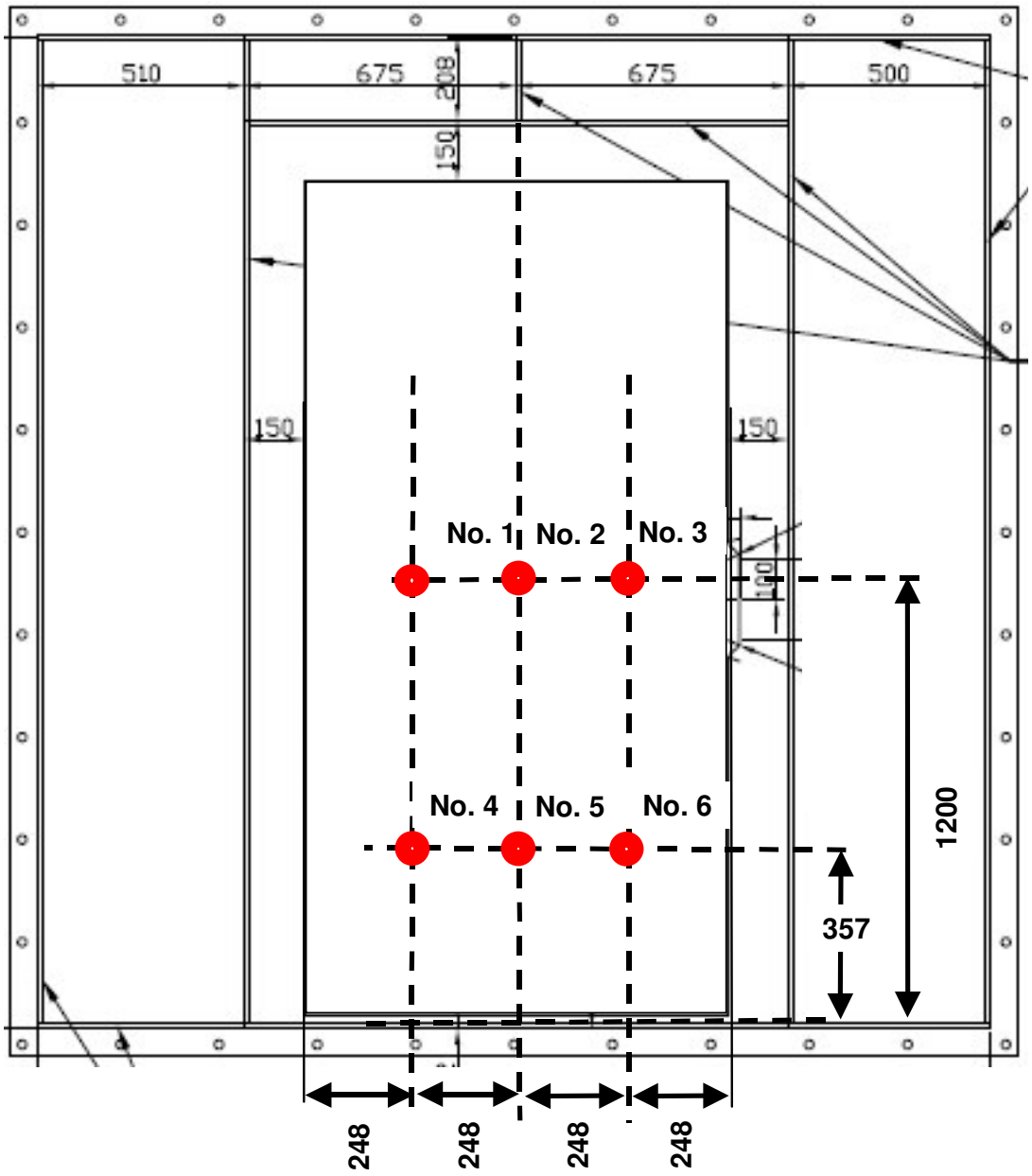


Fig. D2. Dimension plan of a measurement points.

Results of the test are presented on Fig. D3 to Fig. D8.

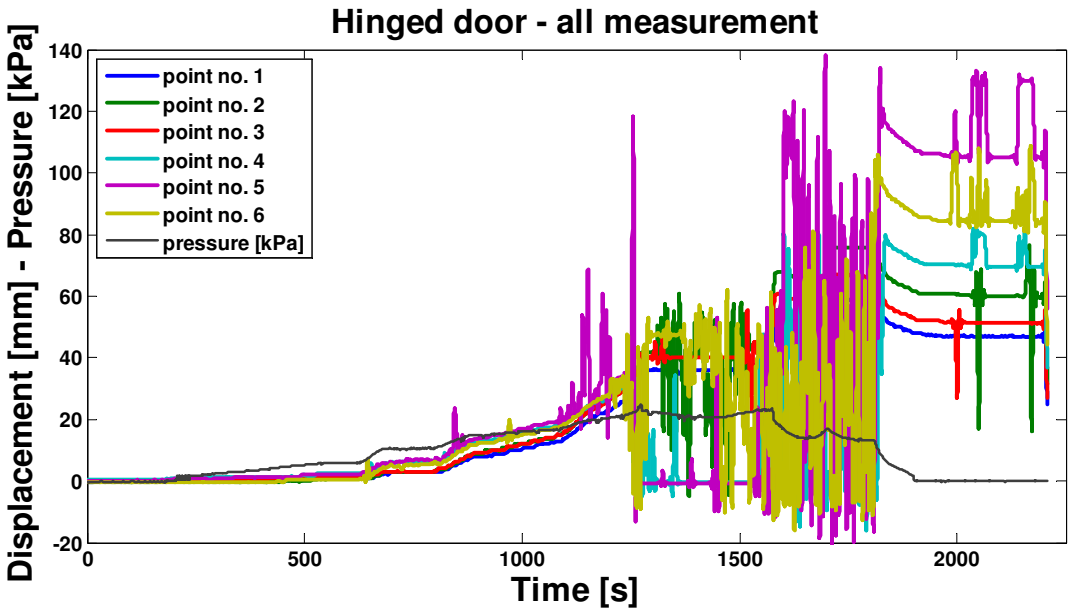


Fig. D3. Measurement results (full time history).

During the test, the measurement of the sensor no 4, 5 and 6 was disrupted by a stream of water directed through the wrong profile geometry of the lower frame of the test object Fig. D4.

Fig. D4. Disrupted by a stream of water the sensors no 2, 4, 5 and 6.

Removed from the Fig. D3 signal from the sensors no 4, 5 and 6. The result presented on the Fig D5.

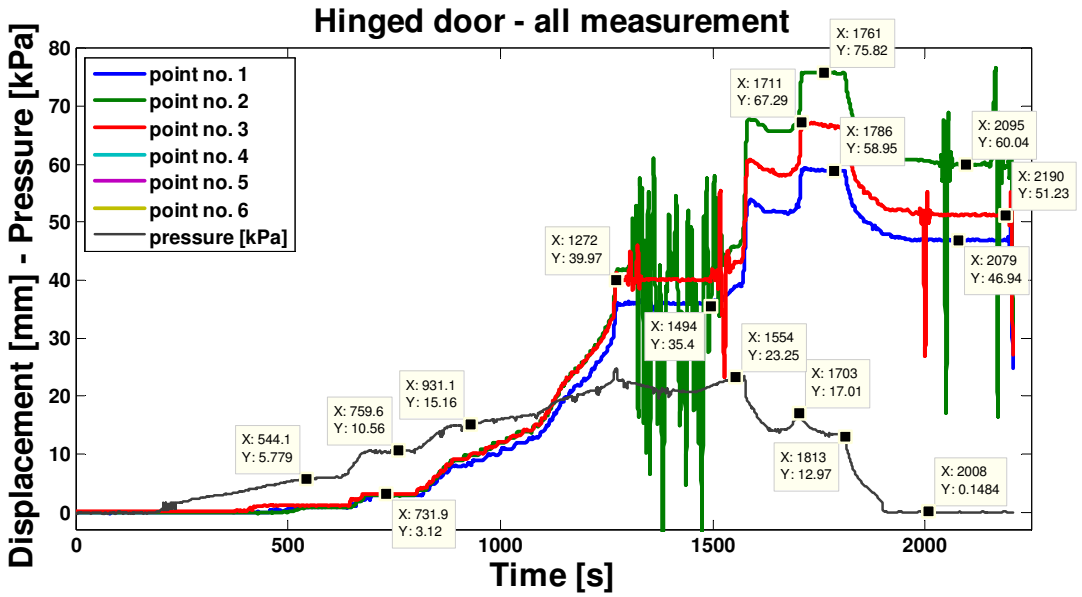


Fig. D5. Measurement results (full time history).

1th phase – tank filling up,

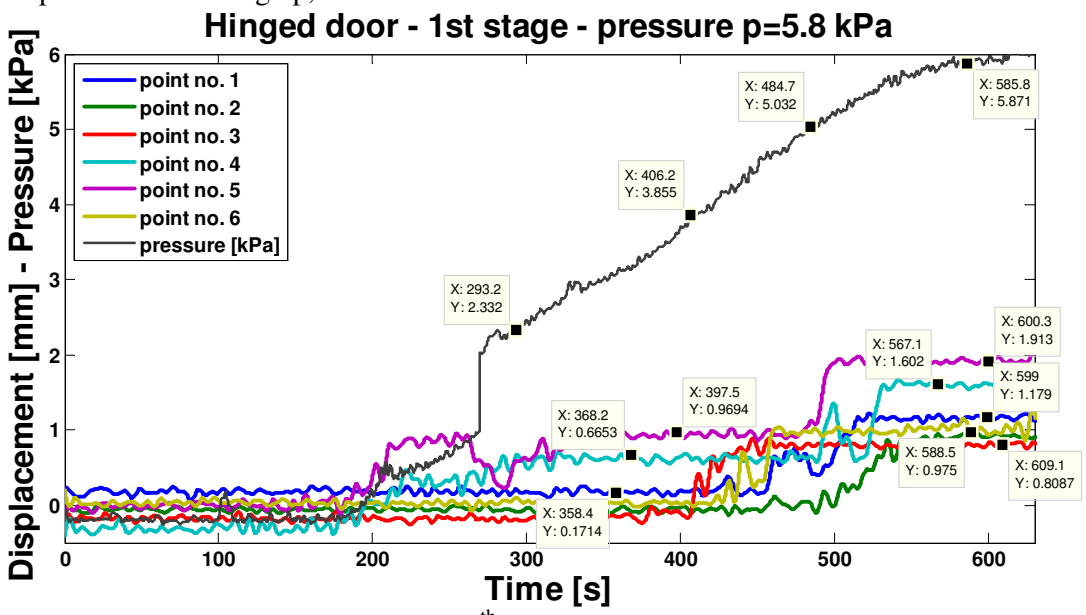


Fig. D6. 1th phase – tank filling up.

2nd phase – pressure level p=11kPa,

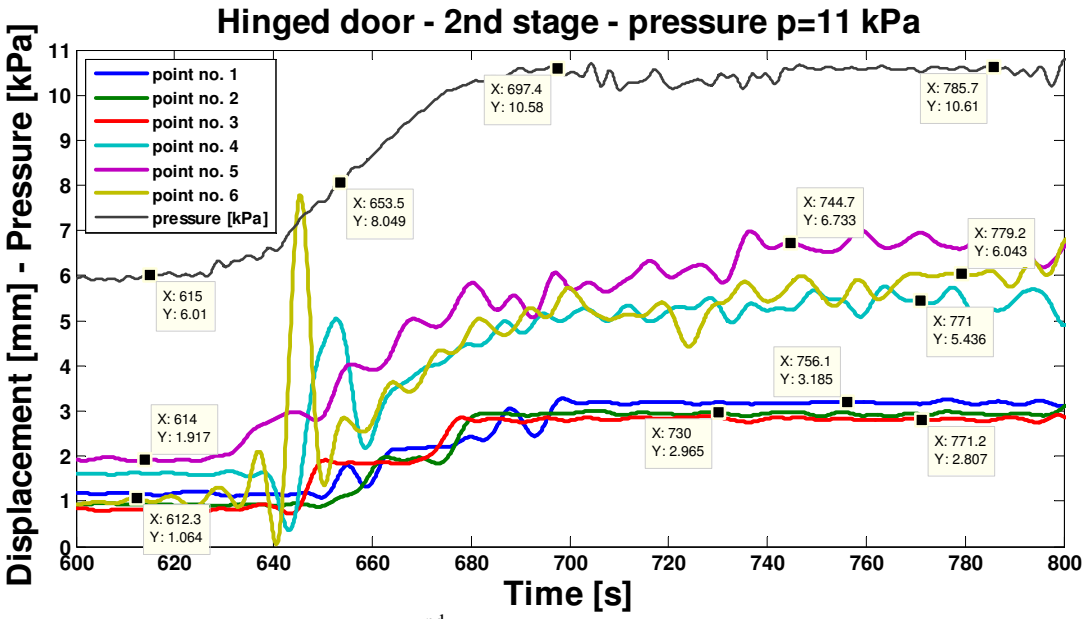


Fig. D7. 2nd phase – pressure level p=11kPa.

3rd phase – pressure level p=16kPa.

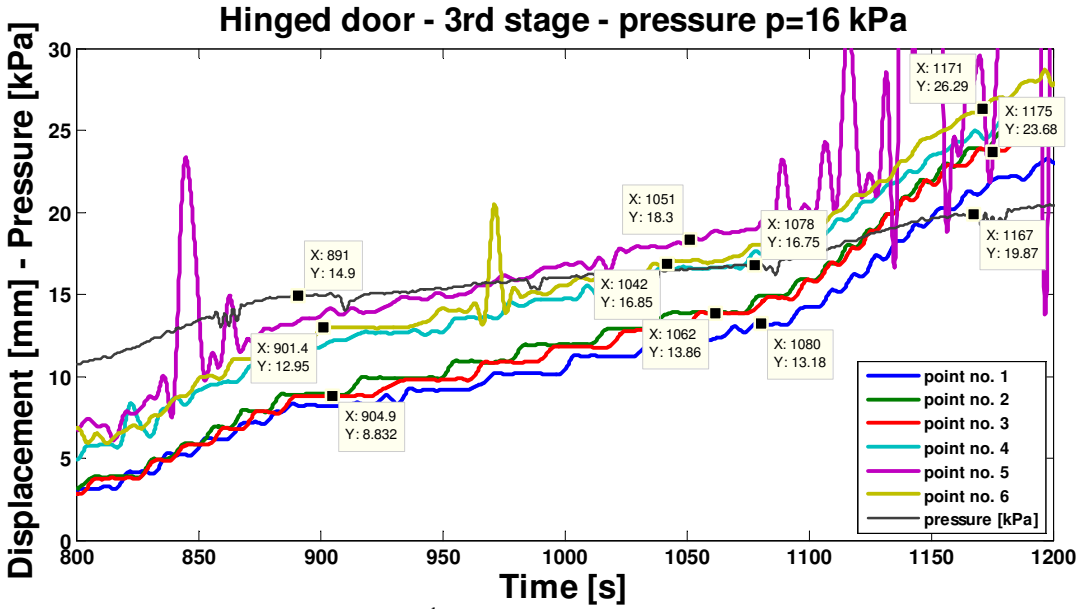


Fig. D8. 3rd phase – pressure level p=16kPa.

4nd phase – finish

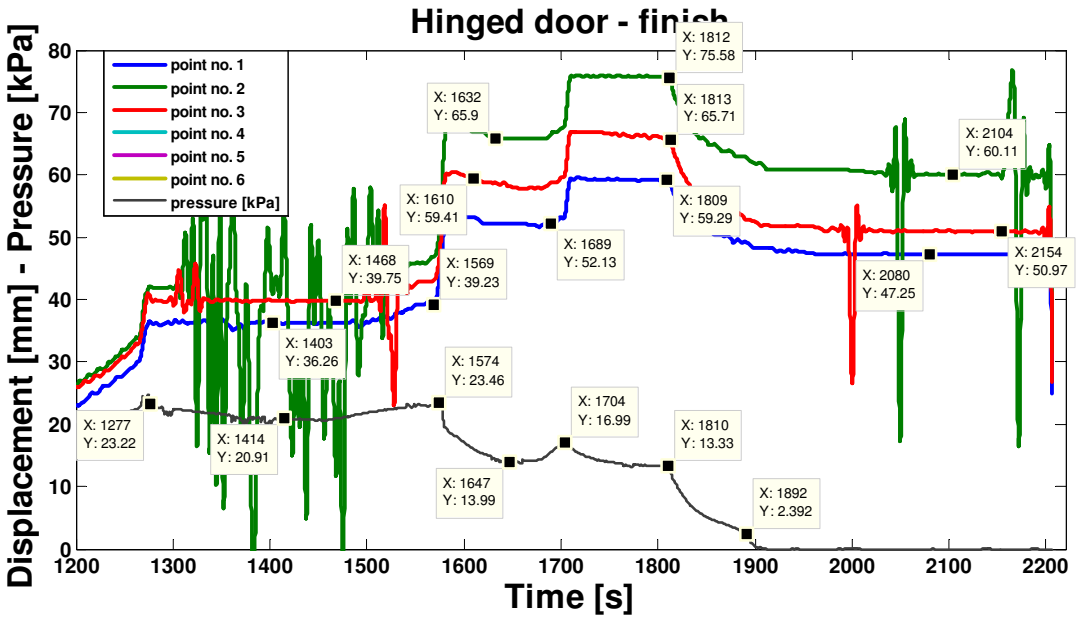


Fig. D9. 4nd phase – finish.

Table TD.1. Displacement, leakage and pressure test results.

Tab. TD.1	Test results object no**. 2,2, test number 15639**							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,9	1,18	0,98	0,81	1,60	1,91	0,98	34,8
2	10,6	5,43	2,96	2,81	5,44	6,73	6,04	27,2
3	16,9	12,19	13,85	12,84	16,53	18,30	17,06	48,8
4	23,2	36,13	42,07	39,85	-----	------	------	61,9
5	23,5	damage	damage	damage	damage	damage	damage	------

Fig. D10. Leak at pressure p=23 kPa.

Fig. D11. Leak at pressure p=16 kPa.

Fig. D12. Leak at pressure p=16 kPa.

Fig. D13. Door damage.

Fig. D14. Door damage.

Fig. D15. Door damage.

Fig. D16. Door damage.

Fig. D17. Door damage.

Fig. D18. Door damage.

e) Model no. 2.3; Hinged door; test no 15632, (direction: "INTO the door latch")

Stand with installed test object no 2.3, test no 15632.

Fig. E1. Stand with installed object test.

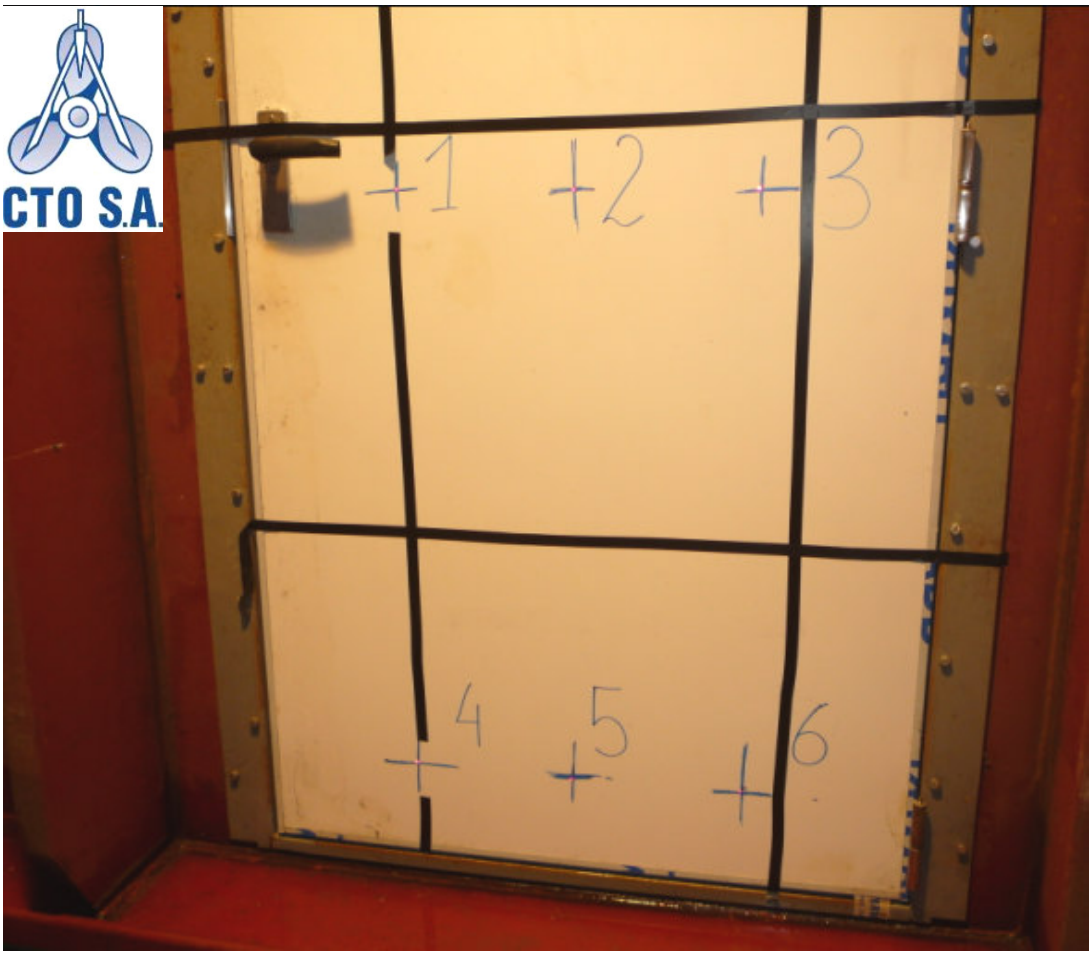


Fig. E2. Measuring points location.

Dimensioning of measurements points of the element no 2.3.

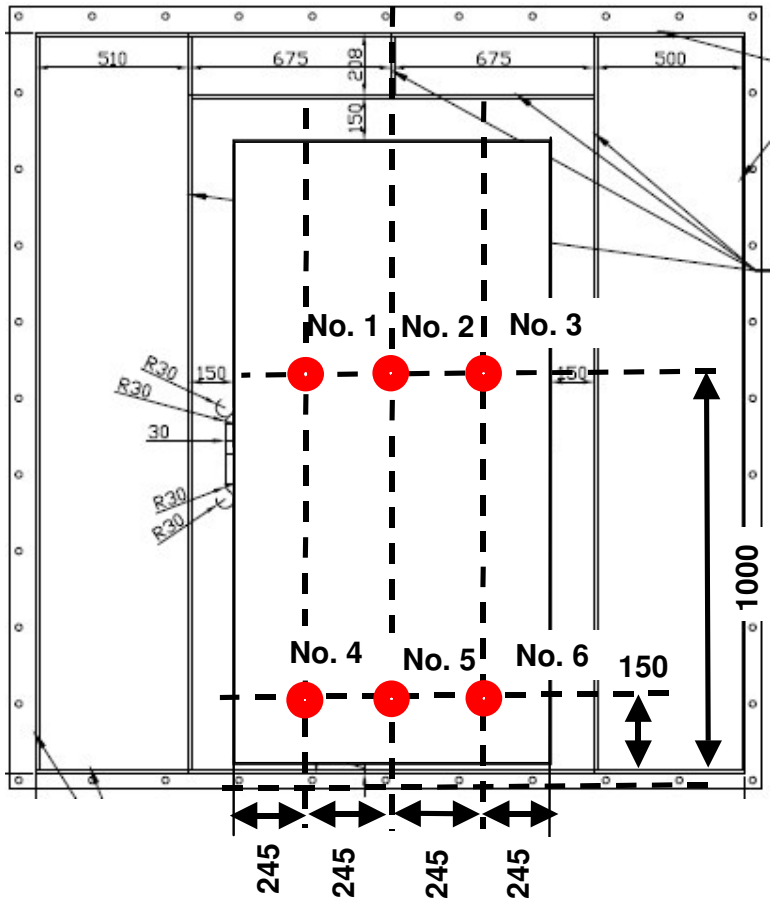


Fig. E3. Dimension plan of a measurement points.

Results of the test are presented on Fig. E4.

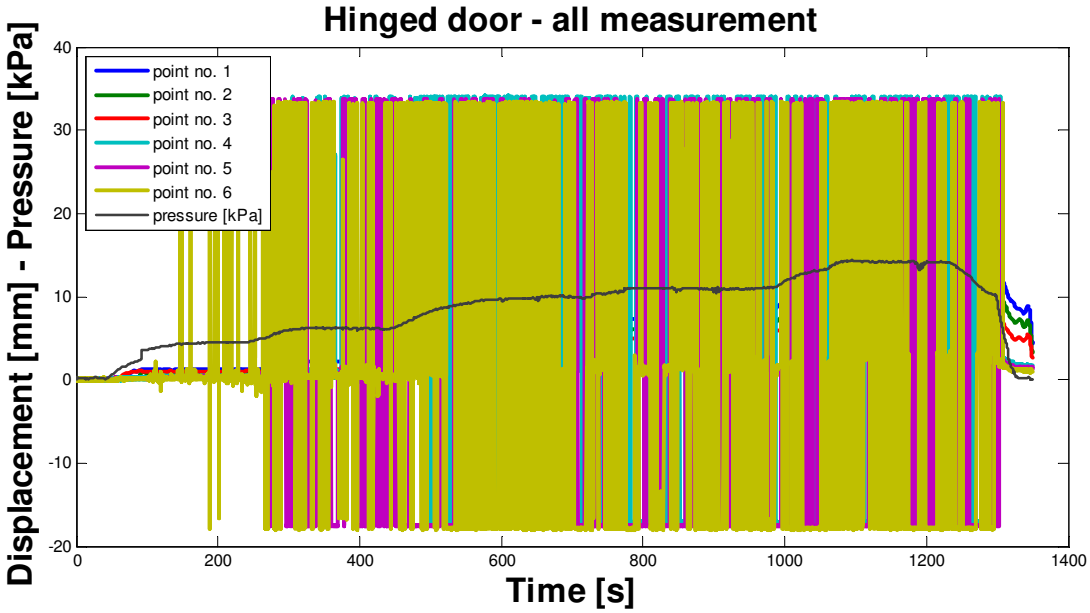


Fig. E4. Measurement results (full time history).

During the test, the measurement of the sensor no 4, 5 and 6 was disrupted by a stream of water directed through the wrong profile geometry of the lower frame of the test object Fig. E5.

Fig. E5. Disturbance sensors no 4, 5 and 6.

On the Fig. E4 removed the sensors no 4, 5 and 6. The result signals from sensor no. 1, 2 and 3 presentation on the Fig E6.

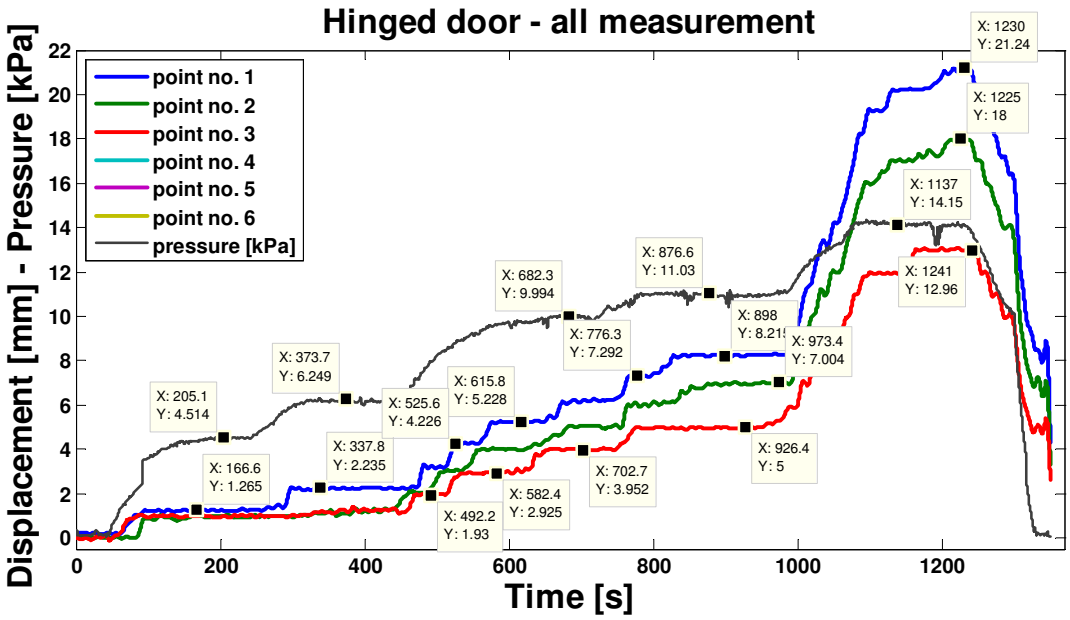


Fig. E6. Measurement results (full time history).

1th phase – pressure level p=4,5kPa and p=6,3kPa,

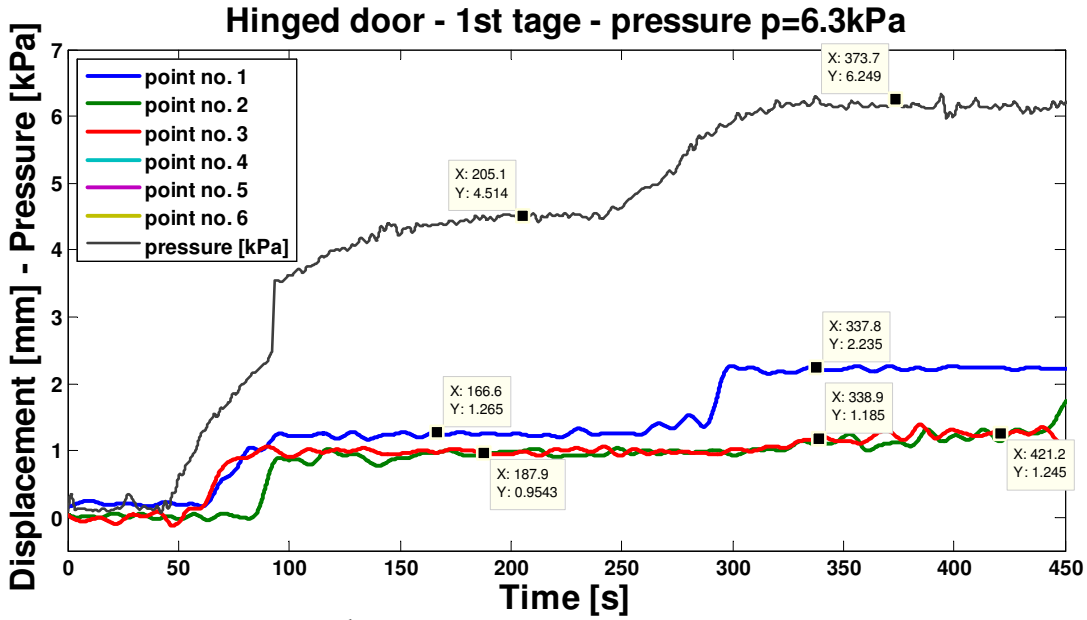


Fig. E7. 1th phase – pressure p=4,5kPa and p=6,3kPa.

2nd phase – pressure level p=10 kPa,

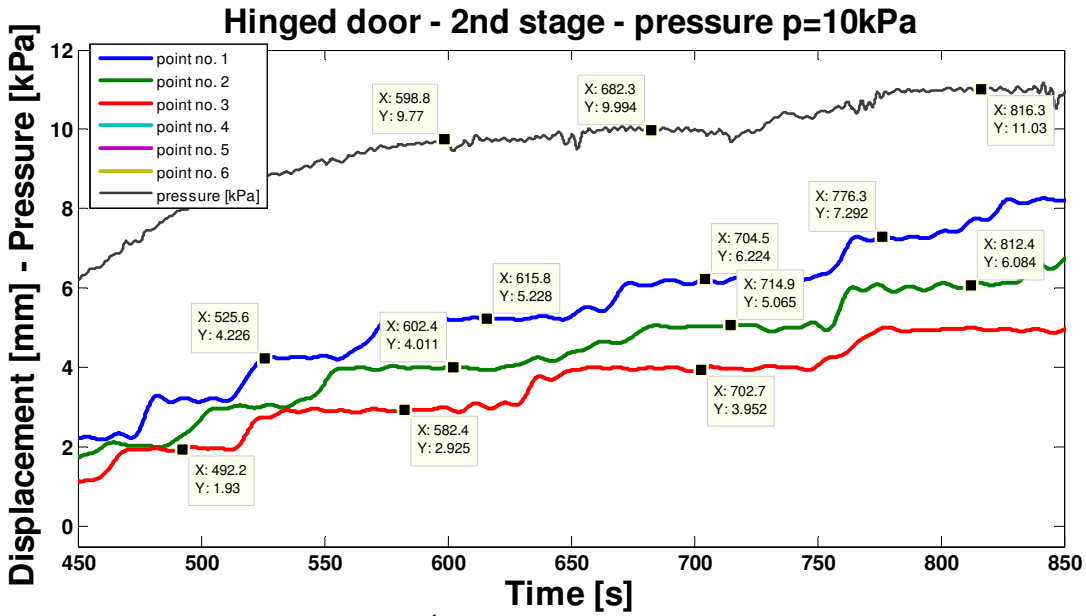


Fig. E8. 2nd phase – pressure level p=10 kPa.

3rd phase – finish

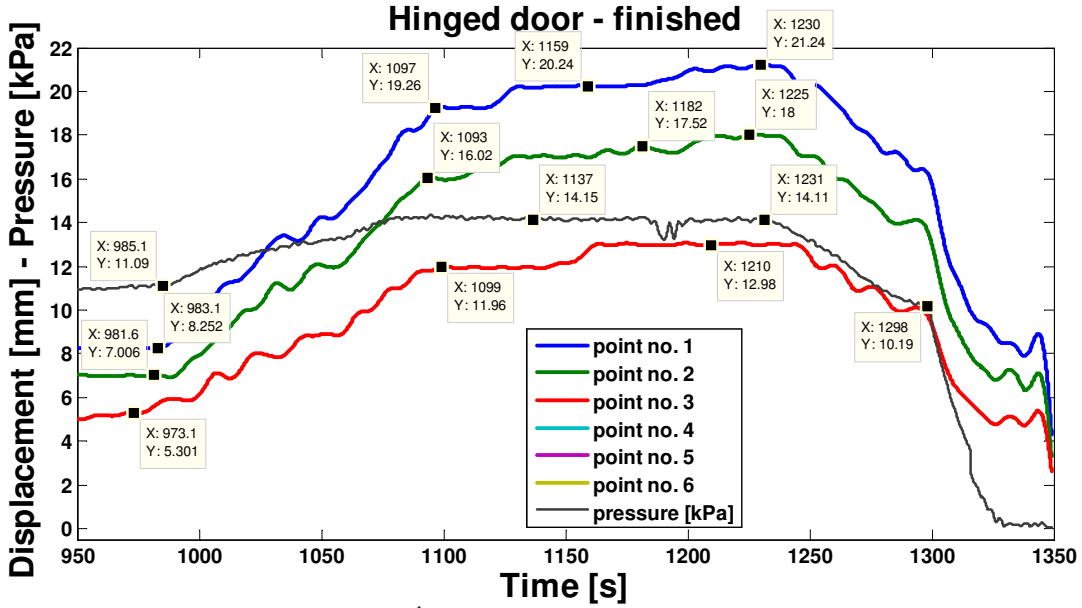


Fig. E9. 3rd phase – pressure p=14 kPa - finish.

Changed the location of measurement points that were plotted in the test object according on the Fig E10 to Fig. E13. Test was repeated and the results are presented on Fig. E14.

New dimensioning of measurements points of the element no. 2.3.

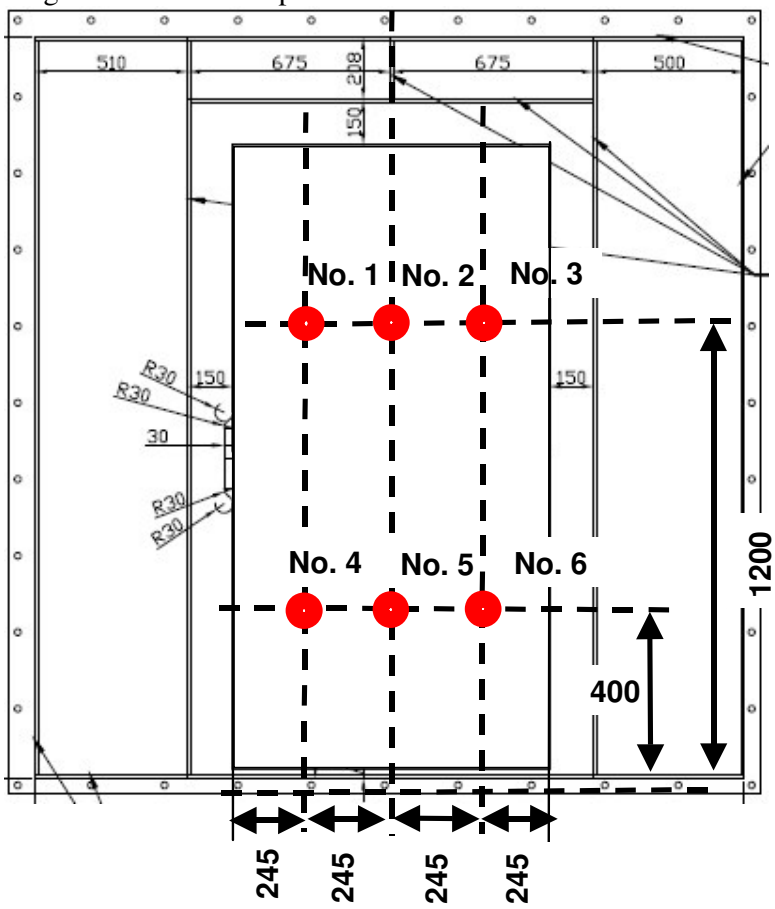


Fig. E10. New dimension plan of a measurement points.

Fig. E11. New measuring points location.

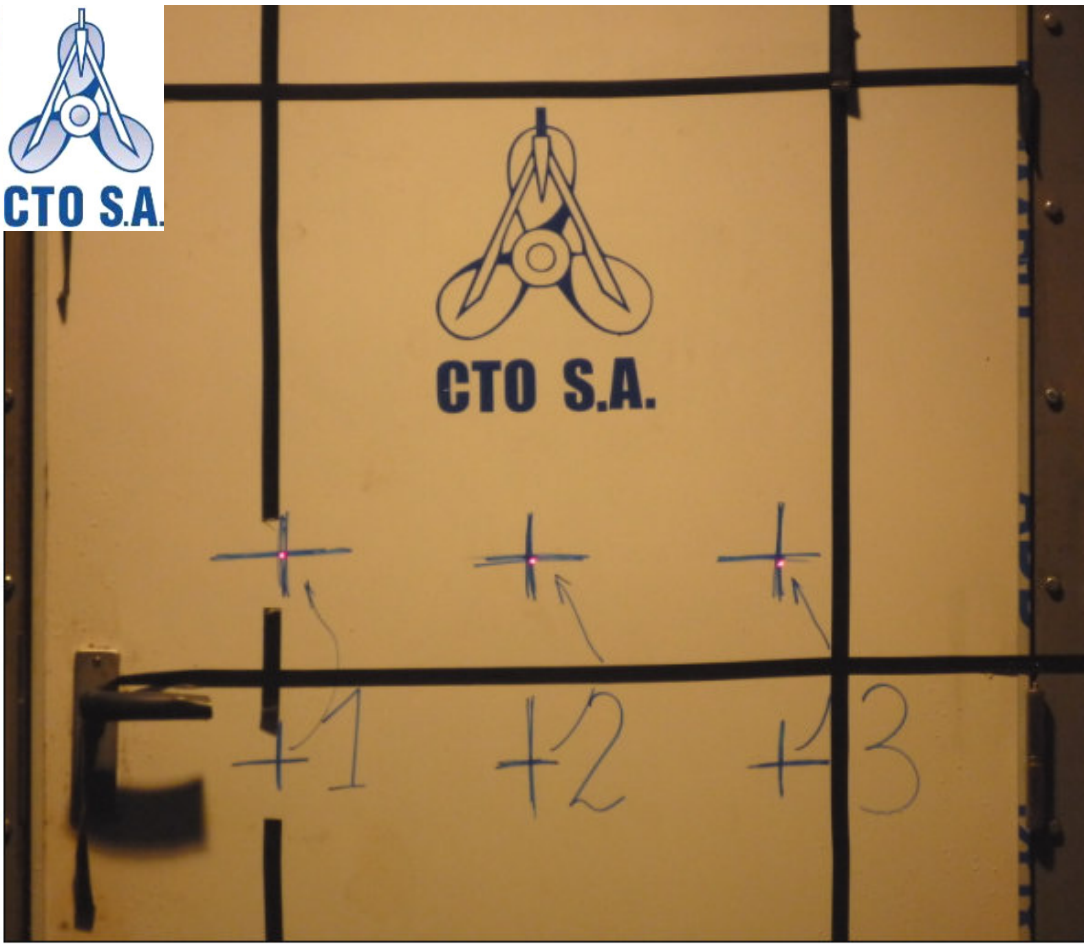


Fig. E12. New measuring points location.

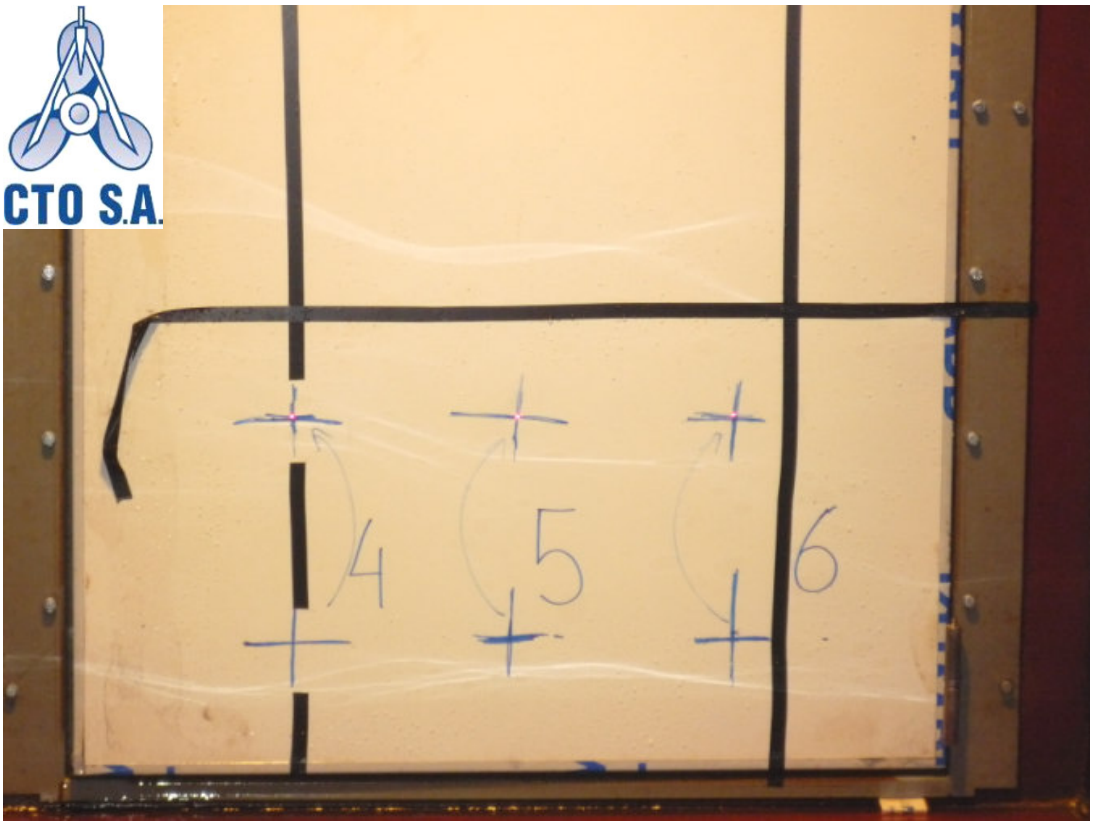


Fig. E13. New measuring points location.

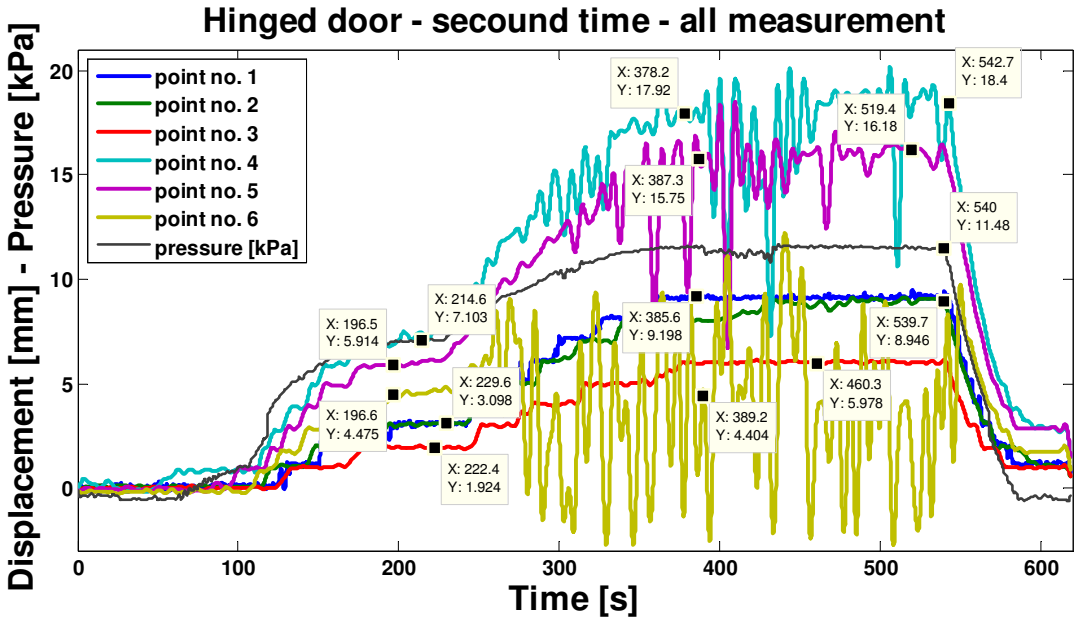


Fig. E14. Measurement results (full time history).

Table TE.1 Displacement, leakage and pressure test results.

Tab. TE.1	**Test results object no. 2,3, test number 15632**							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	7,1	3,10	3,10	1,92	7,00	5,91	4,48	48,9
2	11,5	9,21	8,98	5,98	18,5	16,22	7,50	96,1
3	11,5	------	------	------	------	------	------	------

Fig. E15. Leak for pressure p=11,3 kPa.

Fig. E16. Wrong shape of the profile bracket.

Fig. E17. Door damage.

Fig. E18. Door damage.

Fig. E19. Door damage.

f) Model no. 2.4; Hinged door; test no 15638, (direction: "INTO the door latch")

Test No. 15638, tested object no. 2.4.

Fig. F1. Stand with installed object test.

Dimensioning of measurements points of the element no. 2.4.

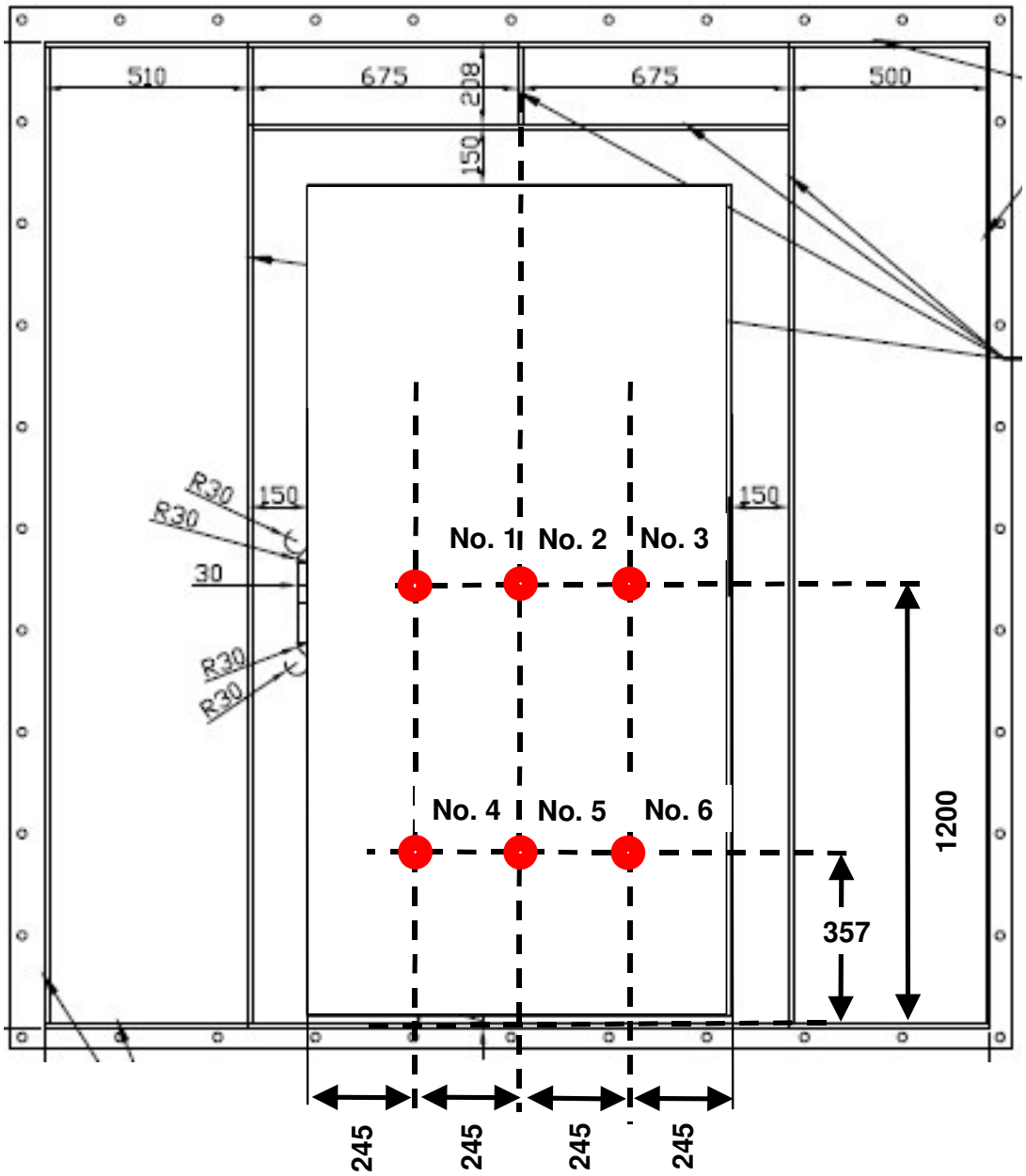


Fig. F2. Dimension plan of a measurement points.

Results of the test are presented on Fig. F3 to Fig. F5.

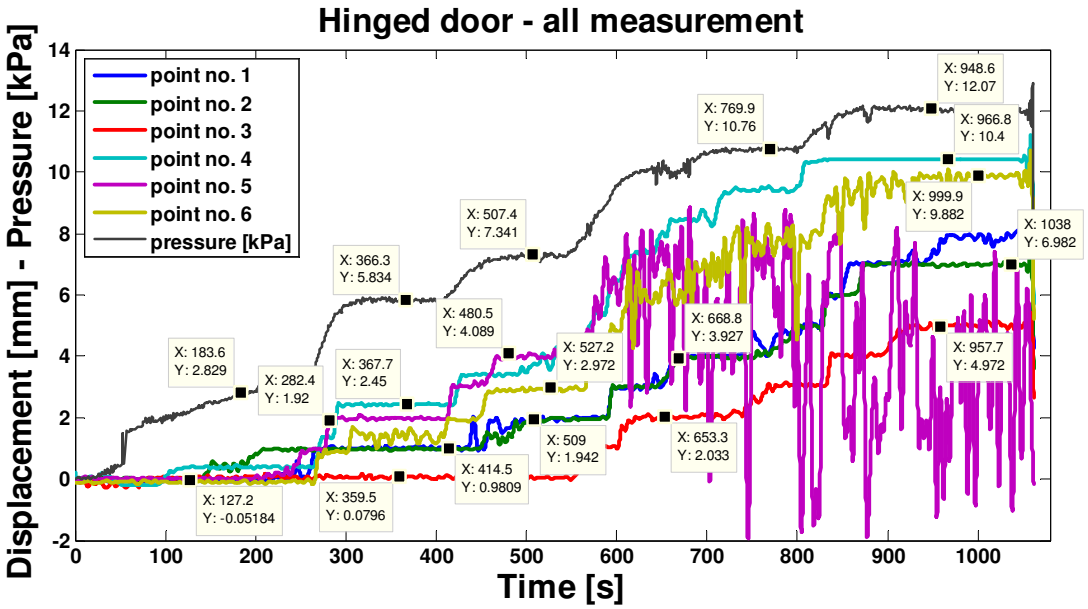


Fig. F3. Measurement results (full time history).

1th phase – tank filling up and pressure level p=5.8kPa.

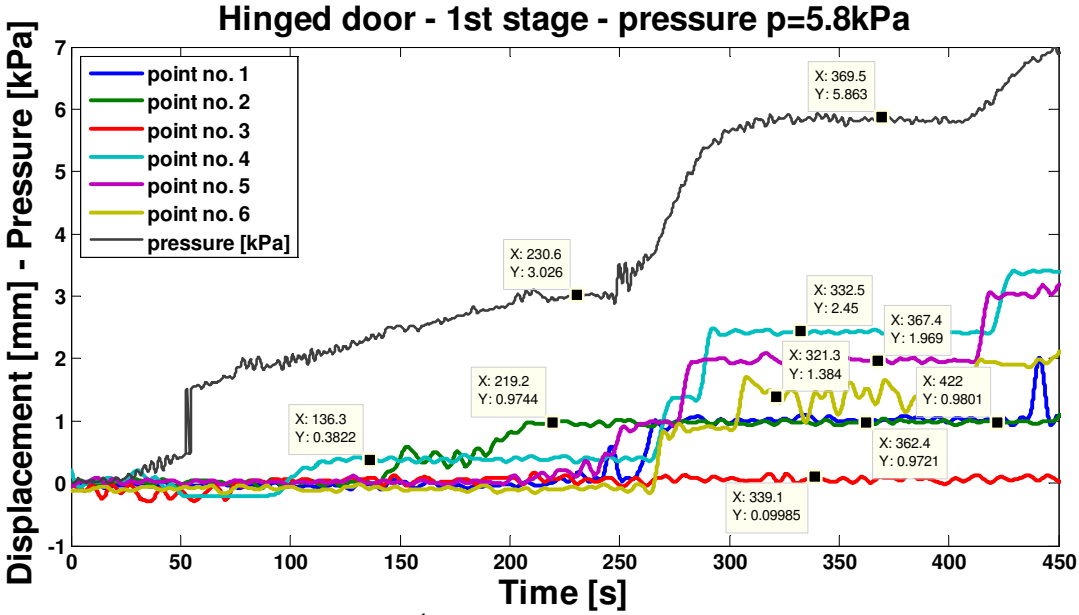


Fig. F4. 1th phase – pressure level p=5.8kPa.

2nd phase – pressure level p=12kPa.

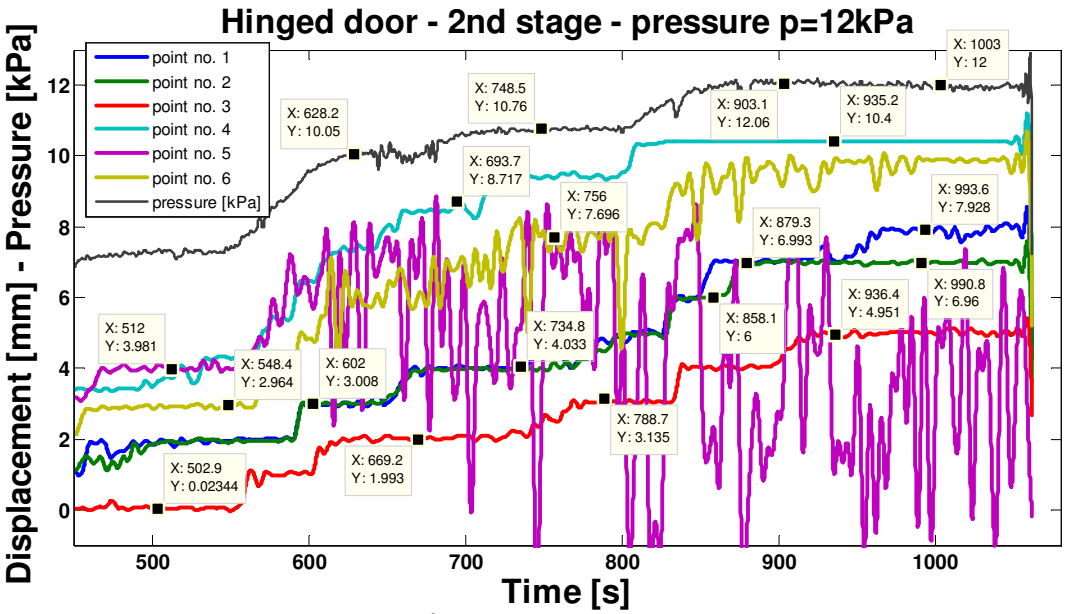


Fig. F5. 2nd phase – pressure level p=12kPa.

Table TF.1. Displacement, leakage and pressure test results.

Tab. TF.1	Test results object no. 2,4, test number 15638							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,9	0,96	0,98	0,01	2,45	1,97	1,39	37,7
2	10,8	4,03	4,05	2,15	9,45	7,80	7,69	82,5
3	12,0	8,10	6,96	4,95	~10,4	~8,00	9,89	96,9

Fig. F6. Leak at pressure p=12 kPa.

Fig. F7. Door damage.

Fig. F8. Door damage.

Fig. F9. Door damage.

g) Model No. 3.1; A-60 double leaf hinged marine fire door; test no 15734, (direction: OUT the door frame")

Fig. G1. Stand with installed object test and measuring points location.

Dimensioning of measurements points of the element no. 3.1.

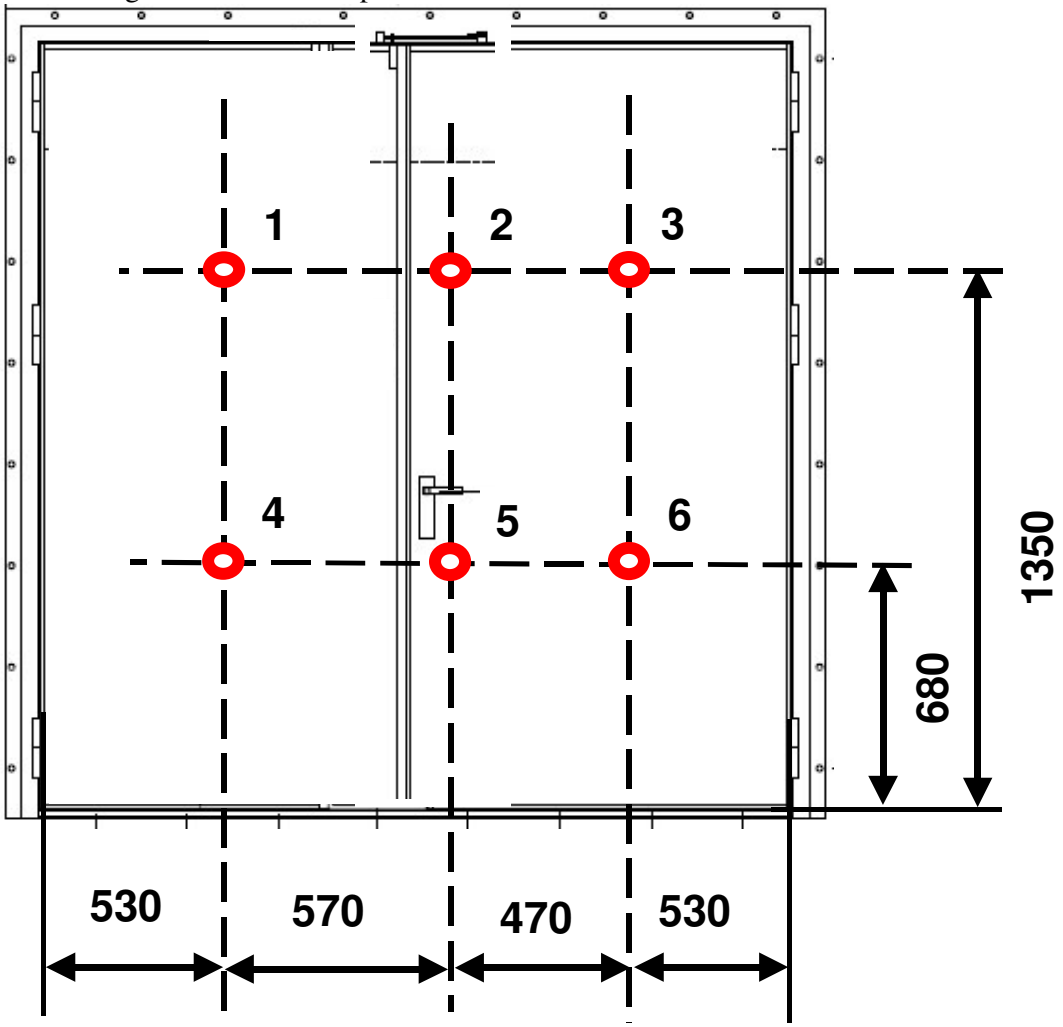


Fig. G2. Dimension plan of a measurement points.

Results of the test are presented on Fig. G3 to Fig. G5.

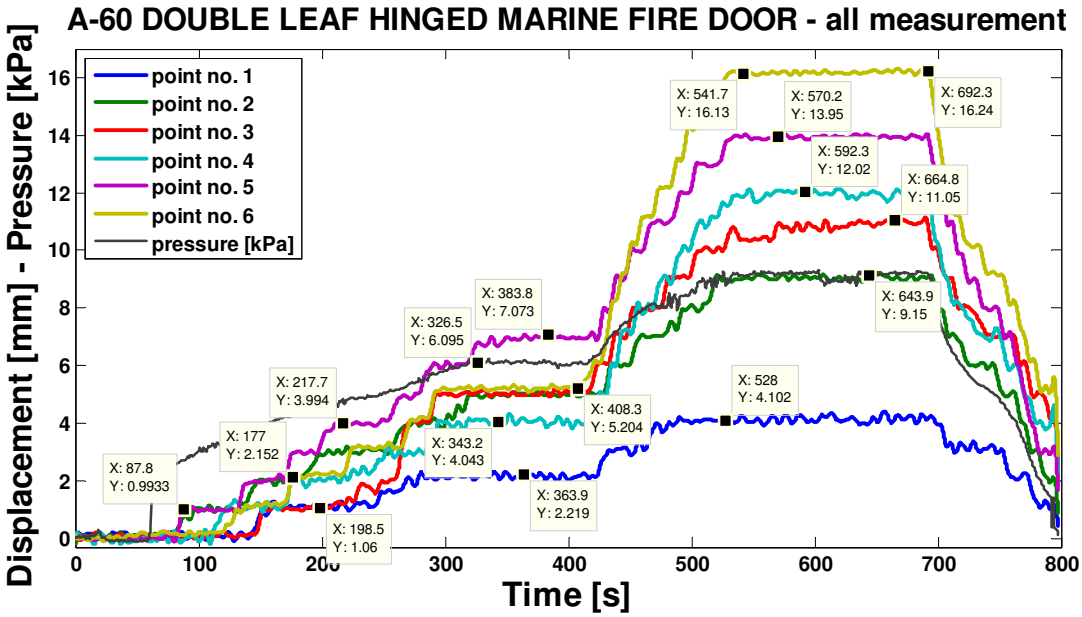


Fig. G3. Measurement results (full time history).

1st stage – pressure level p=6 kPa – tank filling up.

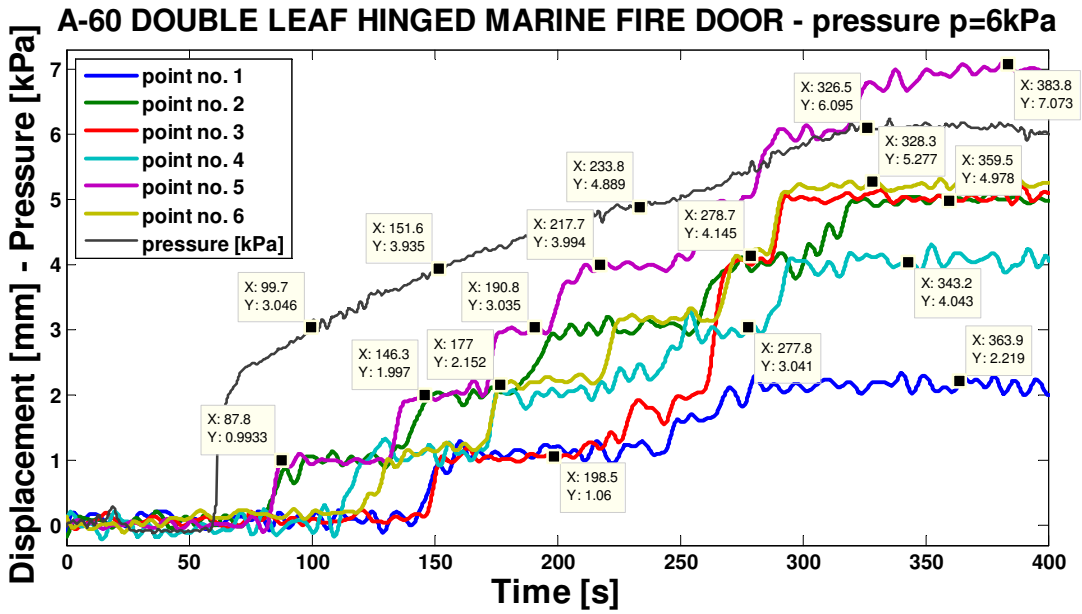


Fig. G4. 1st stage – pressure level p=6 kPa – tank filling up.

2nd stage – pressure level p=9 kPa

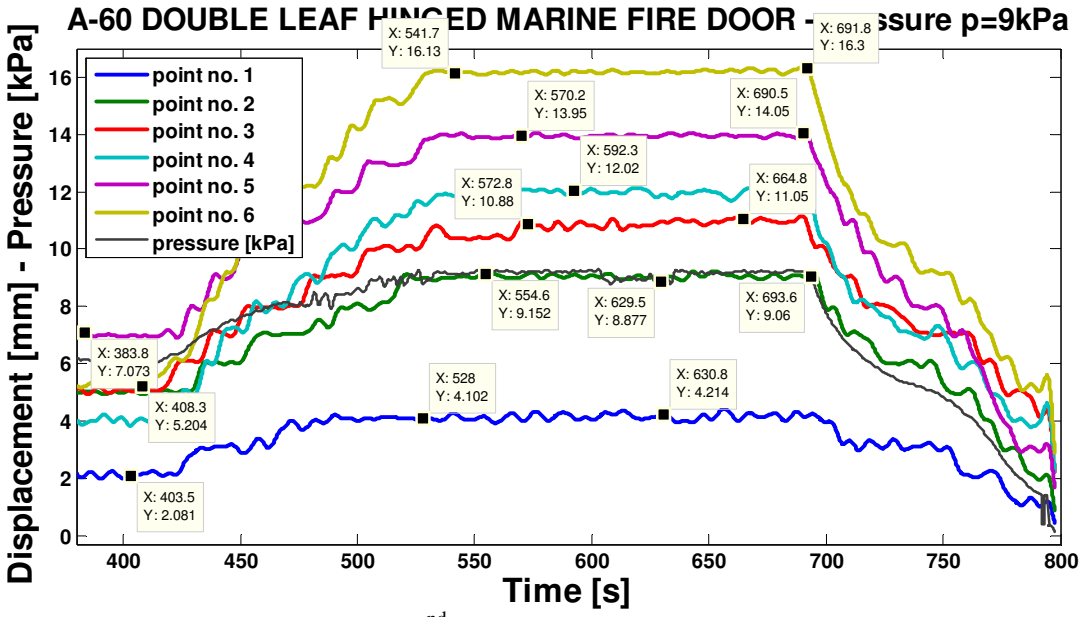


Fig. G5. 2nd stage – pressure level p=9 kPa.

Table TG.1. Displacement, leakage and pressure test results.

Tab. TG.1	Test results object no. 3,1, test number 15734							
Lp.	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	6,1	2,22	4,98	5,08	4,04	7,07	5,27	69,6
2	9,2	4,21	8,88	10,88	12,02	14,05	16,13	~ 90 critical flow

Test photos.

Fig. G6. Leak at pressure p=2,7 kPa.

Fig. G7. Leak at pressure p=4,6 kPa.

Fig. G8. Leak at pressure p=5,1 kPa.

No damage the door.

Fig. G9. The door after the test.

Fig. G10. The door after the test.

Fig. G11. The door after the test.

Fig. G12. The door after the test.

h) Model No. 4; Door - single leaf, test no 15732, (direction: "INTO the door frame")

Stand with installed test object no. 4, test number 15732.

Fig. H1. Stand with installed object test.

Dimensioning of measurements points of the element no. 4.

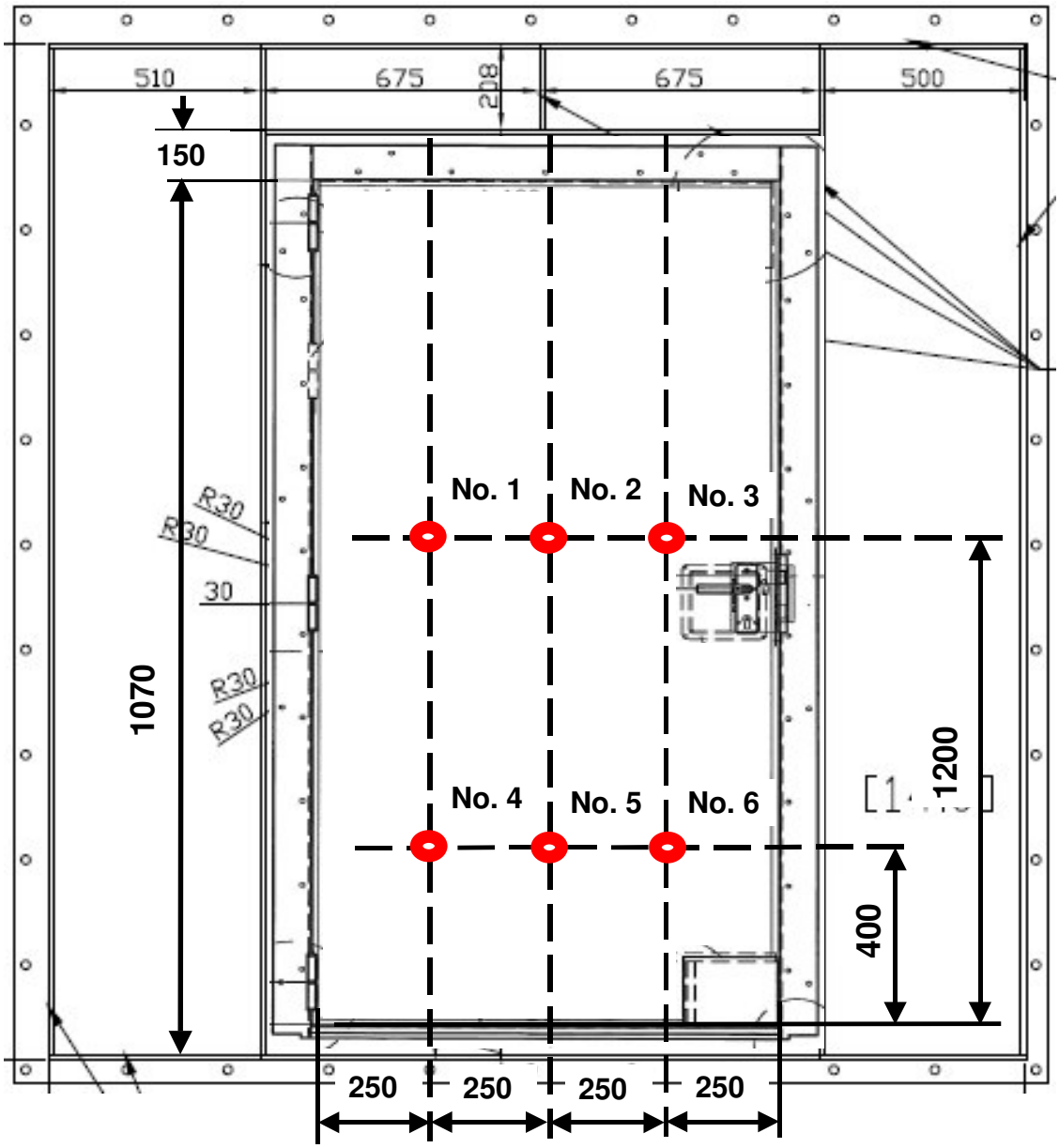


Fig. H2. Dimension plan of a measurement points.

Results of the test are presented on Fig. H3 to Fig. H8.

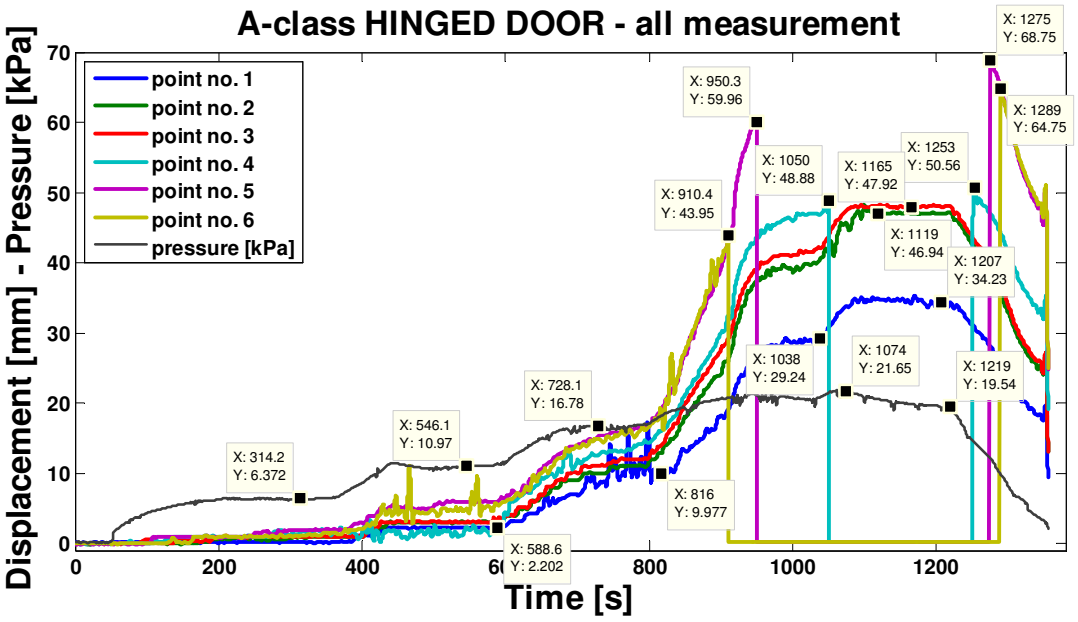


Fig. H3. Measurement results (full time history).

1st stage – pressure level p=6,5 kPa – tank filling up.

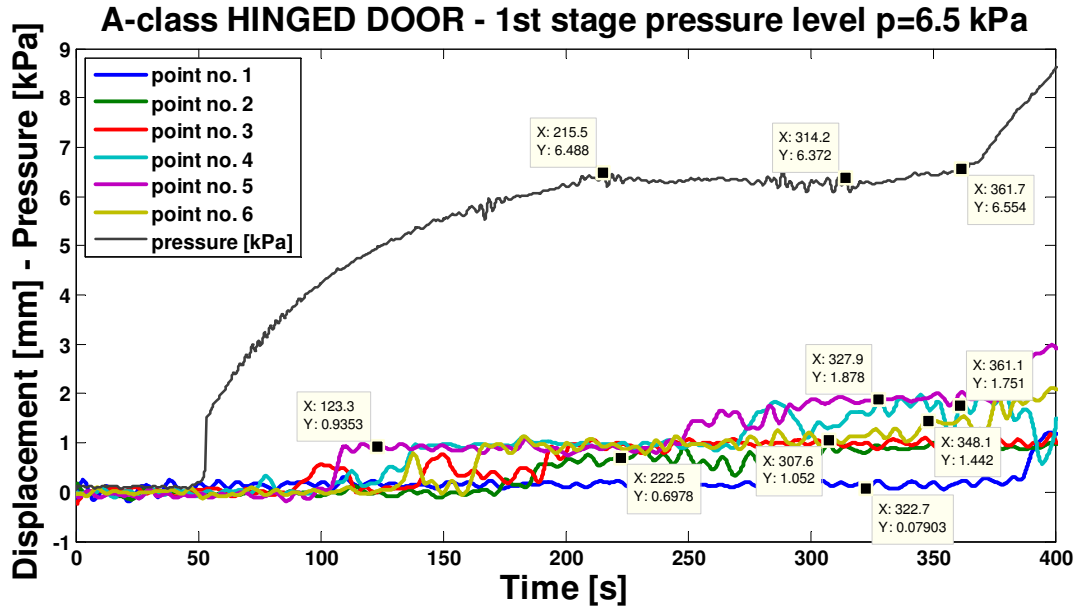


Fig. H4. 1st stage – pressure level p=6,5 kPa – tank filling up.

2nd stage – pressure level p=11 kPa

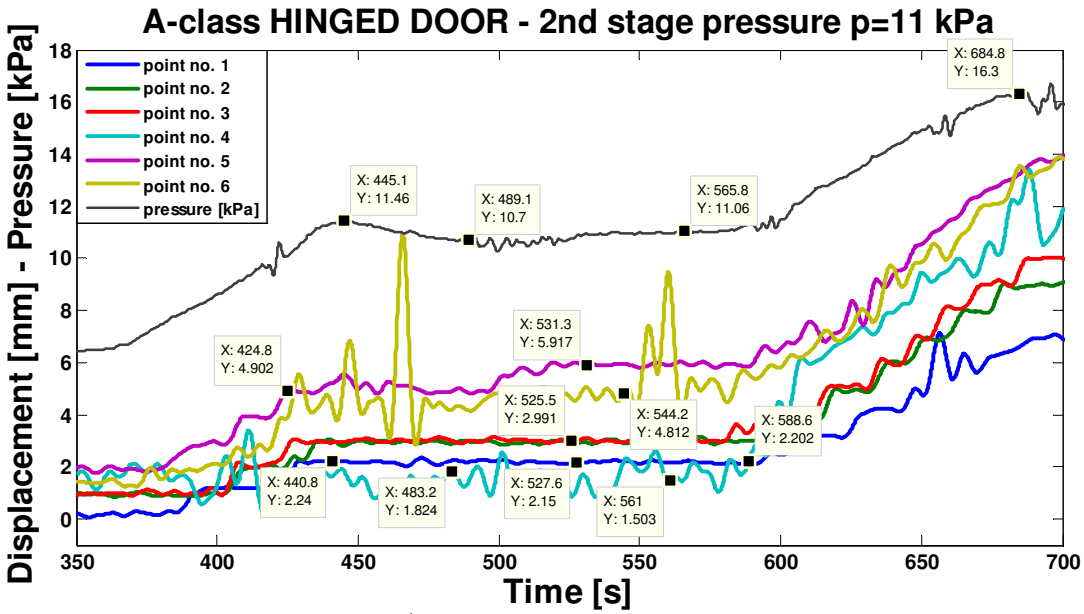


Fig. H5. 2nd stage – pressure level p=11 kPa.

3rd stage – pressure level p=17 kPa

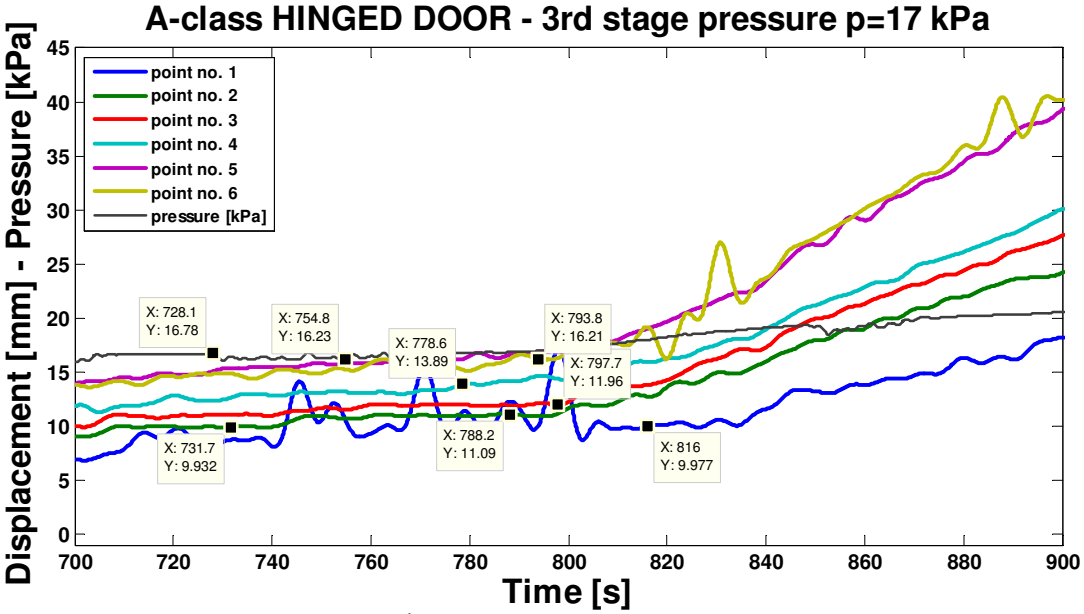


Fig. H6. 3rd stage – pressure level p=17 kPa.

4th stage – pressure level p=20.5 kPa

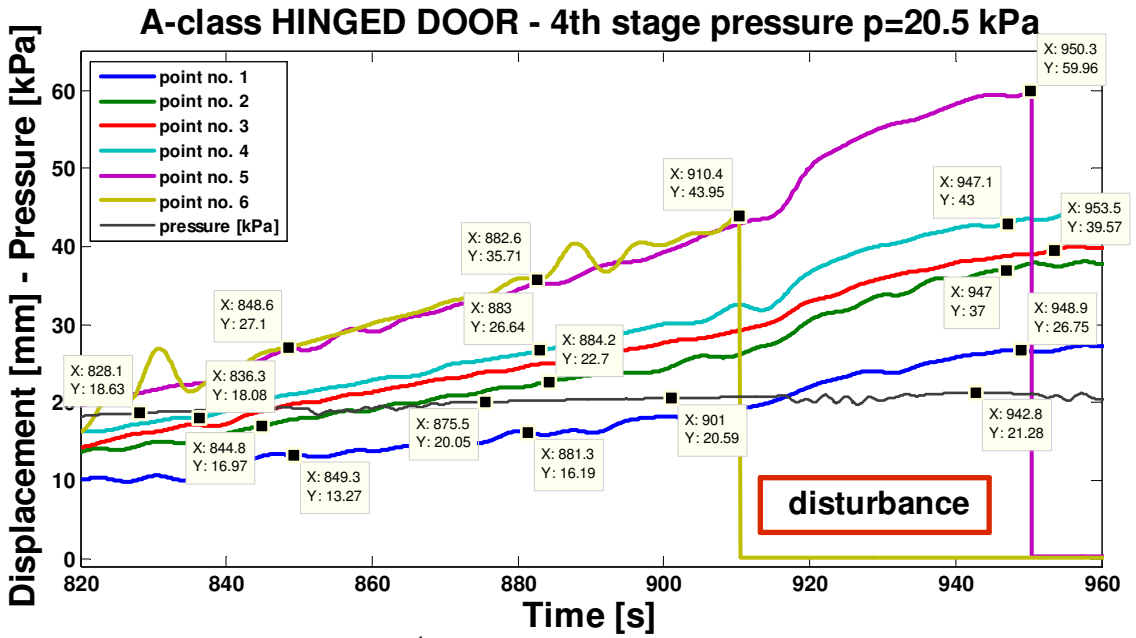


Fig. H7. 4th stage – pressure level p=20.5 kPa.

5th stage – finished

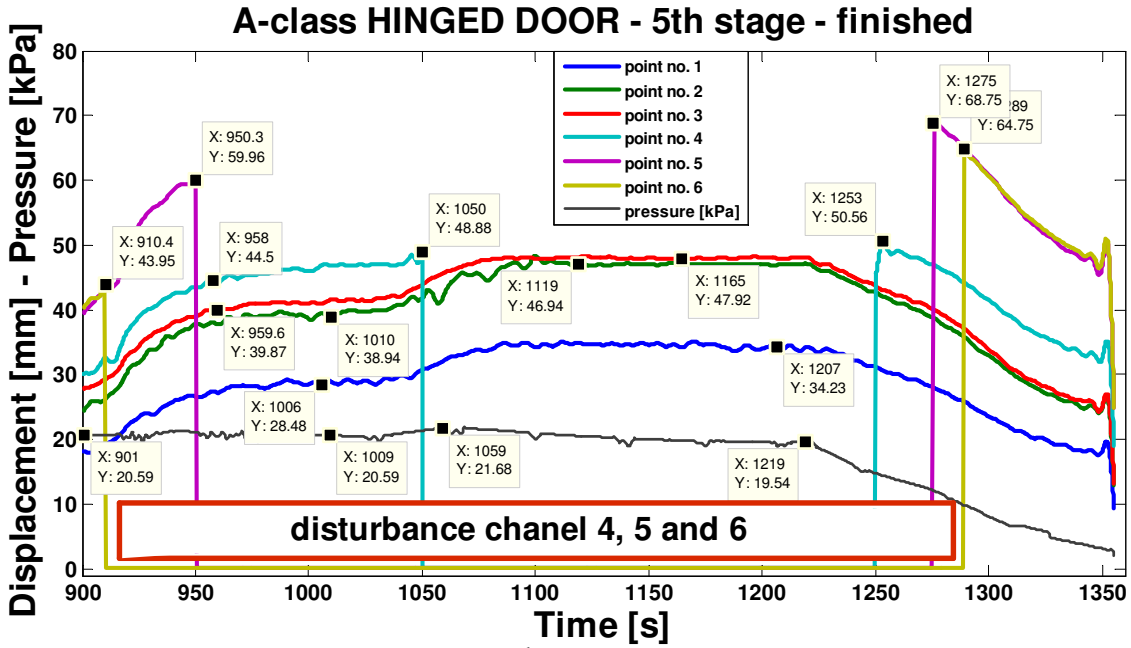


Fig. H8. 5th stage – finished.

Table TH.1. Displacement, leakage and pressure test results.

Tab. TH.1	**Test results object no. 4, test number 15732**							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	6,4	0,08	0,89	1,13	1,73	1,94	1,20	26,8
2	11,1	2,15	2,99	3,01	1,95	5,92	4,81	57,5
3	16,6	10,60	11,00	12,01	13,89	16,77	16,15	72,0
4	21,2	26,75	37,70	38,96	43,00	59,96	disturbance over 60,0	72,6
5	22,0	34,23	46,94	47,92	disturbance	disturbance	disturbance	~ 90,0 damage

Test photos.

Fig. H9. Leak at pressure p=17 kPa.

Fig. H10. Leak at pressure p=19 kPa.

Fig. H11. Leak at pressure p=21,9 kPa.

Fig. H12. Door damage.

Fig. H13. Door damage.

Fig. H14. Door damage.

Fig. H15. Door damage.

Fig. H16. Door damage.

Fig. H17. Door damage.

Fig. H18. Door damage.

4.2 ELEMENTS: TYPE B3, B class joiner door

j) Model No. 5.1; B class joiner door – hinged, Steelframes for B-wall; test no 15578, (direction: "OUT the door frame")

Stand with installed test object no. 5,1, test number 15578.

Fig. J1. Stand with installed object test.

Measuring points

Fig. J2. Measuring points location.

Dimensioning of measurements points of the element no. 5.1.

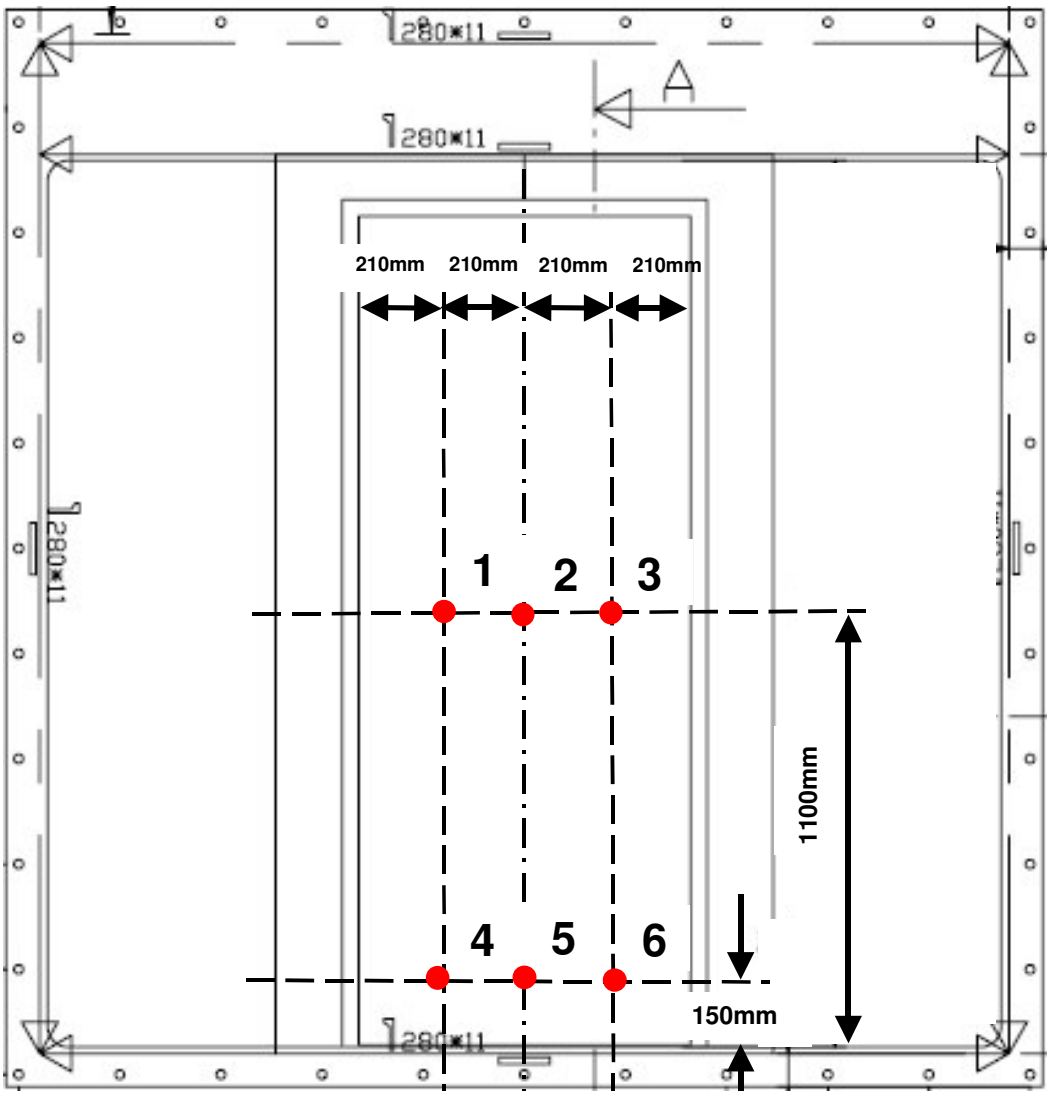


Fig. J3. Dimension plan of a measurement points.

Results of the test are presented on Fig. J4 to Fig. J8.

All measurements on object test no 5.1.

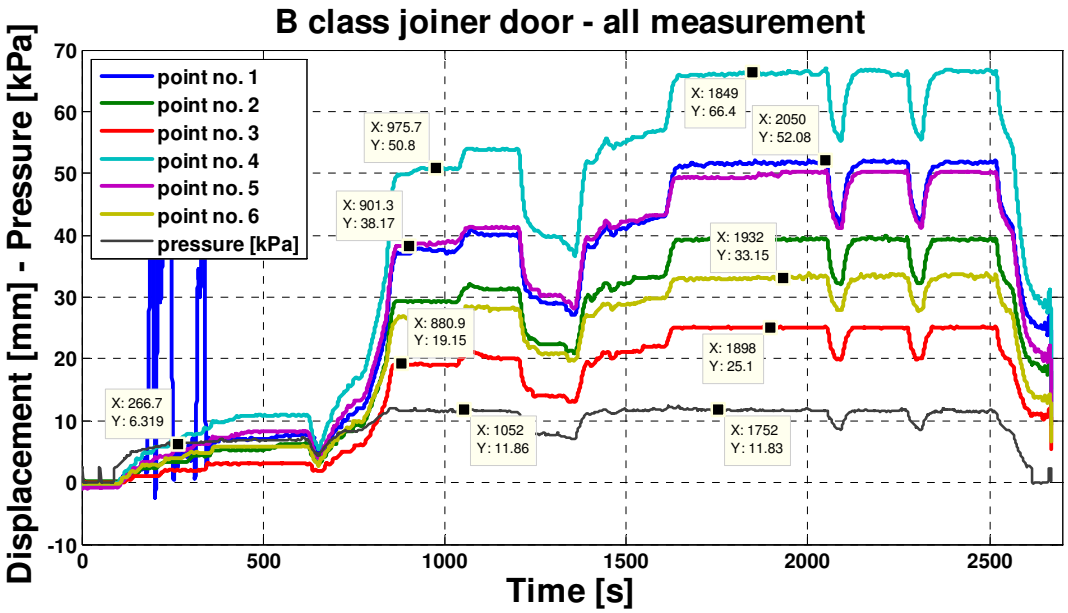


Fig. J4. Measurement results (full time history).

Interference

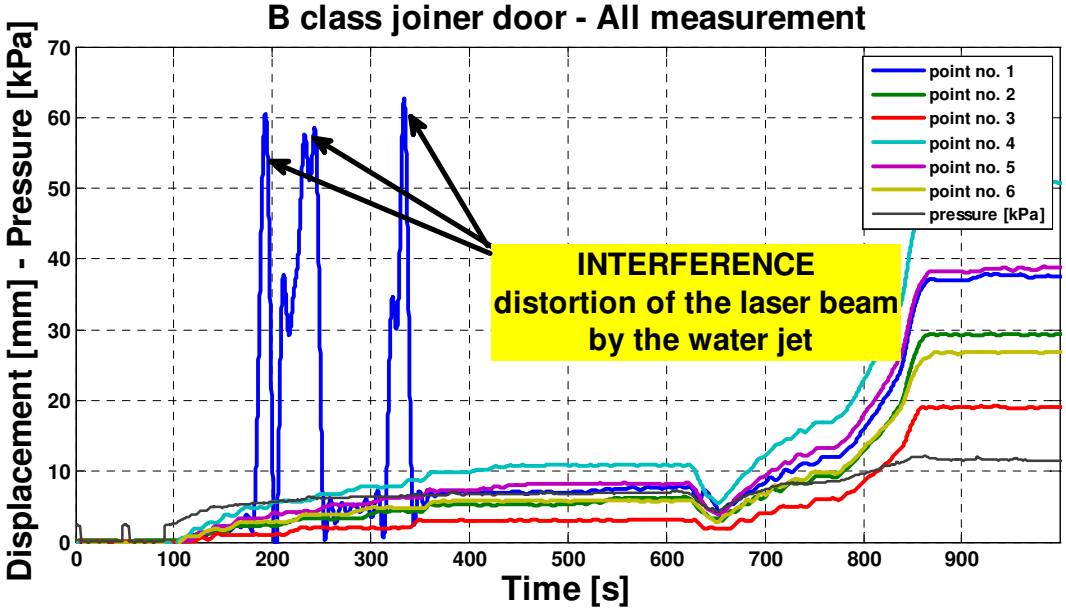


Fig. J5. Distortion of the laser beam by the water jet.

1st stage – pressure level p=6,7 kPa – tank filling up

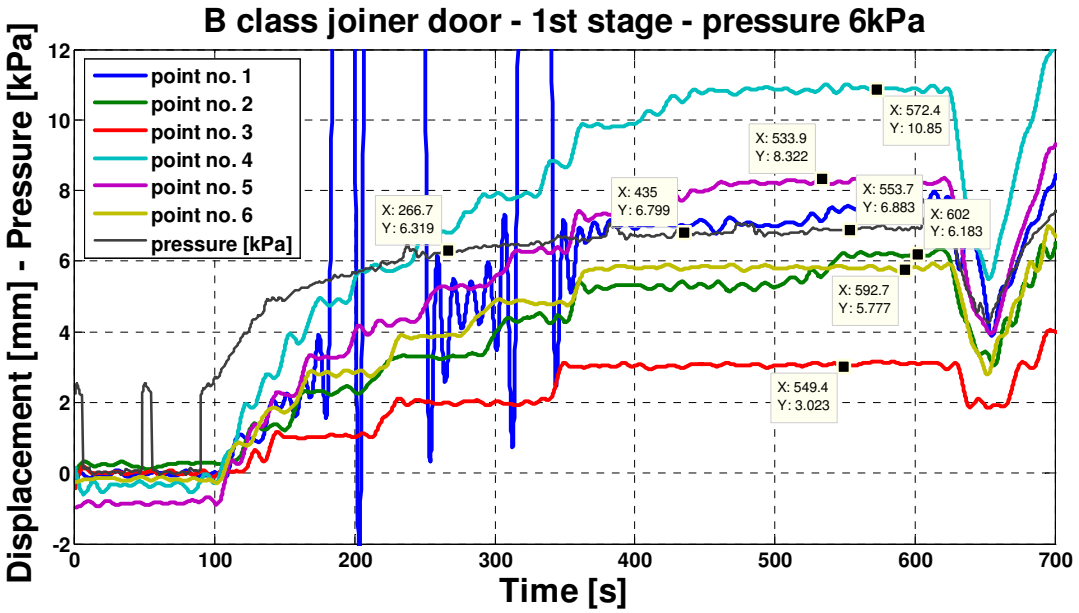


Fig. J6. 1st stage, pressure level p=6,7kPa.

2nd stage – pressure level p=12 kPa

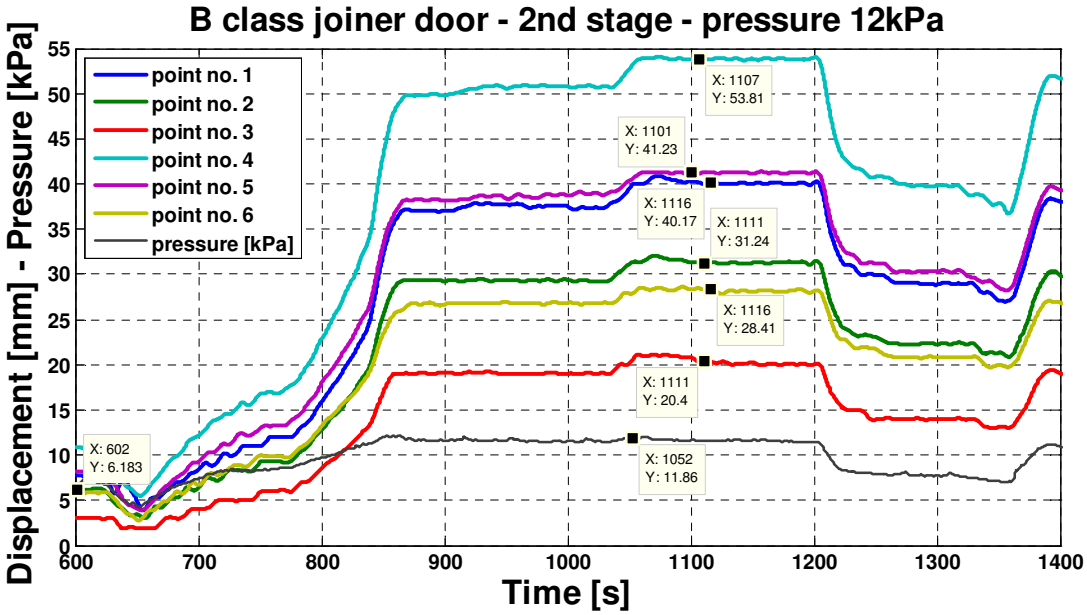


Fig. J7. 2nd stage, pressure level p=12 kPa.

3rd stage – finish

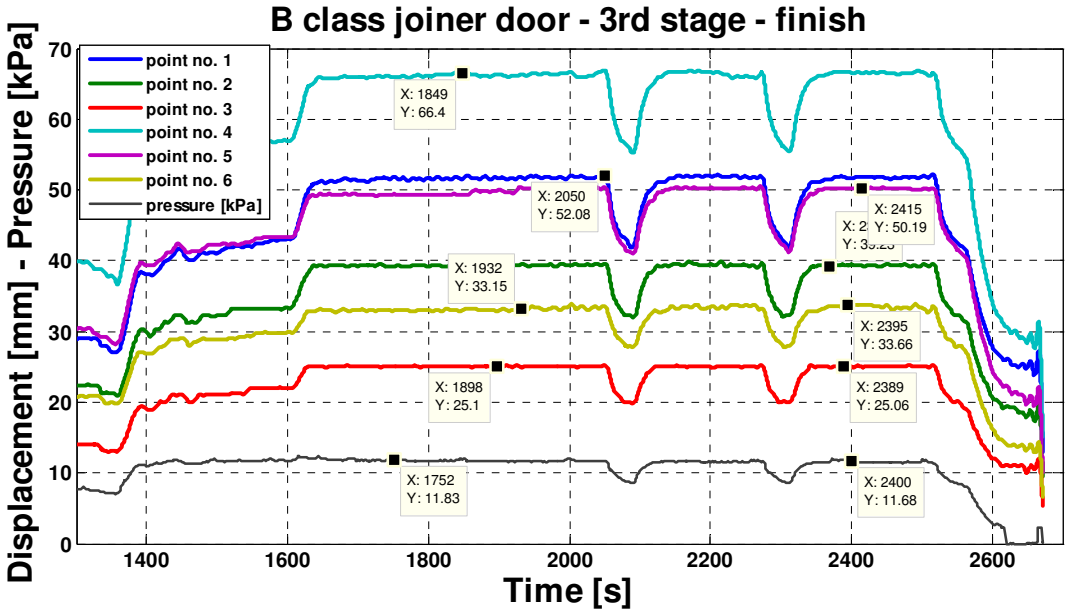


Fig. J8. 3rd stage, finish.

Table TJ.1. Displacement, leakage and pressure test results.

Tab. TJ.1	Test results object no. 5,1, test number 15578							
Lp.	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	6,8	7,03	5,42	3,02	10,85	8,32	5,47	31,0
2	11,9	40,17	31,24	20,40	53,81	40,23	28,41	54,9
3	11,7	50,28	39,25	25,10	66,40	50,18	33,66	91,6

Test photos.

Disturbance during the measurement;

Fig. J9. Leak at pressure p=6,3 kPa.

Fig. J10. Leak at pressure p=11,9 kPa – 2nd stage.

Fig. J11. Leak for pressure p=11,3 kPa – 3rd stage - finish.

Damage the door

Fig. J12. Door damage.

Fig. J13. Door handle.

Fig. J14. Door - damage.

Fig. J15. Door – damage – bottom.

Fig. J16. Door – down.

k) Model No. 5.2; B class joiner door – hinged, Steelframes for B-wall; test no 15574, (direction: "INTO the door frame")

Stand with installed test object no. 5,2, test number 15574.

Fig. K1. Stand with installed test object no. 5,2.

Dimensioning of measurements points of the element no. 5.2.

Fig. K2. Measuring points location.

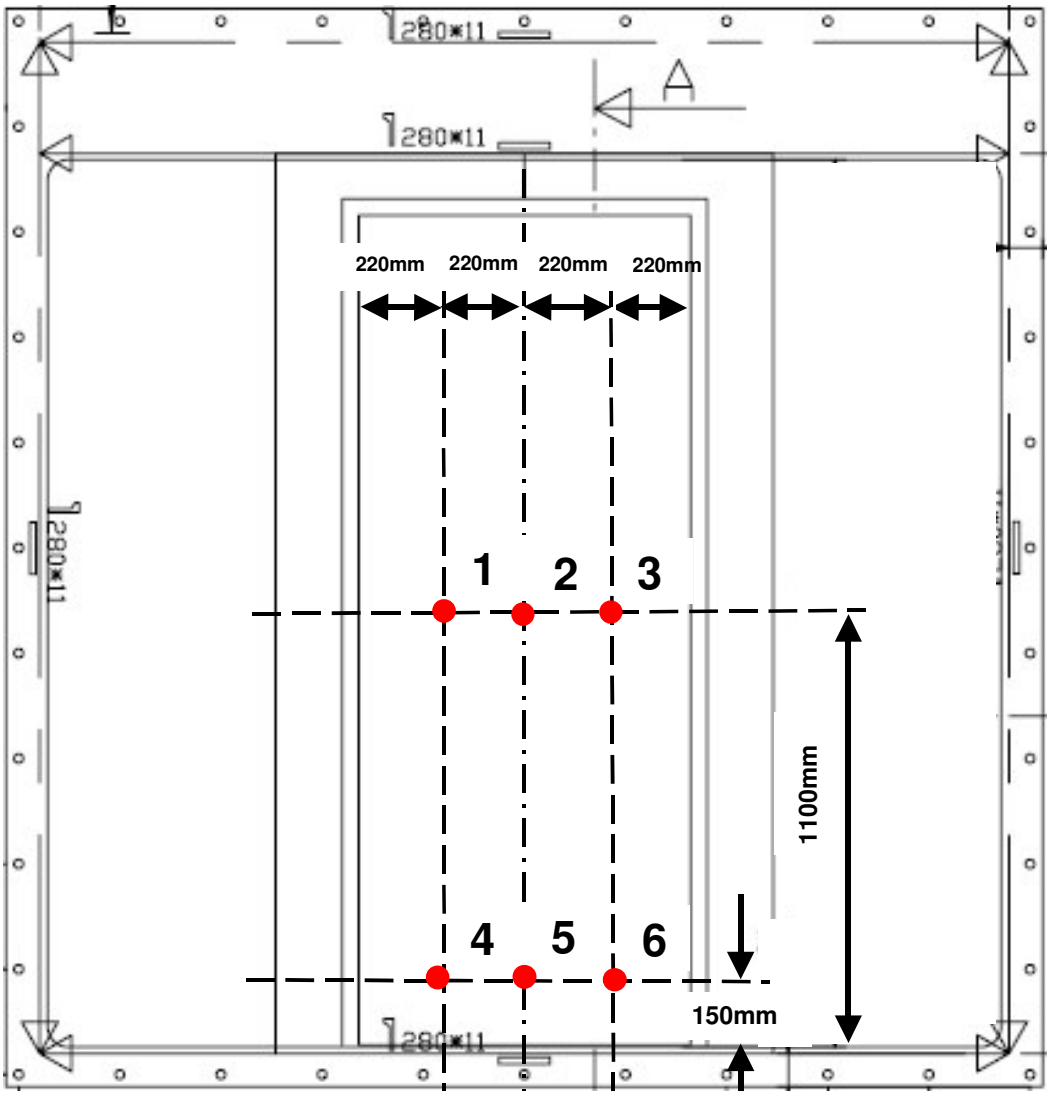


Fig. K3. Dimension plan of a measurement points.

Results of the test are presented on Fig. K4 to Fig. K7.

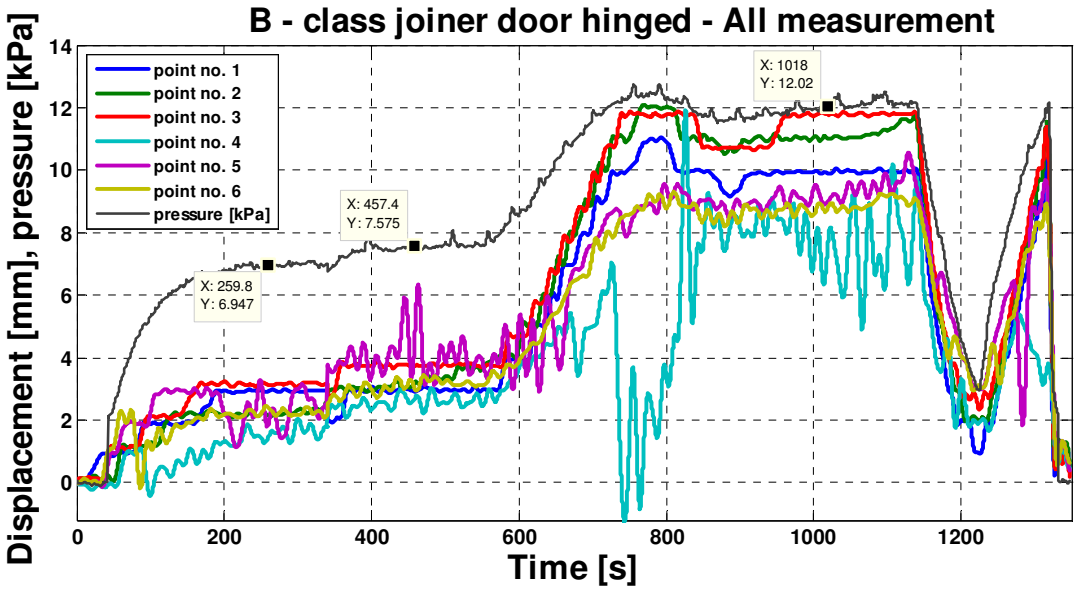


Fig. K4. Measurement results (full time history).

1st stage – pressure p=7kPa

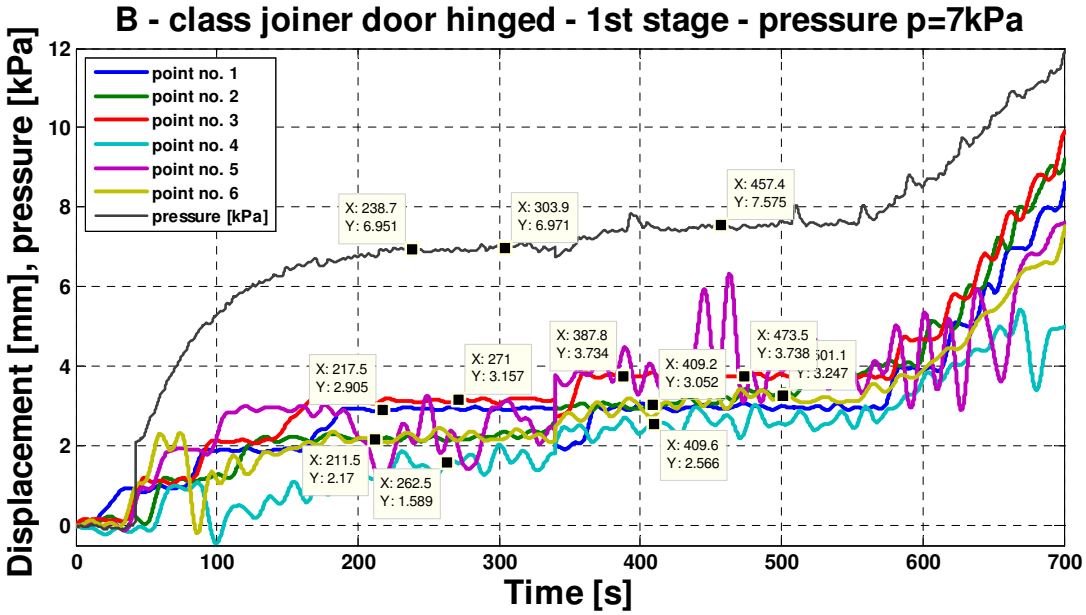


Fig. K5. 1st stage – pressure p=7kPa.

2nd stage – pressure p=12 kPa

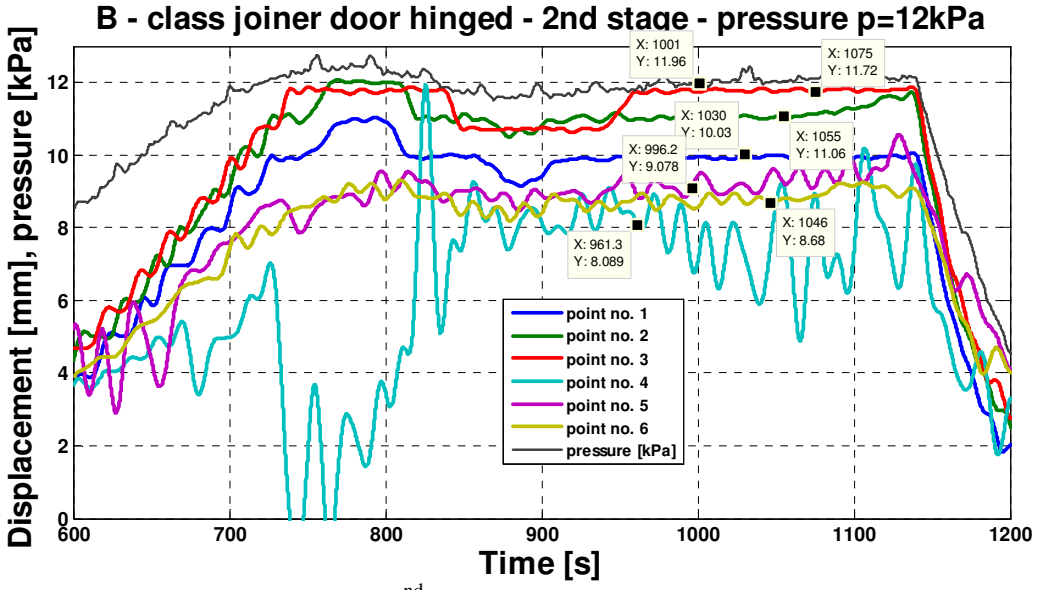


Fig. K6. 2nd stage – pressure p=12 kPa.

Finish test

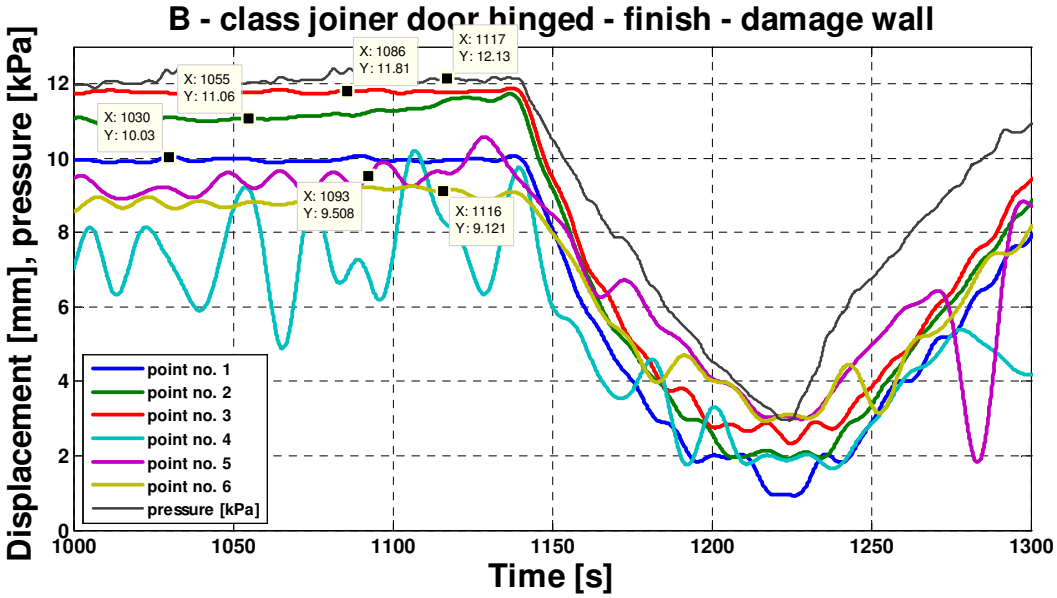


Fig. K7. Damage test object no 52, push a wall.

Table TK.1. Displacement, leakage and pressure test results.

Tab. TK.1	Test results object no. 5,2, test number 15574							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	7,0	2,97	2,17	3,16	1,58	2,31	2,17	~20,5
2	11,9	9,93	11,03	11,72	8,52	9,12	8,68	~63,8
3	12,3	damage	damage	damage	damage	damage	damage	------

Fig. K8. Test object no 5.2 damage, pushed wall.

Fig. K9. Leak for pressure p=5 kPa.

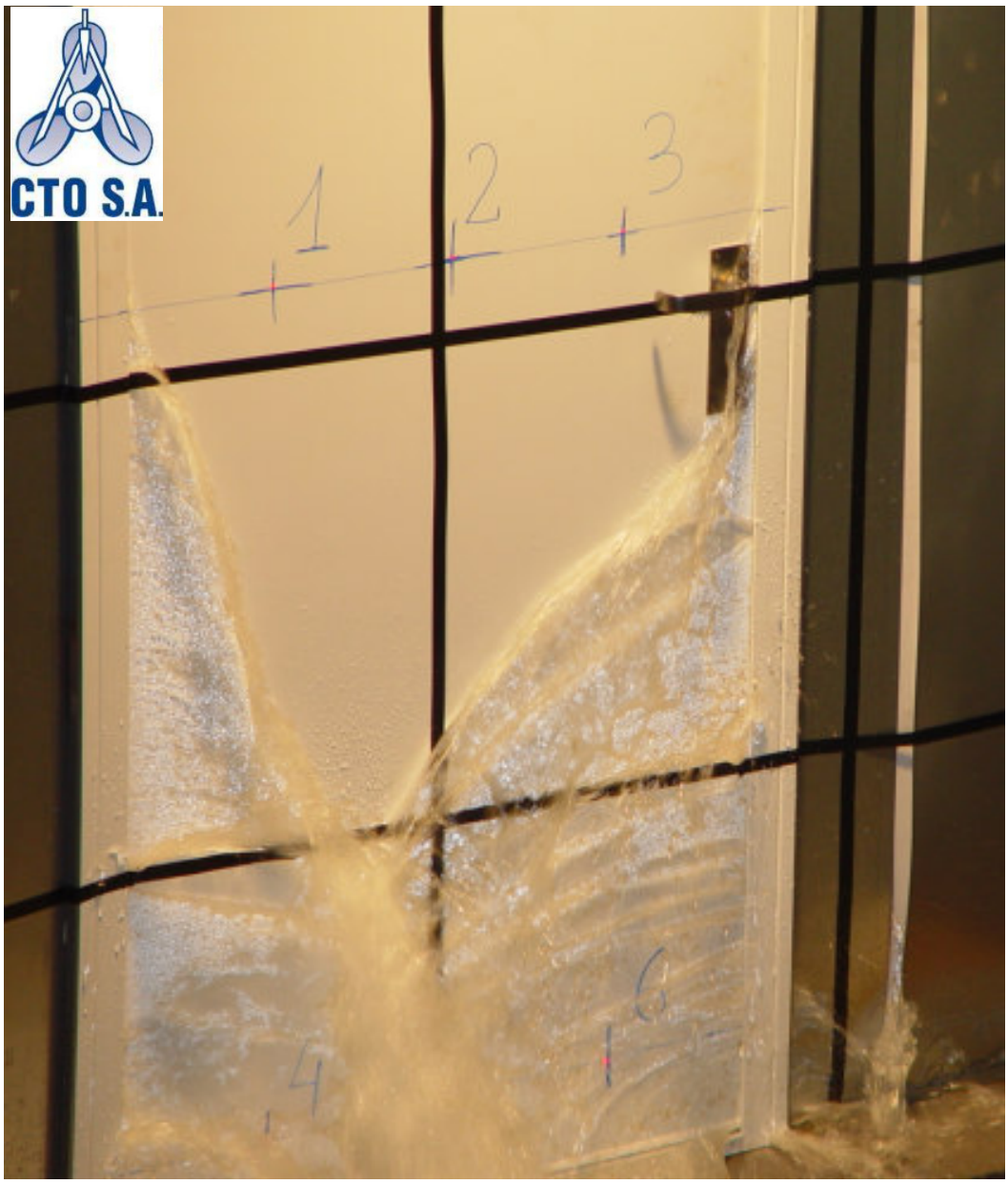


Fig. K10. Leak for pressure p=12 kPa.

Fig. K11. Test object damage, pushed wall.

Fig. K12. Test object damage, pushed wall.

Fig. K13. Test object damage, pushed wall.

Fig. K14. Object no 5,2.

l) Model No. 5.3; B class joiner door – hinged, Steelframes for B-wall; test no 15579, (direction: "INTO the door frame")

Stand with installed test object no. 5,3, test number 15579.

Fig. L1. Stand with installed test object no. 5,3.

Dimensioning of measurements points of the element no. 5.3.

Fig. L2. Measuring points location.

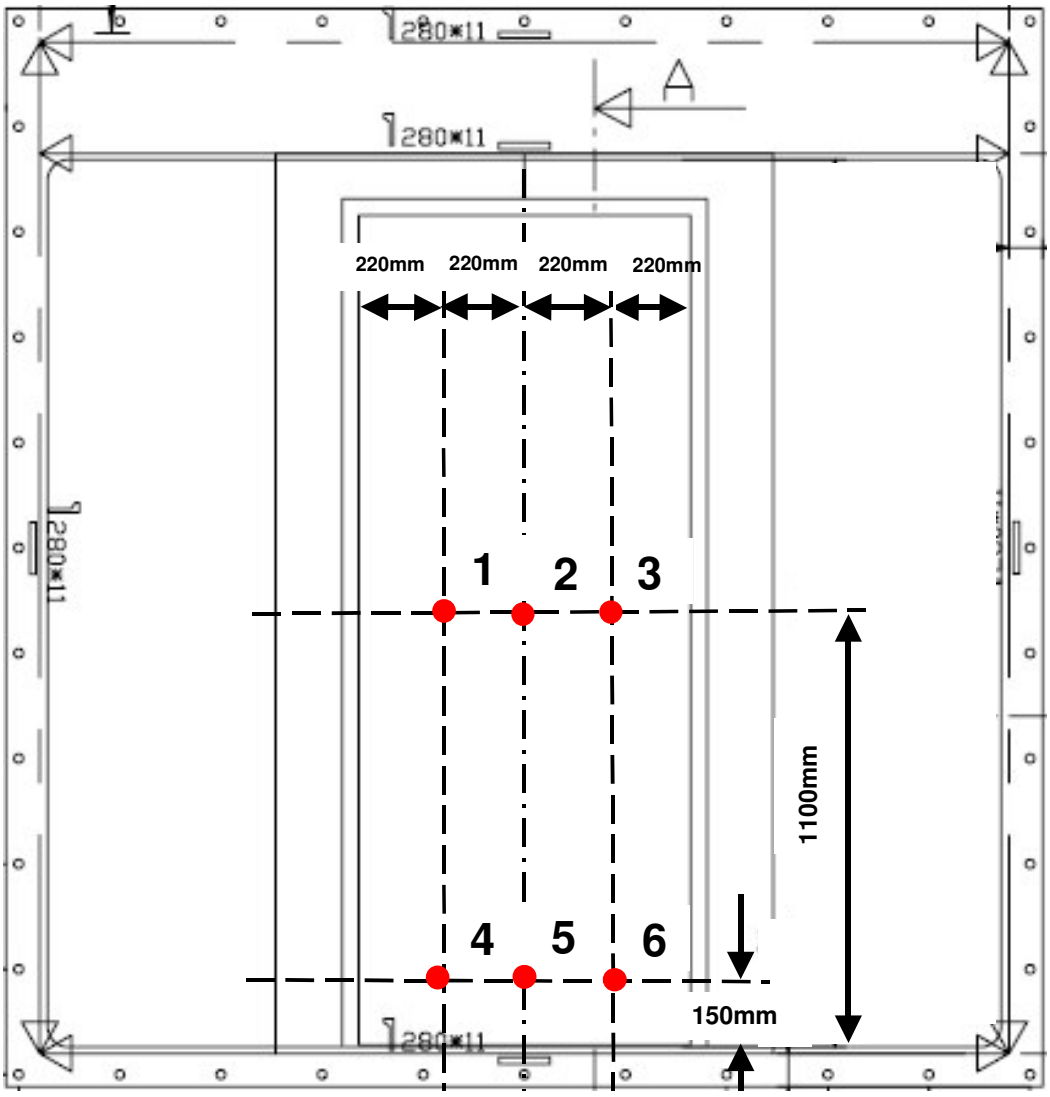


Fig. L3. Dimension plan of a measurement points.

Results of the test are presented on Fig. L4 to Fig. L5.

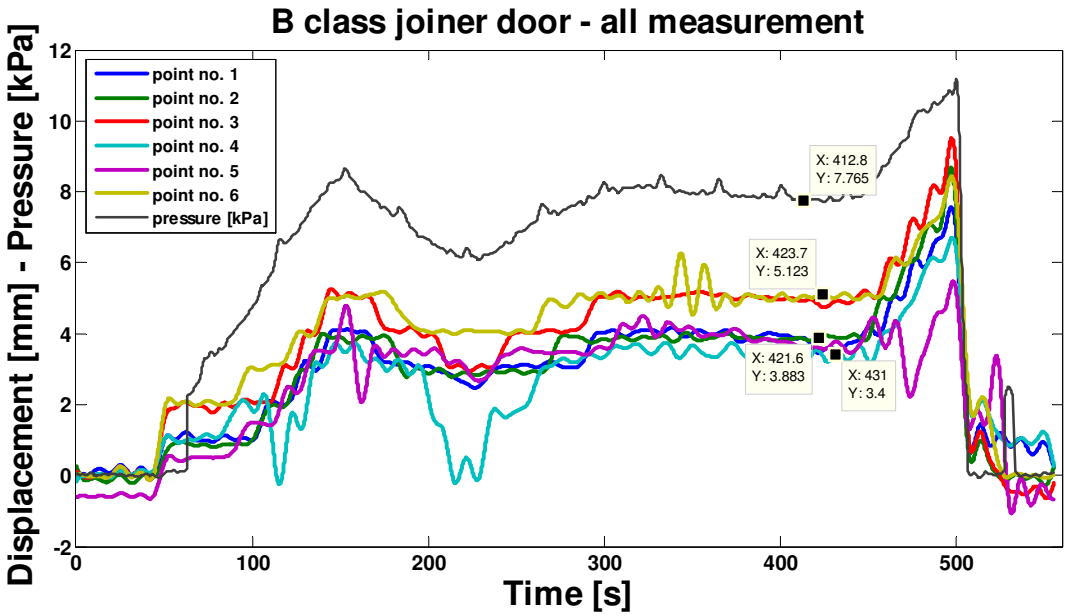


Fig. L4. Measurement results (full time history).

Finished – damage the door.

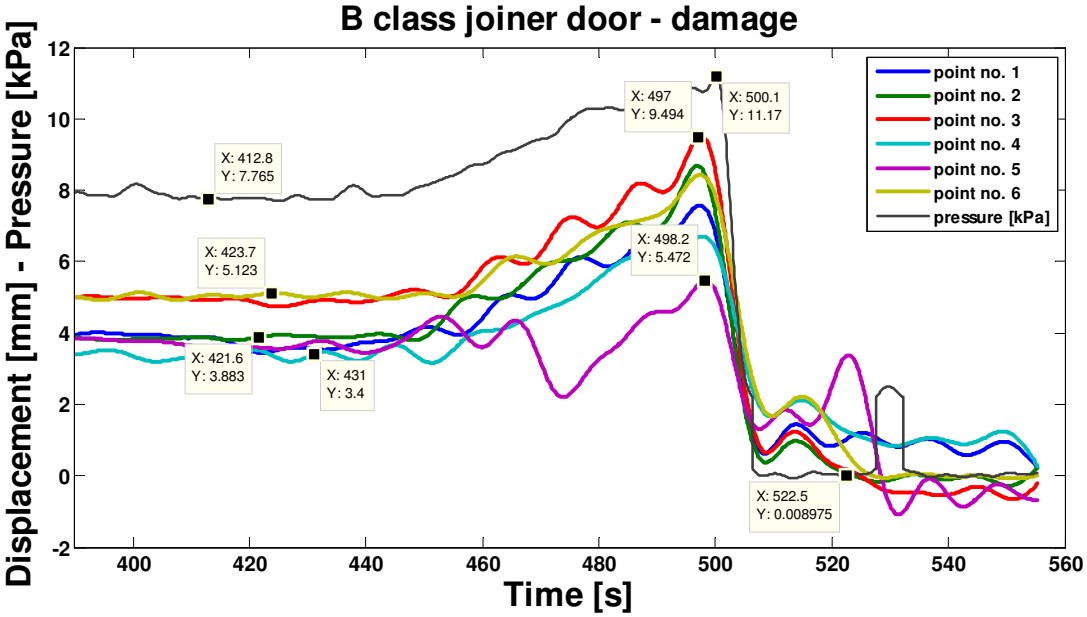


Fig. L5. Test object no. 5.3. damage

Table TL.1. Displacement, leakage and pressure test results.

Tab. TL.1	Test results object no. 5,3, test number 15579							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	7,8	3,81	3,91	4,84	3,35	3,63	5,12	32,1
2	11,2	7,56 damage	8,67 damage	9,49 damage	6,71 damage	5,47 damage	8,43 damage	61,1 damage

Test photos.
Leak at pressure p=7,8 kPa;

Fig. L6. Leak at pressure p=7,8 kPa.

Door damage.

Fig. L7. Wall damage.

Fig. L8. Wall damage.

Fig. L9. Wall damage.

Fig. L10. Wall damage.

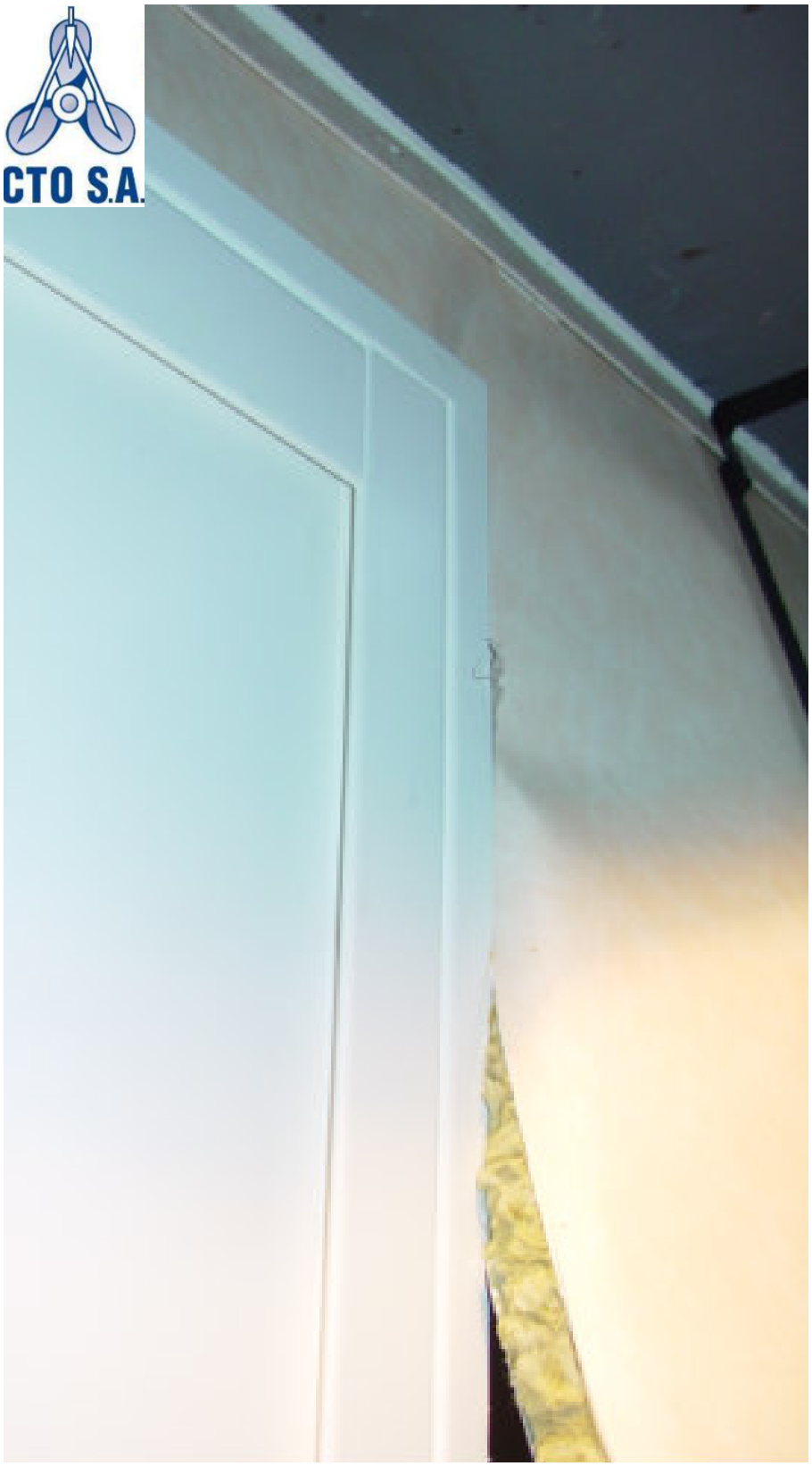


Fig. L11. Wall damage.

Fig. L12. Wall damage.

Fig. L13. Wall damage.

Fig. L14. Wall damage.

m) Model No. 5.4; B class joiner door – hinged, Steelframes for B-wall; test no 15582, (direction: "OUT the door frame")

Stand with installed test object no. 5,4, test number 15582.

Fig. M1. Stand with installed object test.

Measuring points

Fig. M2. Measuring points location.

Dimensioning of measurements points of the element no. 5.4.

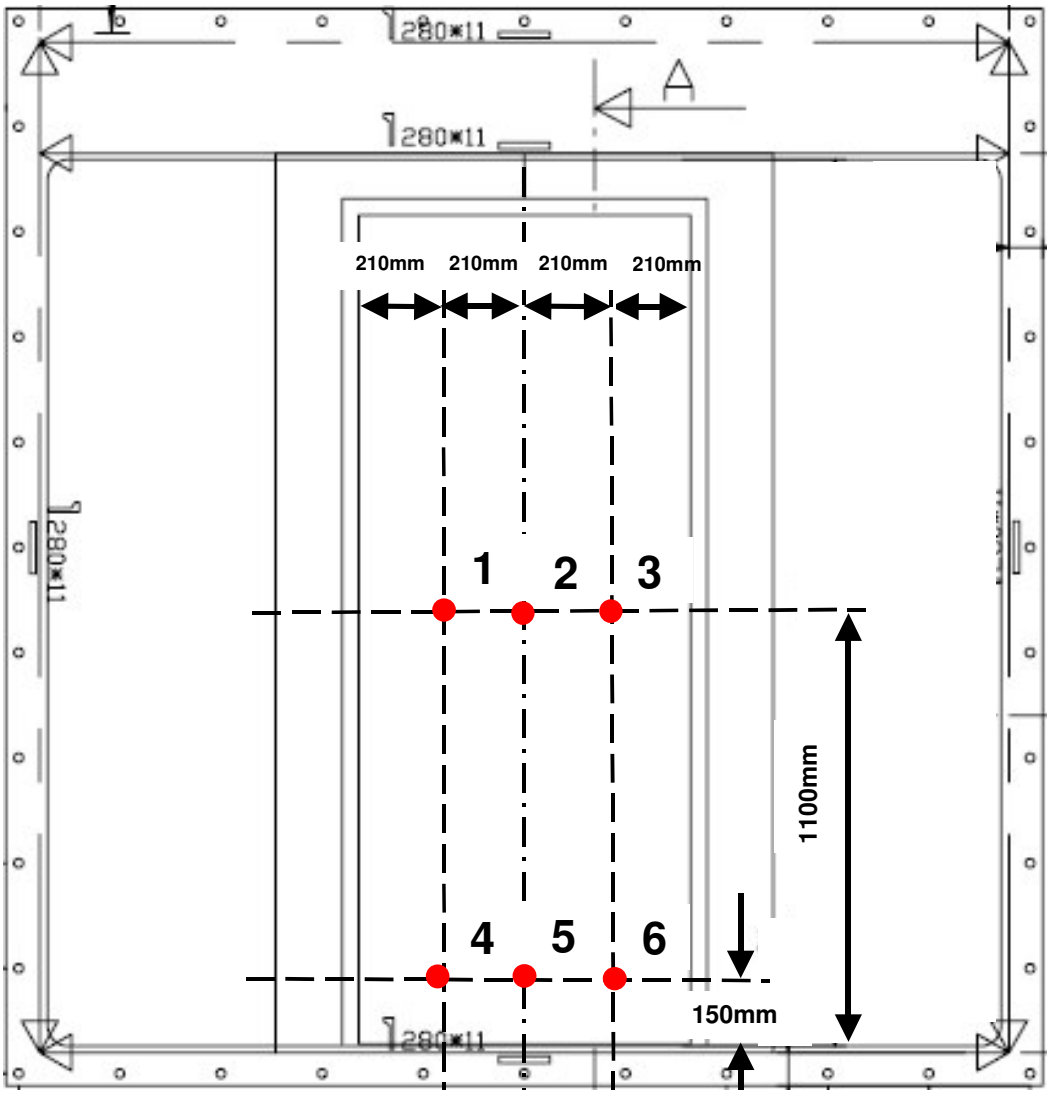


Fig. M3. Dimension plan of a measurement points.

Results of the test are presented on Fig. M4 to Fig. M6.

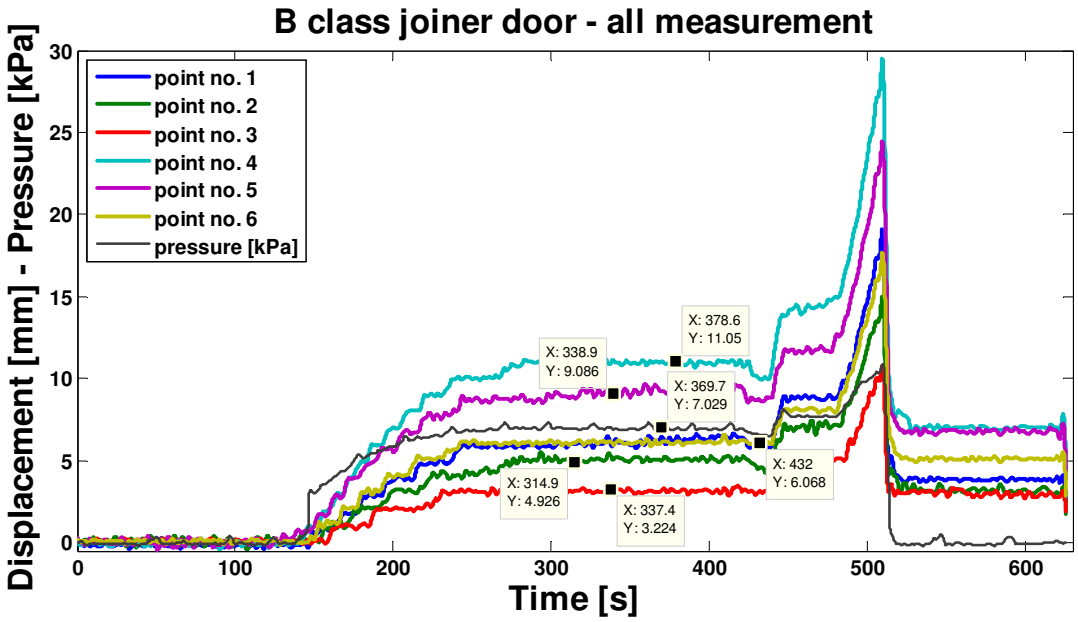


Fig. M4. Measurement results (full time history).

1st stage – pressure level p=6,7 kPa tank filling up

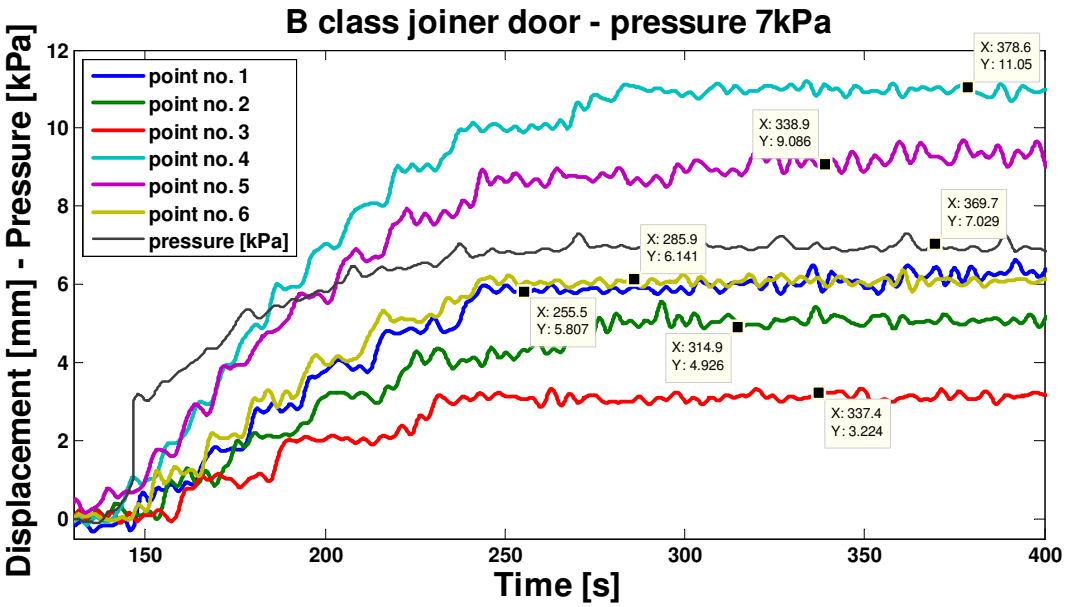


Fig. M5. 1st stage, pressure level p=6,7kPa.

2nd stage – pressure level p=10 kPa

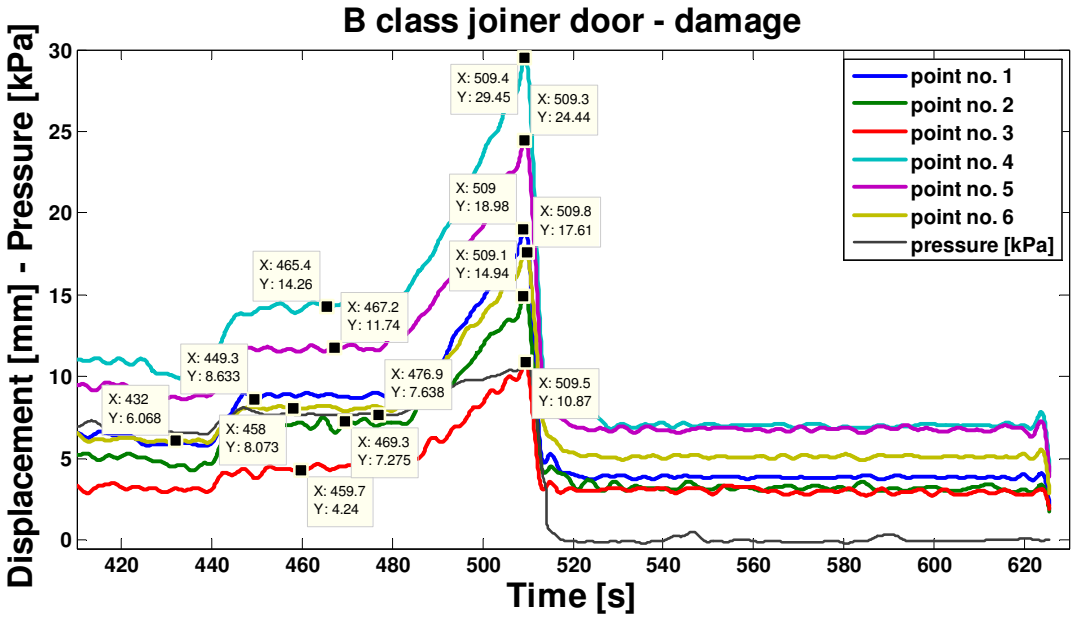


Fig. M6. 2nd stage, pressure level p=10 kPa.

Table TM.1. Displacement, leakage and pressure test results.

Tab. TM.1	Test results object no. 5,4, test number 15582							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	7,0	5,81	4,93	3,22	11,05	9,08	6,14	30,4
2	10,8	18,98 damage	14,94 damage	10,79 damage	29,45 damage	24,44 damage	17,61 damage	49,7 damage

Test photos.

Fig. M7. Leak at pressure p=7,0 kPa.

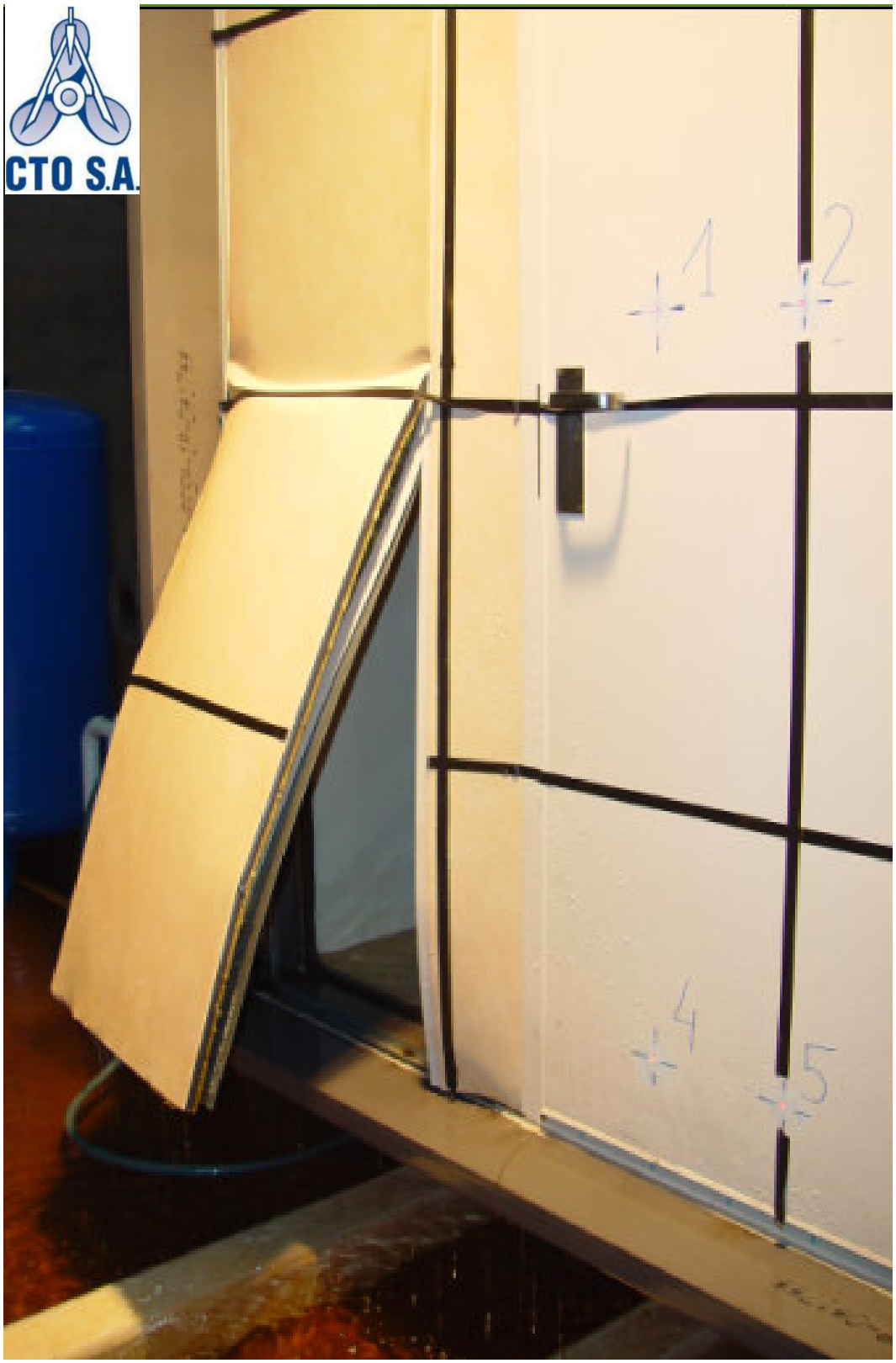


Fig. M8. Wall damage.

Fig. M9. Wall damage.

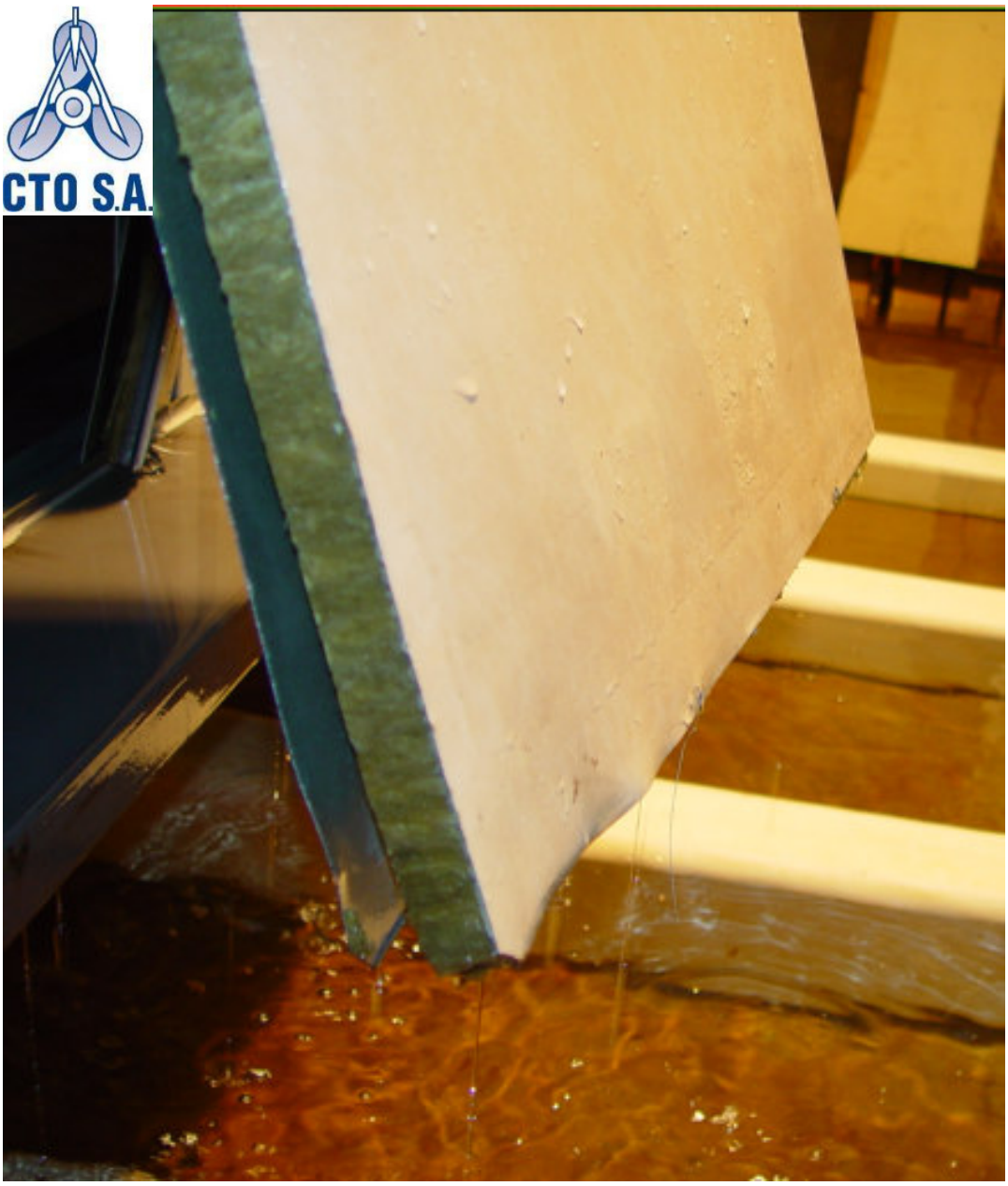


Fig. M10. Wall damage.

Fig. M11. Wall damage.

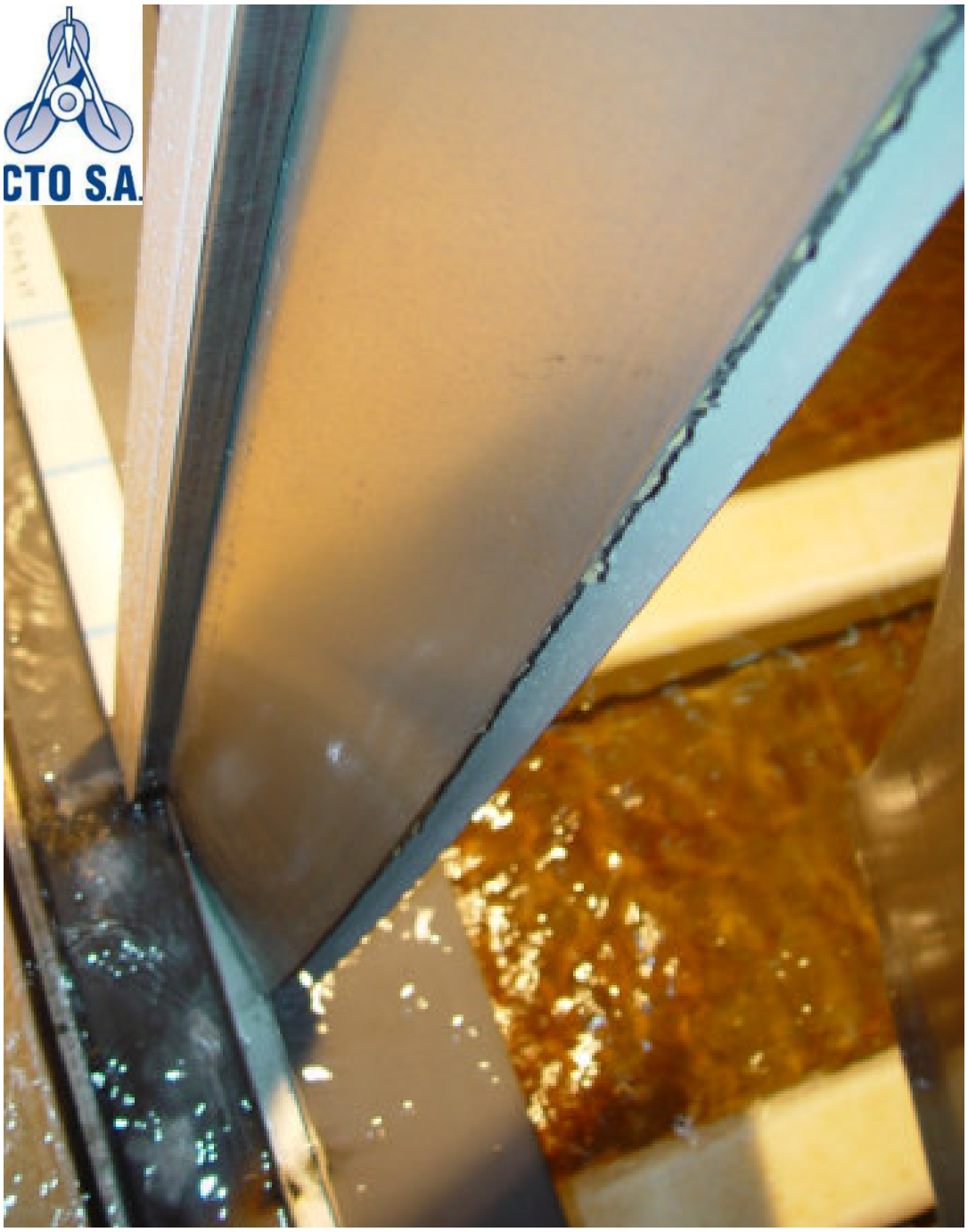


Fig. M12. Wall damage.

Fig. M13. Wall damage.

Fig. M14. Wall – damage.

4.3 ELEMENTS TYPE: OTHER, Cabin wall panel

n) Model No. 6; Cool Room sliding door; test no 15580, (direction: ”NTO the door wall”)

Stand with installed test object no. 6, test number 15580.

Fig. N1. Stand with installed object test.

Dimensioning of measurements points of the element no 6.

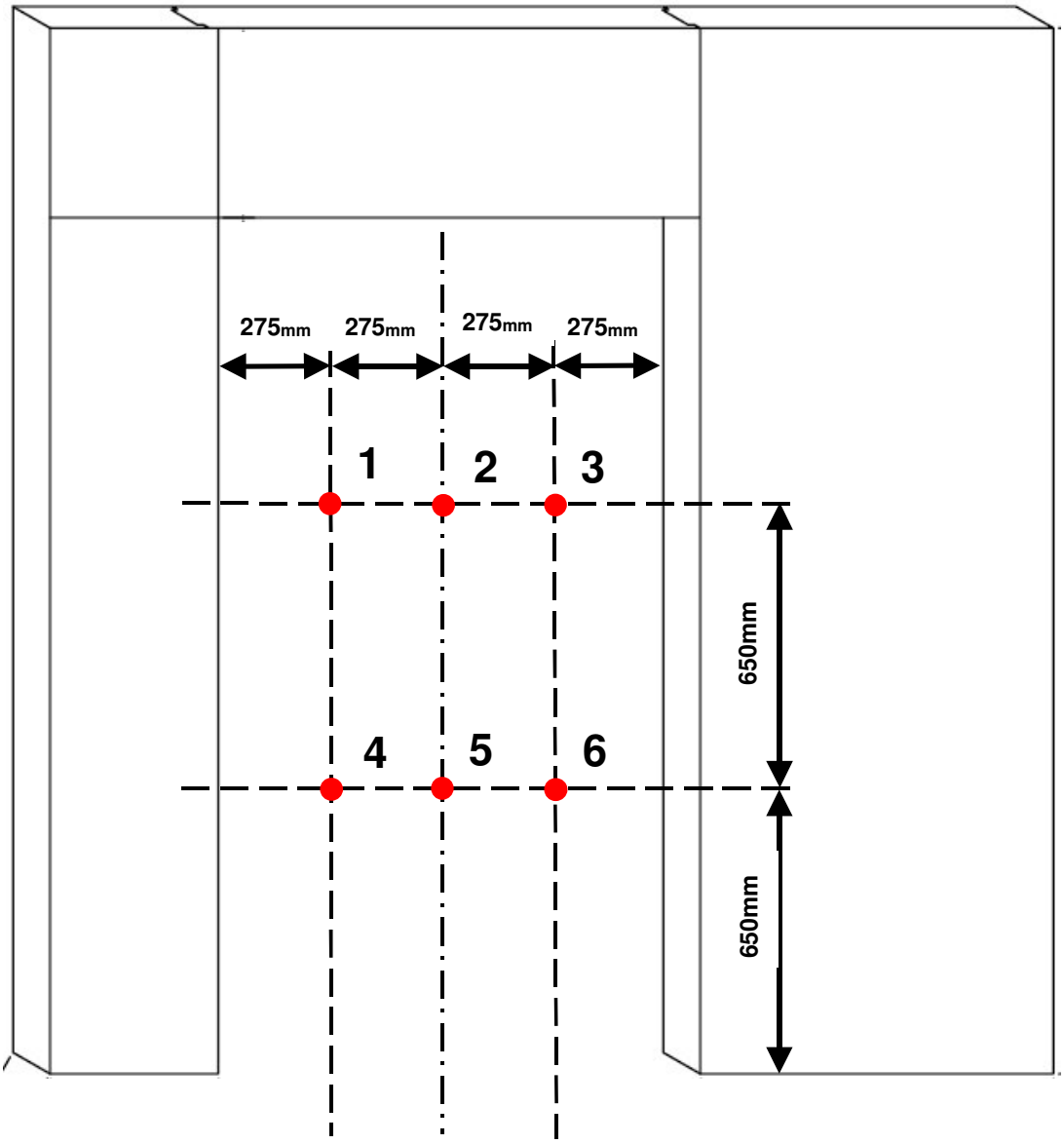


Fig. N2. Dimension plan of a measurement points.

Results of the test are presented on Fig. N3 to Fig. N8.

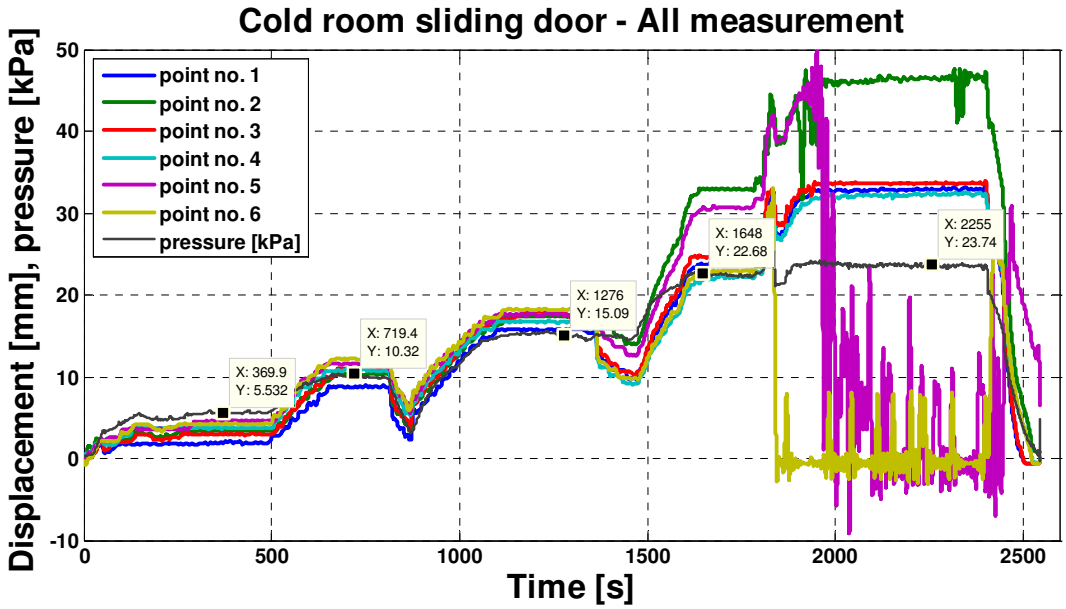


Fig. N3. Measurement results (full time history).

1st stage, pressure level p=5.5 kPa.

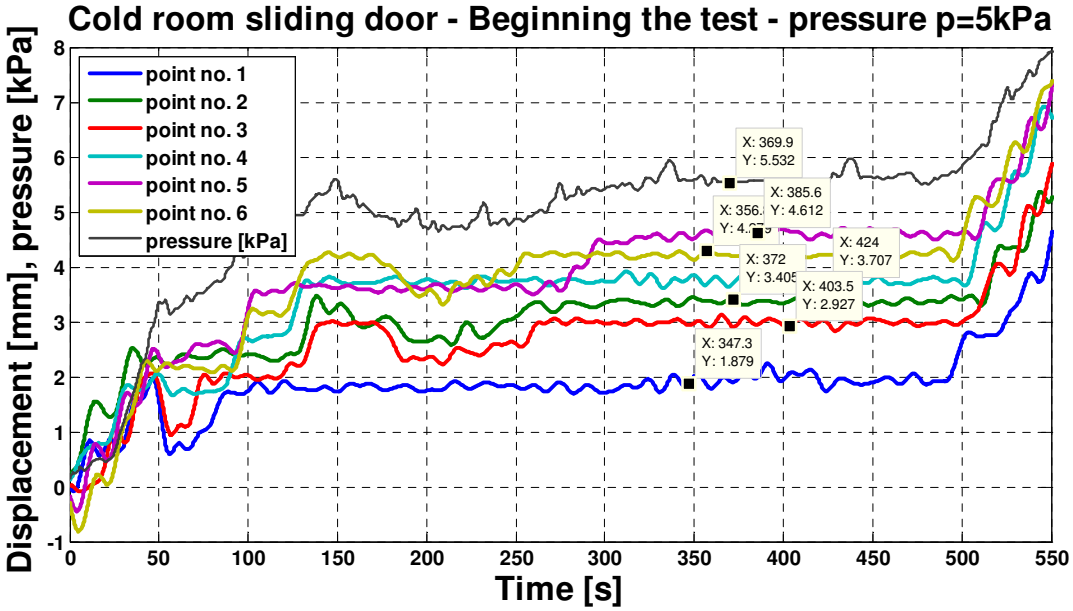


Fig. N4. 1st stage, pressure level p=5.5 kPa.

2nd stage – pressure level p=10 kPa

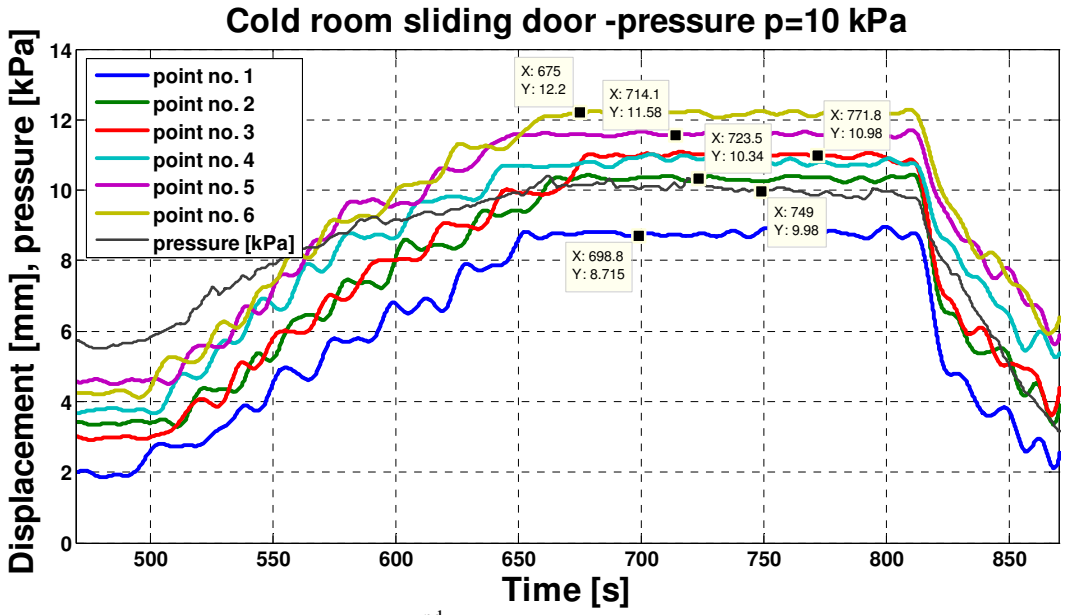


Fig. N5. 2nd stage – pressure level p=10 kPa.

3rd stage – pressure level p=15 kPa

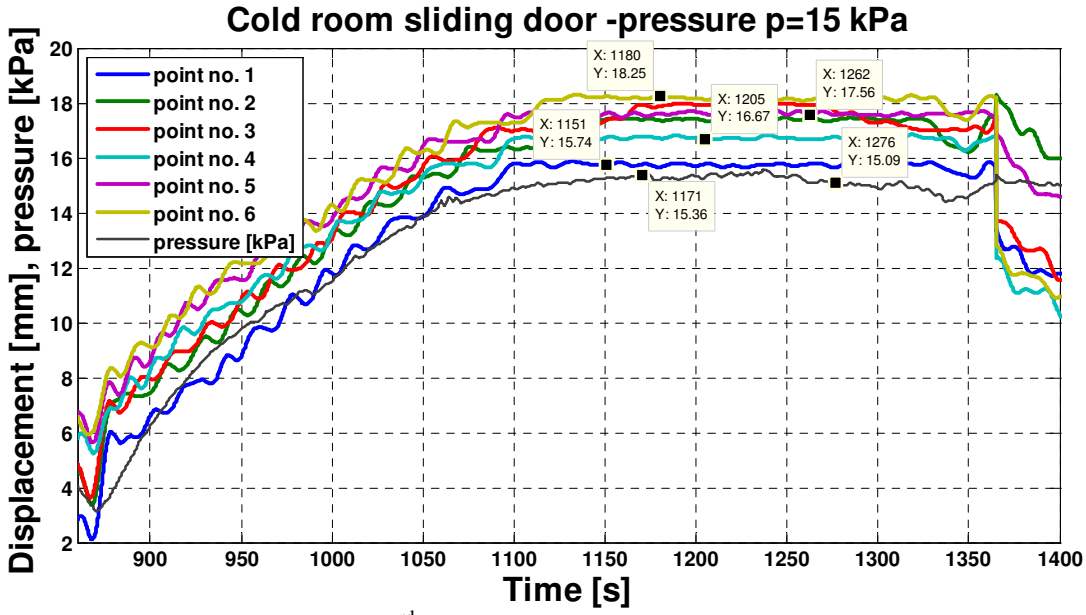


Fig. N6. 3rd stage – pressure level p=15 kPa.

4rd stage – pressure level p=22 kPa

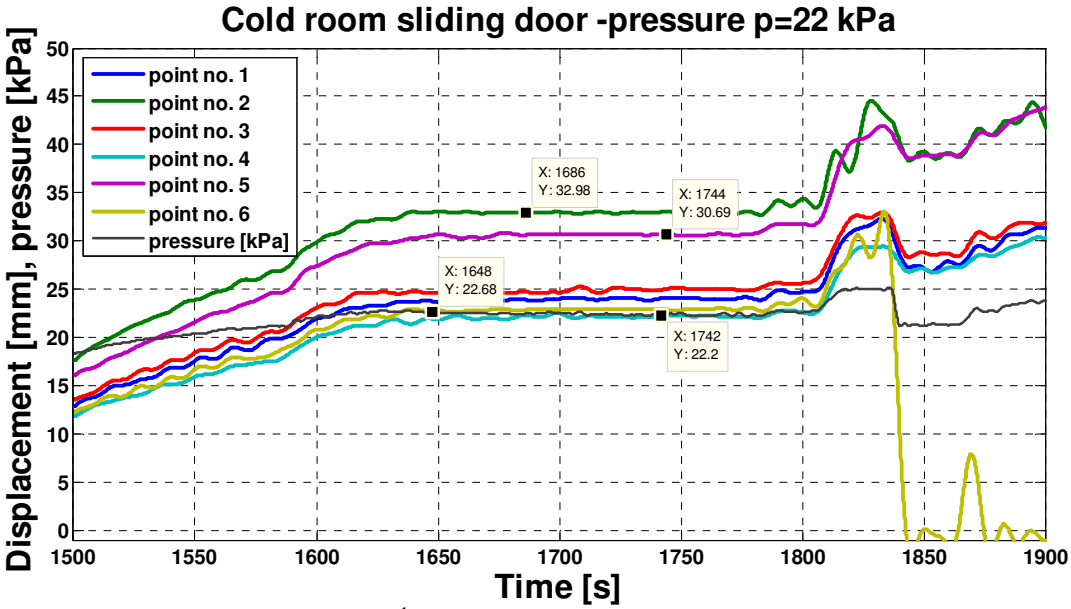


Fig. N7. 4rd stage – pressure level p=22 kPa.

5rd stage – finish.

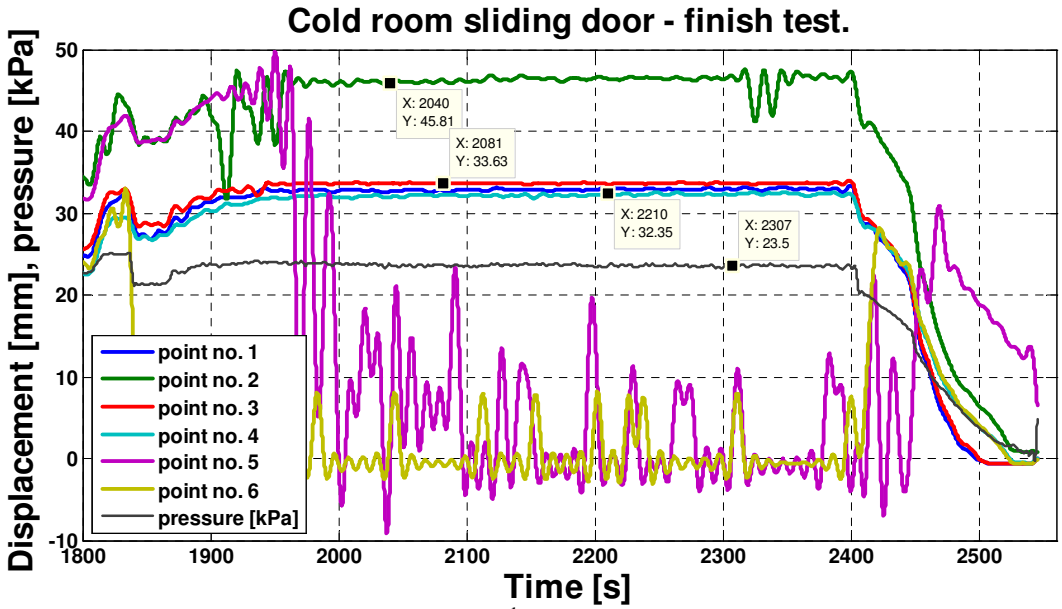


Fig. N8. 5rd stage – finish.

Table TN.1. Displacement, leakage and pressure test results.

Tab. TN.1	Test results object no. 6, test number 15580							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	5,5	1,87	3,40	2,92	3,70	4,62	4,27	4,3
2	10,3	8,71	10,34	10,81	10,84	11,53	12,20	24,7
3	15,4	16,81	17,61	18,17	16,73	17,67	18,17	42,2
4	22,2	24,13	32,98	24,69	22,44	30,72	22,68	54,0
5	23,5	33,63	45,81	33,84	32,35	interference		84,3

Test photos.

Fig.N9. Leak at pressure p=15kPa.

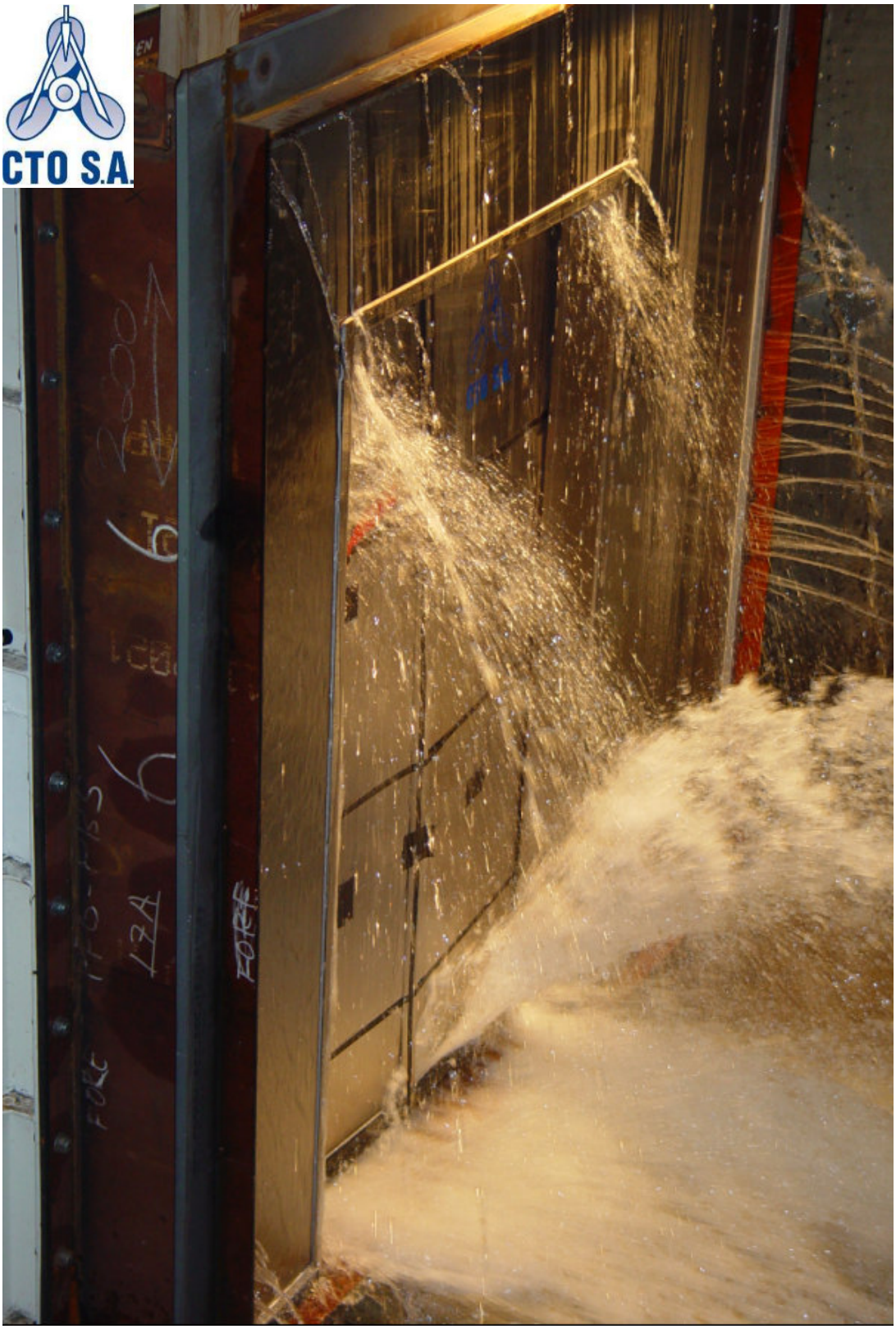


Fig.N10. Leak at pressure p=22kPa.

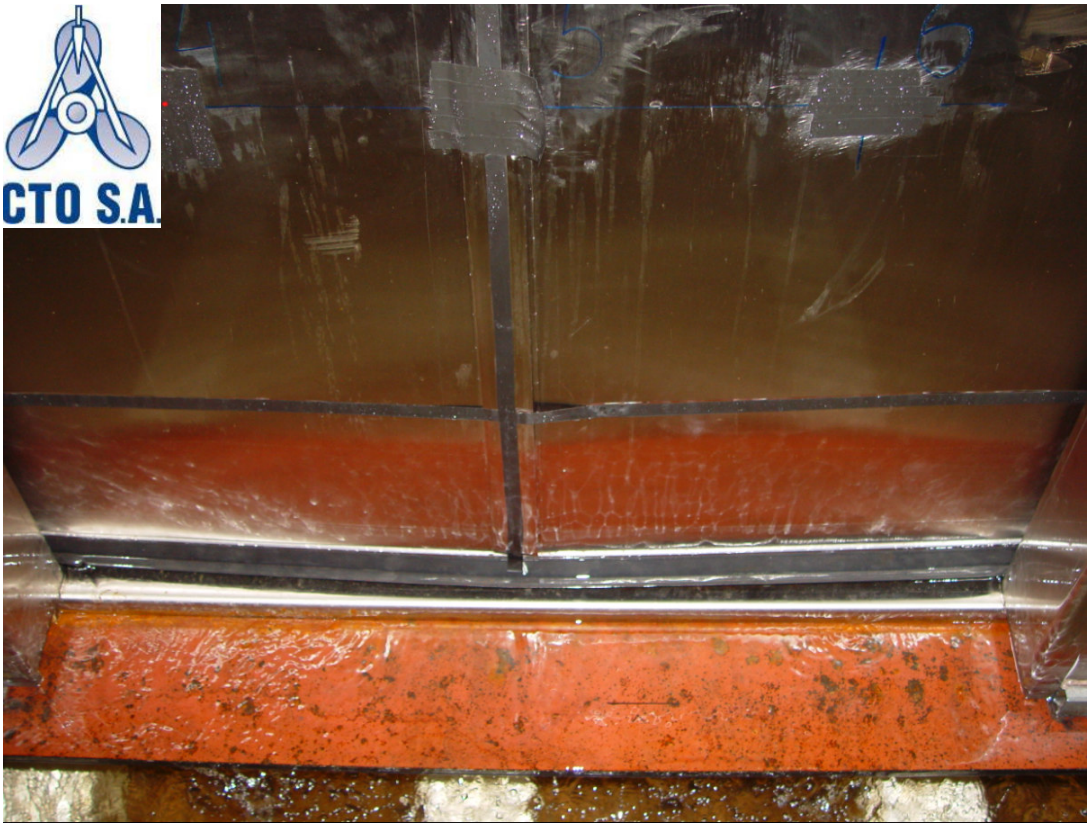


Fig.N11. Damage the sliding door.

Fig.N12. Damage the sliding door.

o) Model No. 8.1; B class Steelframes for cabin wall; test no 15569, (direction: "INTO the panel wall")

Stand with installed test object no. 8,1, test number15569.

Fig. O1. Stand with installed object test no 8,1.

Dimensioning of measurements points of the element no. 8,1.

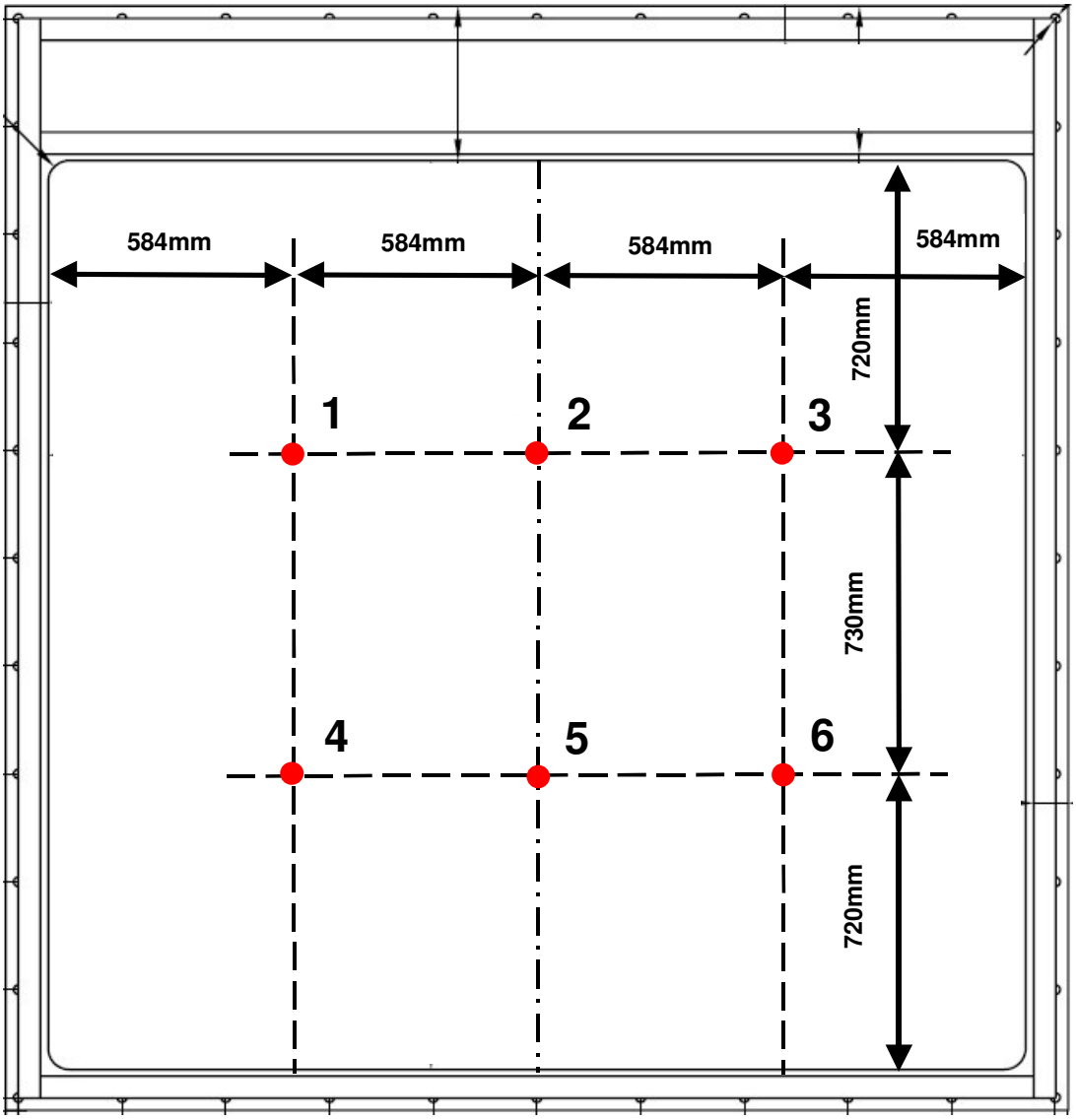


Fig. O2. Dimension plan of a measurement points.

Results of the test are presented on Fig. O3 to Fig. O6.

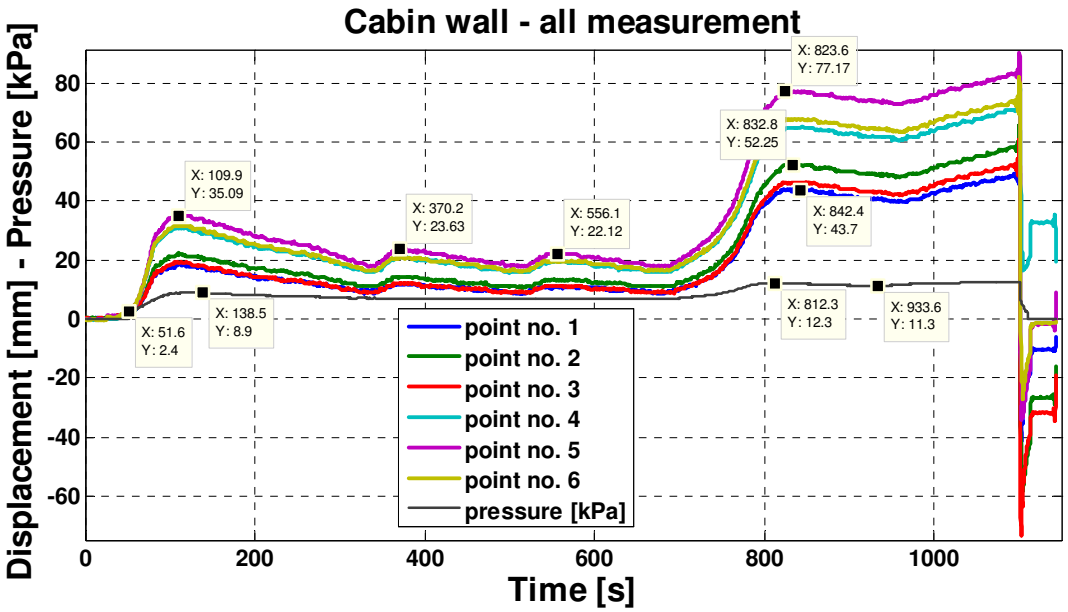


Fig. O3. Measurement results (full time history).

1st stage – pressure level p=8,5 kPa – tank filling up.

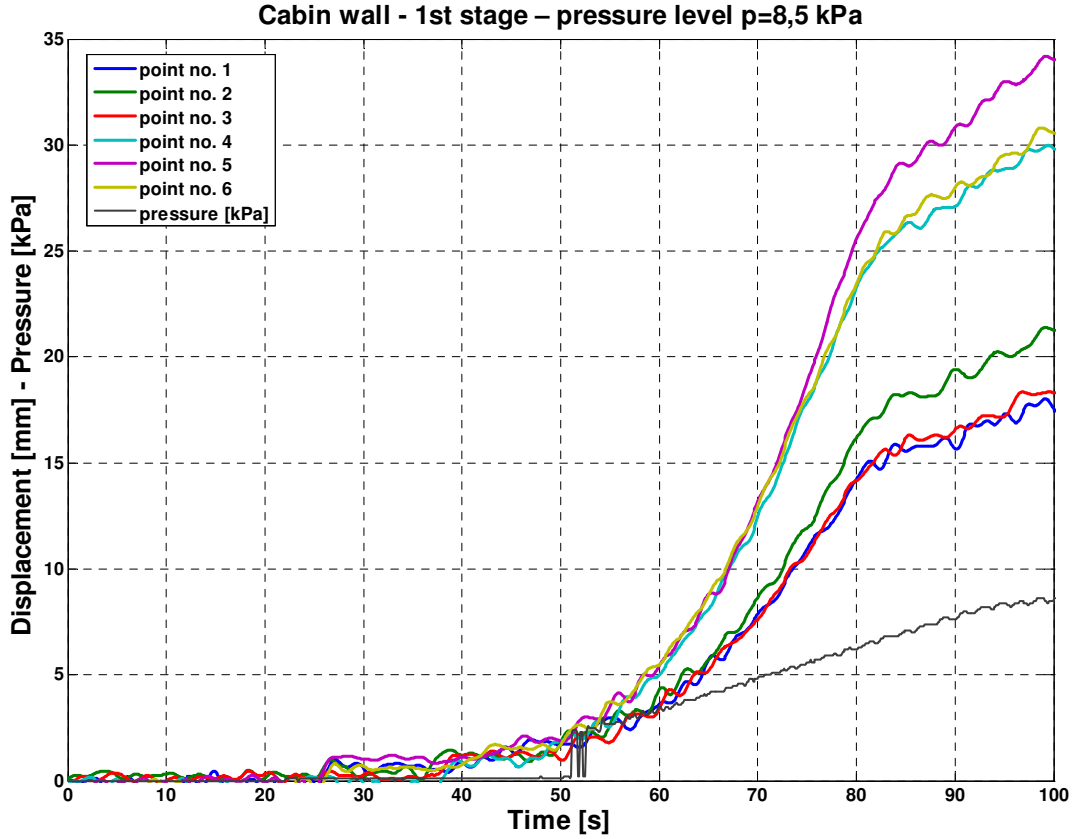


Fig. O4. 1st stage, pressure level p=8,5kPa.

2nd stage – pressure level p=7 kPa

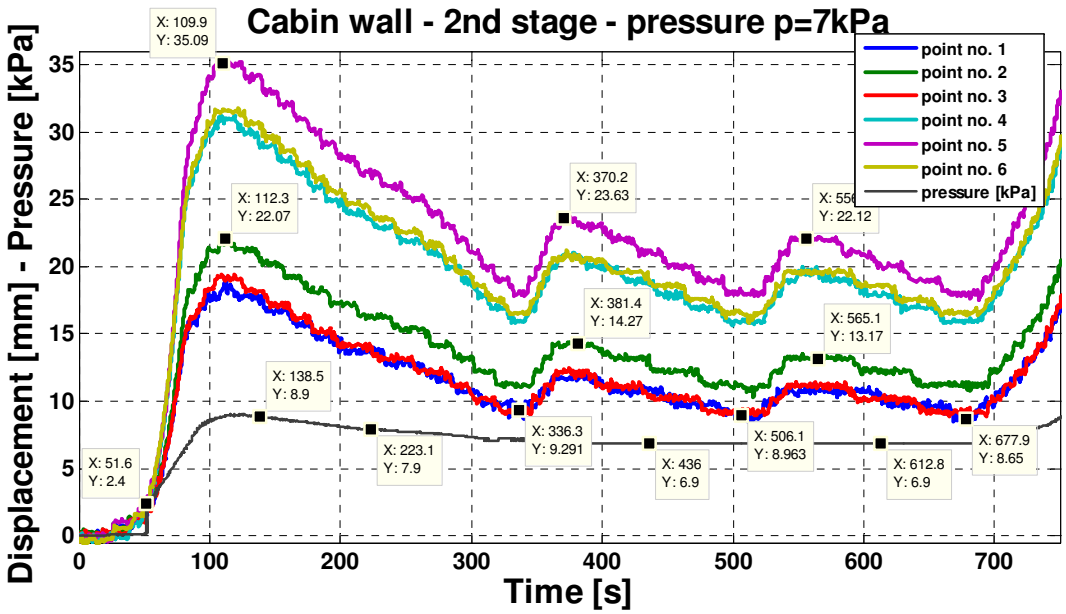


Fig. O5. 2nd stage, pressure level p=7 kPa.

3rd stage – increase pressure to p=12kPa,

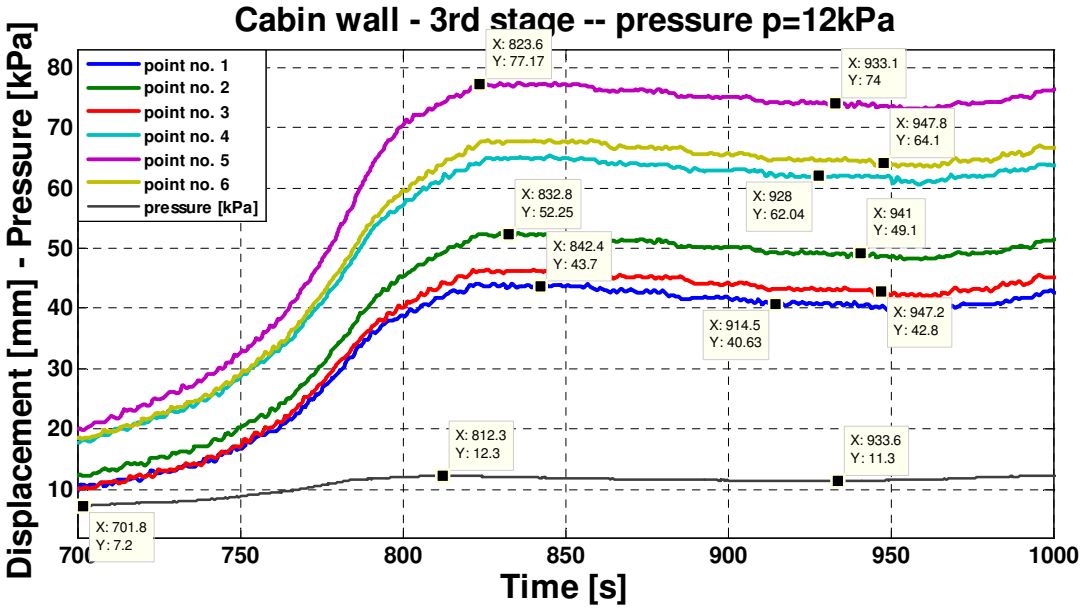


Fig. O6. 2nd stage, pressure level p=12 kPa.

4th stage – finish

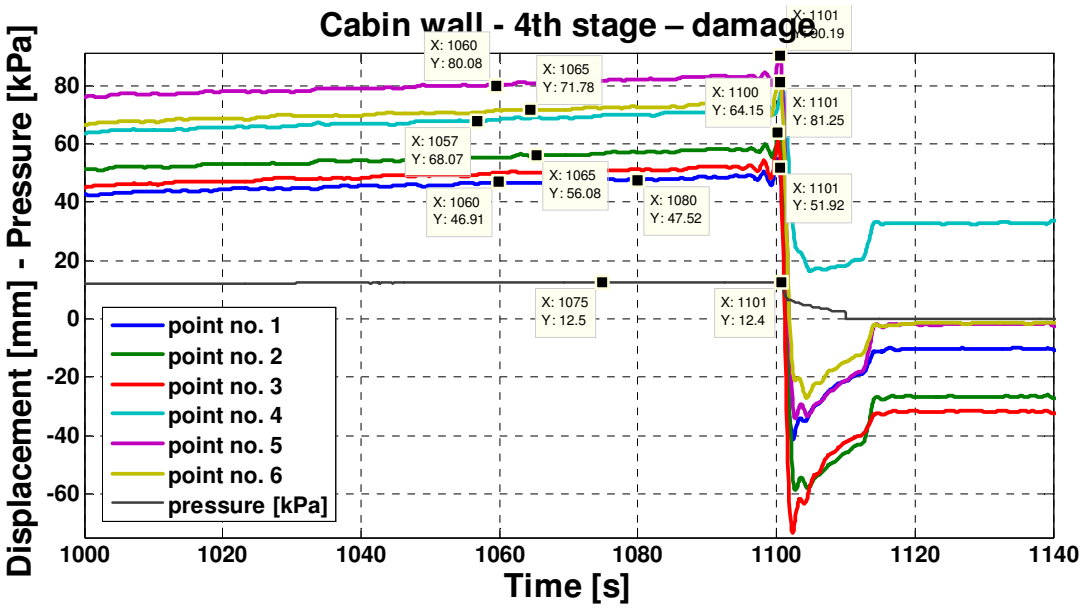


Fig. O6. 3rd stage, damage.

Table TO.1. Displacement, leakage and pressure test results.

Tab. TO.1	Test results object no 8,1, test number 15569							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	6,9	~9,00	~10,00	~8,50	~18,00	~21,00	~19,00	~2,5
2	11,4	~40,00	~49,00	~43,00	~62,00	~74,00	~64,00	~28
3	14,2	damage	damage	damage	damage	damage	damage	------

Test photos.

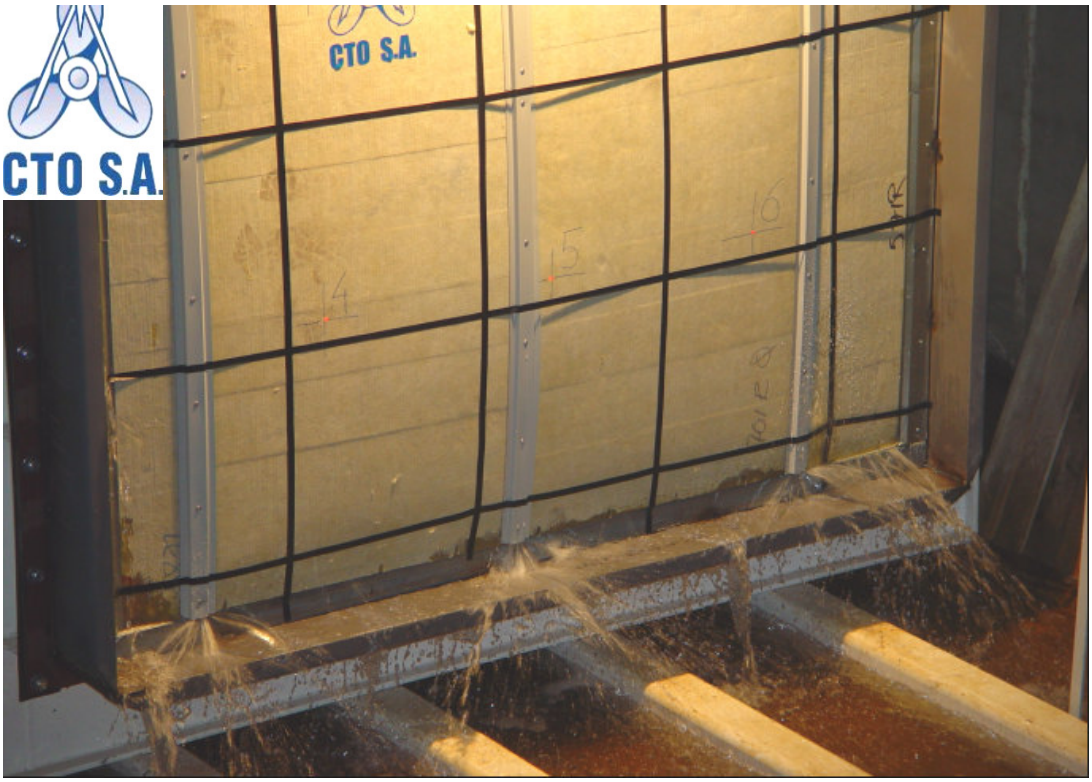


Fig. O7. Wall damage.

Fig. O8. Wall damage.

Fig. O9. Wall damage.

Fig. O10. Wall damage.

Fig. O11. Wall damage.

Fig. O12. Wall damage.

Fig. O13. Damage test object no. 8.1.

Fig. O14. Damage test object no. 8.1.

p) Model No. 8.2; B class Steelframes for cabin wall; test no 15563, (direction: INTO the wall with the frame structure")

Stand with installed test object no. 8,2, test number 15563.

Fig. P1. Stand with installed object test.

Dimensioning of measurements points of the element no. 8.2.

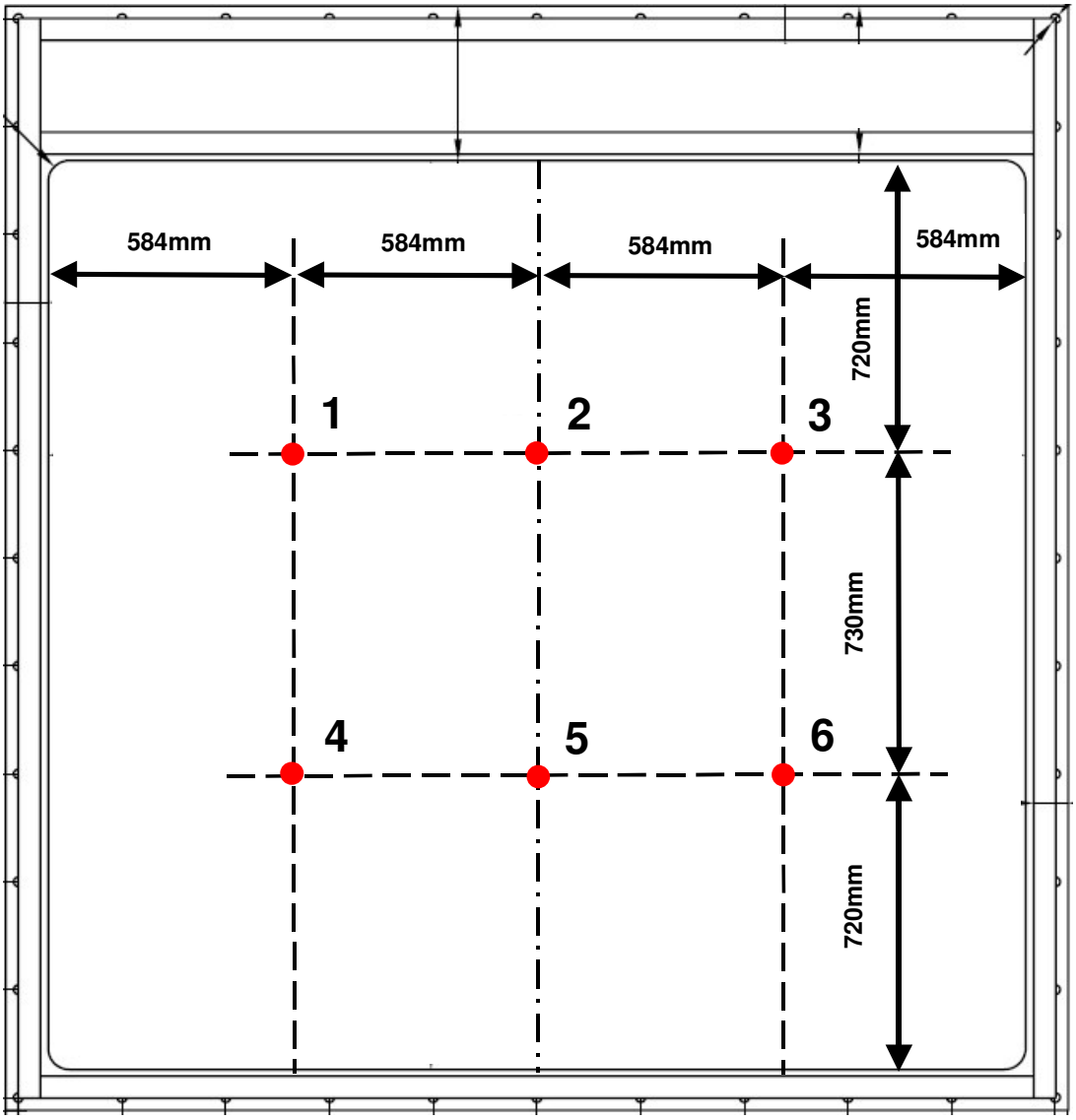


Fig. P2. Dimension plan of a measurement points.

Results of the test are presented on Fig. P3 to Fig. P7.

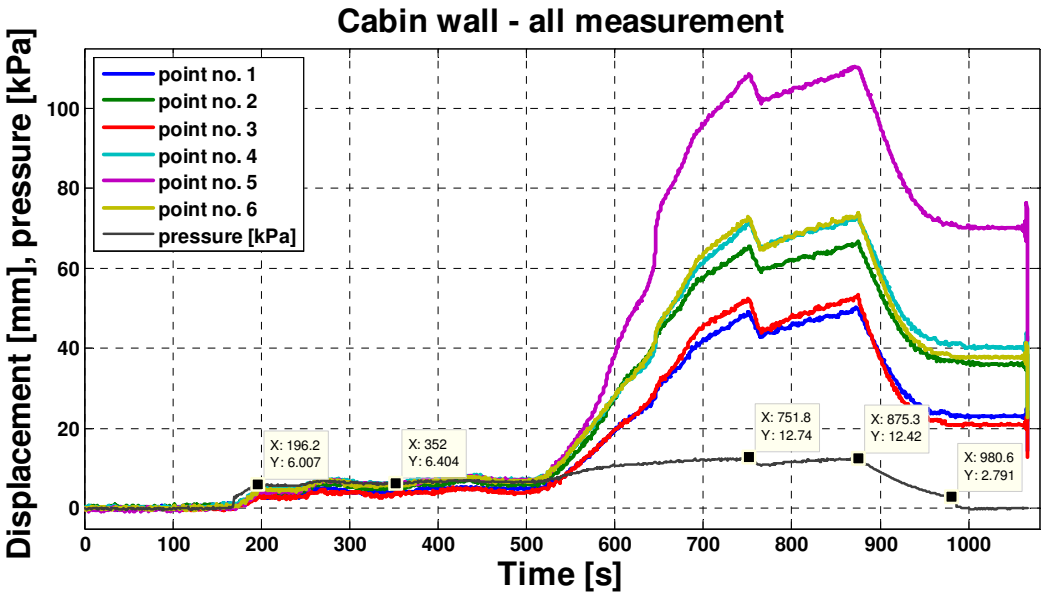


Fig. P3. Measurement results (full time history).

1st stage – pressure level p=6,0 kPa, – tank filling up

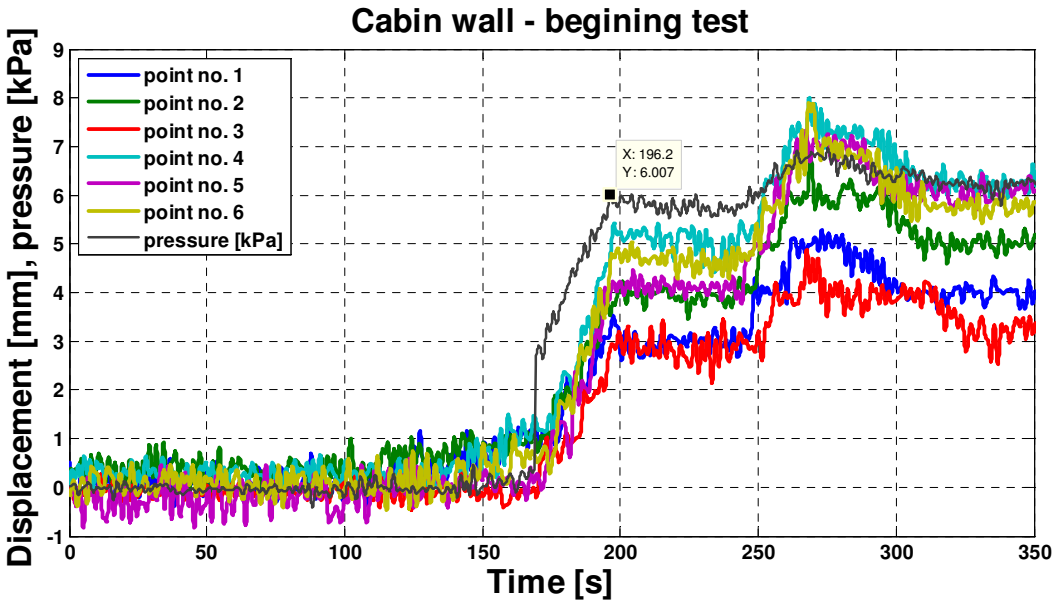


Fig. P4. 1st stage – pressure level p=6,0 kPa, – tank filling up.

2nd stage – pressure level p=6.5 kPa

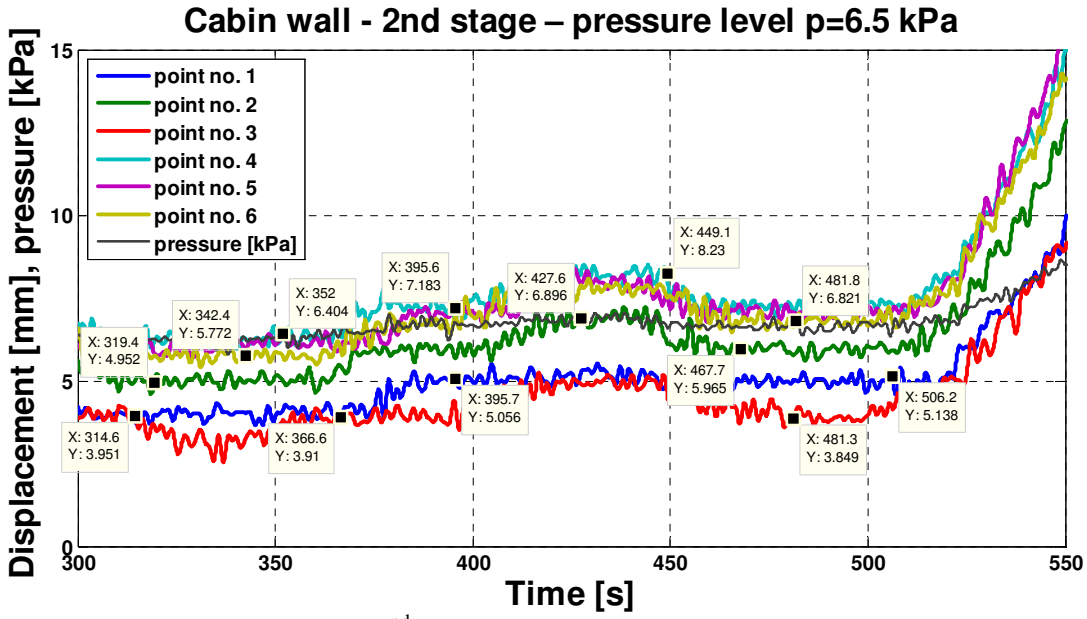


Fig. P5. 2nd stage – pressure level p=6.5 kPa.

3rd stage – pressure level p=12 kPa

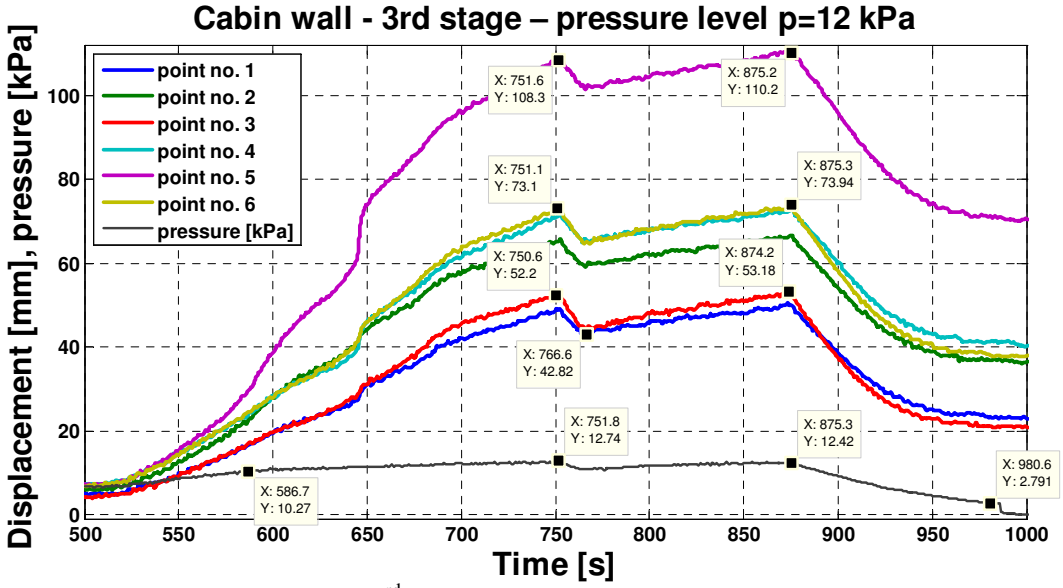


Fig. P6. 3rd stage – pressure level p=12 kPa.

4th stage – damage

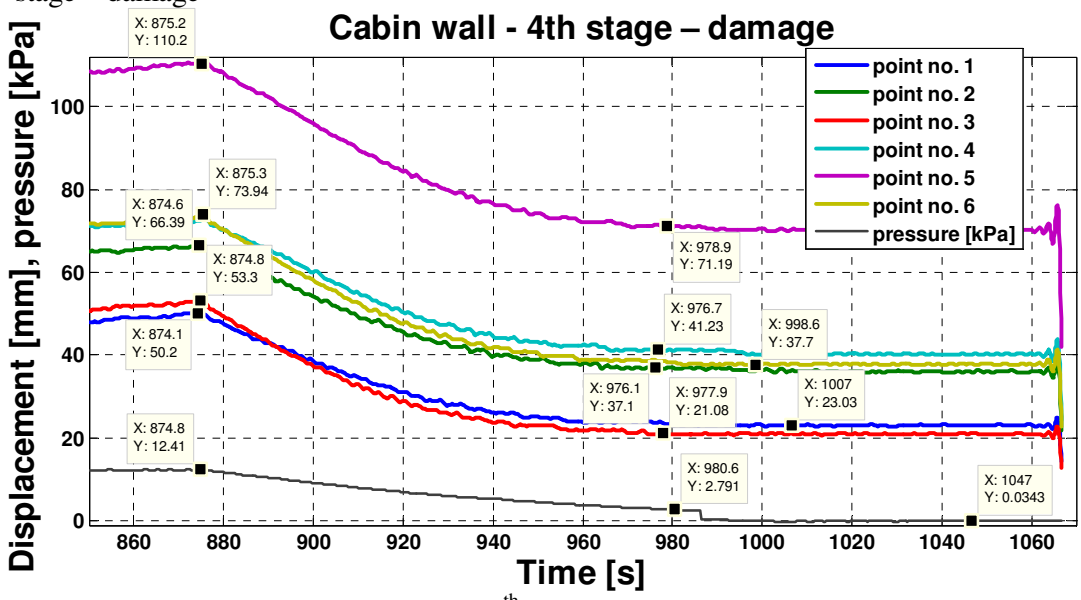


Fig. P7. 4th stage, damage.

Table TP.1. Displacement, leakage and pressure test results.

Tab. TP.1	Test results object no. 8,2, test number 15563							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	6,0	5,37	3,89	2,29	5,08	4,21	4,62	34,7
2	12,7	46,83	63,05	49,01	69,00	106,23	69,36	64,4
3	12,4	49,98 damage	66,77 damage	53,18 damage	72,26 damage	110,20 damage	73,94 damage	82,4 -----

Test photos.

Fig. P8. Wall damage.

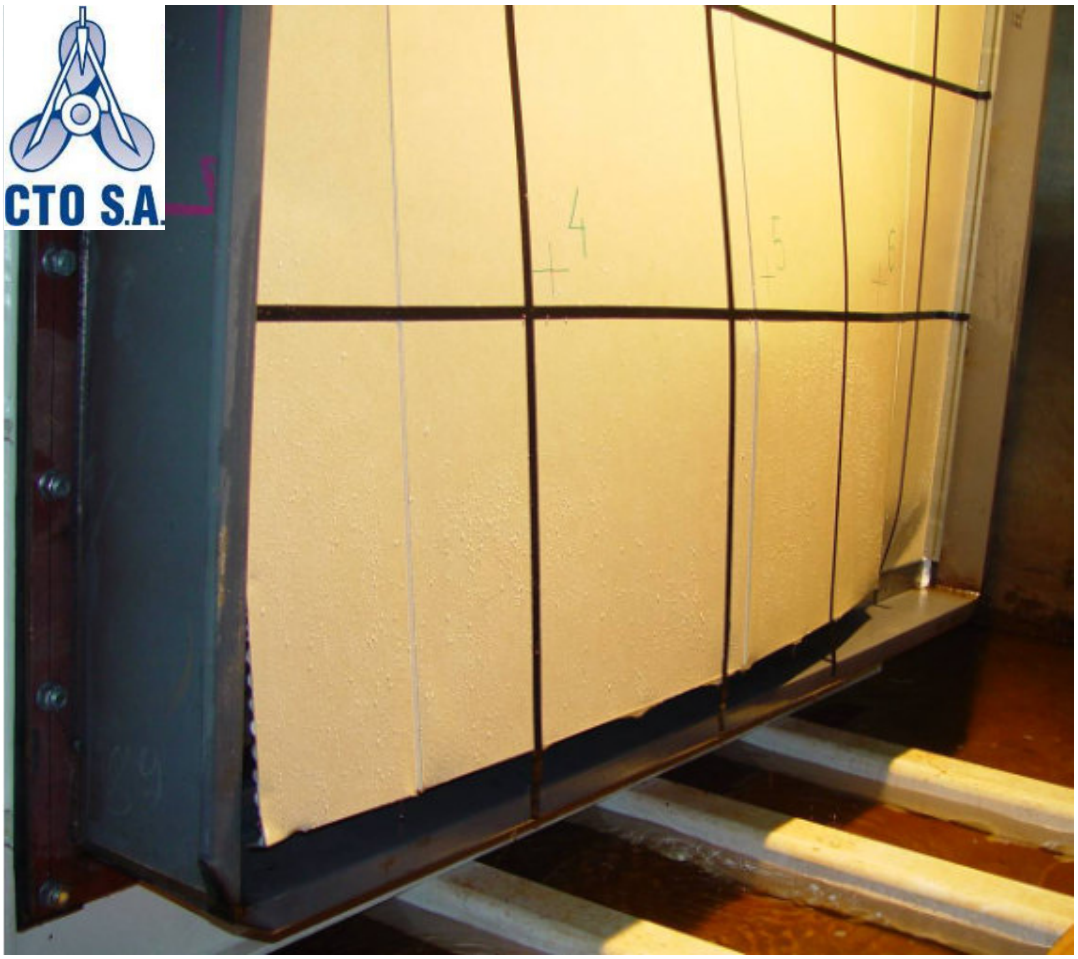


Fig. P9. Wall damage.

Fig. P10. Wall damage.

Fig. P11. Wall damage.

Fig. P12. Wall damage.

r) Model no. 9; B-Wall; test no 15643, (direction: "OUT of the frame")

Test No. 15643, tested object no. 9.

Fig. R1. Stand with installed object test.

Fig. R2. Measuring points location.

Dimensioning of measurements points of the element no. 9.

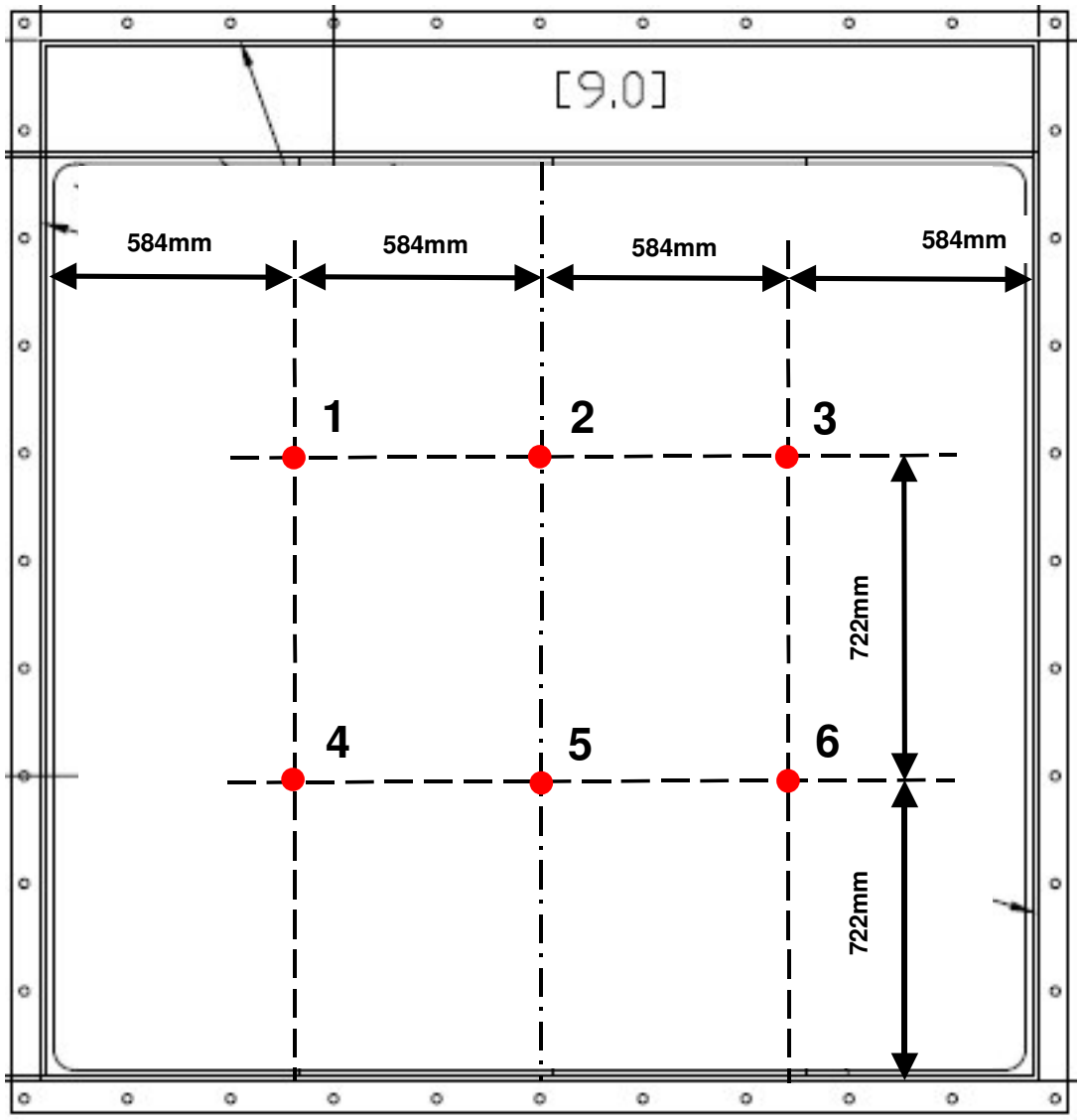


Fig. R3. Dimension plan of a measurement points.

Results of the test are presented on Fig. R4 to Fig. R6.

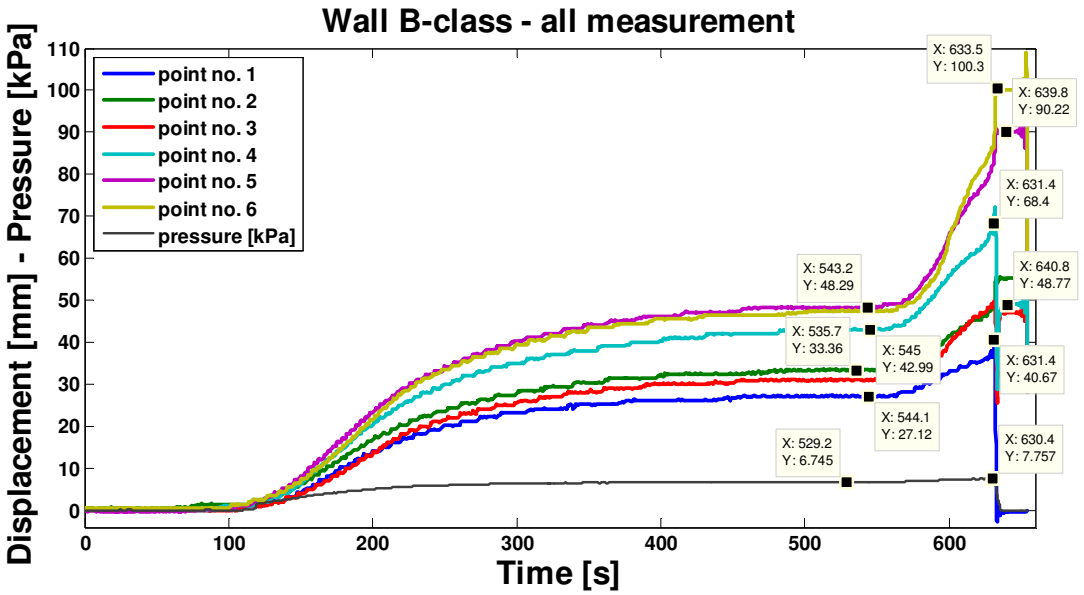


Fig. R4. Measurement results (full time history).

1th phase – tank filling up to the pressure level p=6.75kPa.

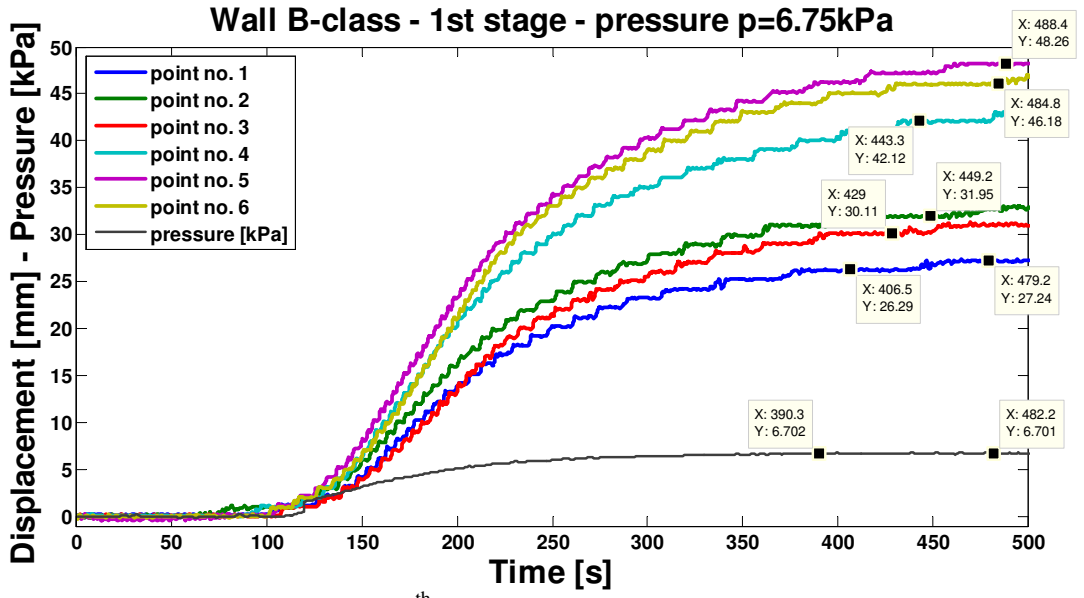


Fig. R5. 1th phase - pressure level p=6.75kPa.

2nd phase – pressure level p=7.55kPa

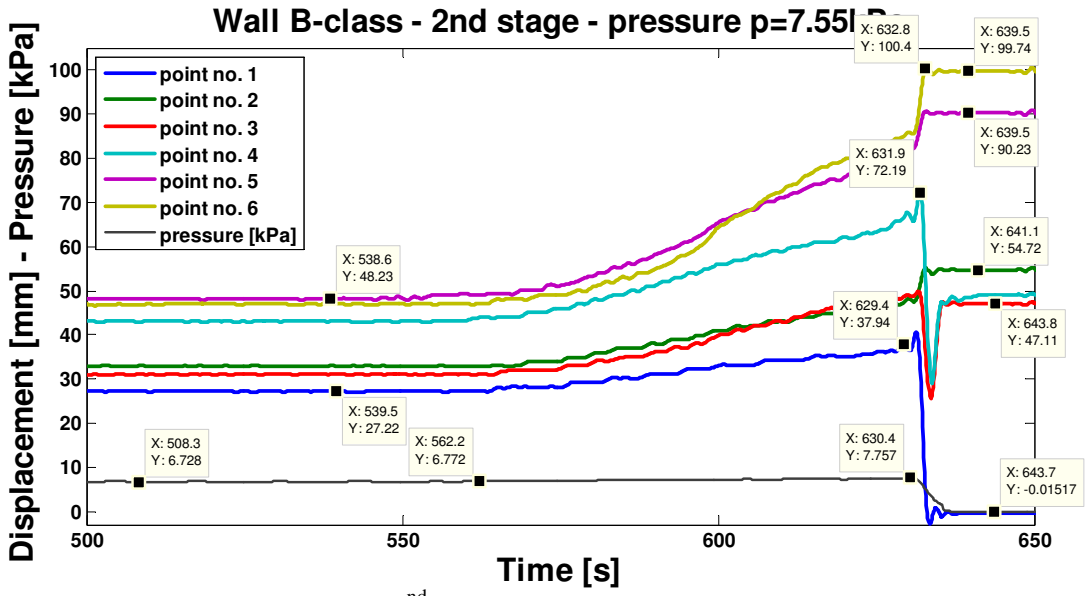


Fig. R6. 2nd phase – pressure level p=7.55 kPa.

Table TR.1. Displacement, leakage and pressure test results.

Tab. TR.1	Test results object no. 9, test number 15643							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	6,7	26,36	31,95	30,77	42,10	48,22	46,18	10,7
2	7,8	damage	damage	damage	damage	damage	damage	------

Test photos.

Fig. R7. Leak at pressure p=6 kPa.

Fig. R8. Wall damage.

Fig. R9. Wall damage.

Fig. R10. Wall damage.

Fig. R11. Wall damage.

Fig. R12. Wall damage.

4.4 ELEMENTS: TYPE A2, Door

s) Model No. 10; SWT door – sliding Steelframes; test no. 15572, (direction: OUT the door frame")

Dimensioning of measurements points of the element no. 10, test no. 15572.

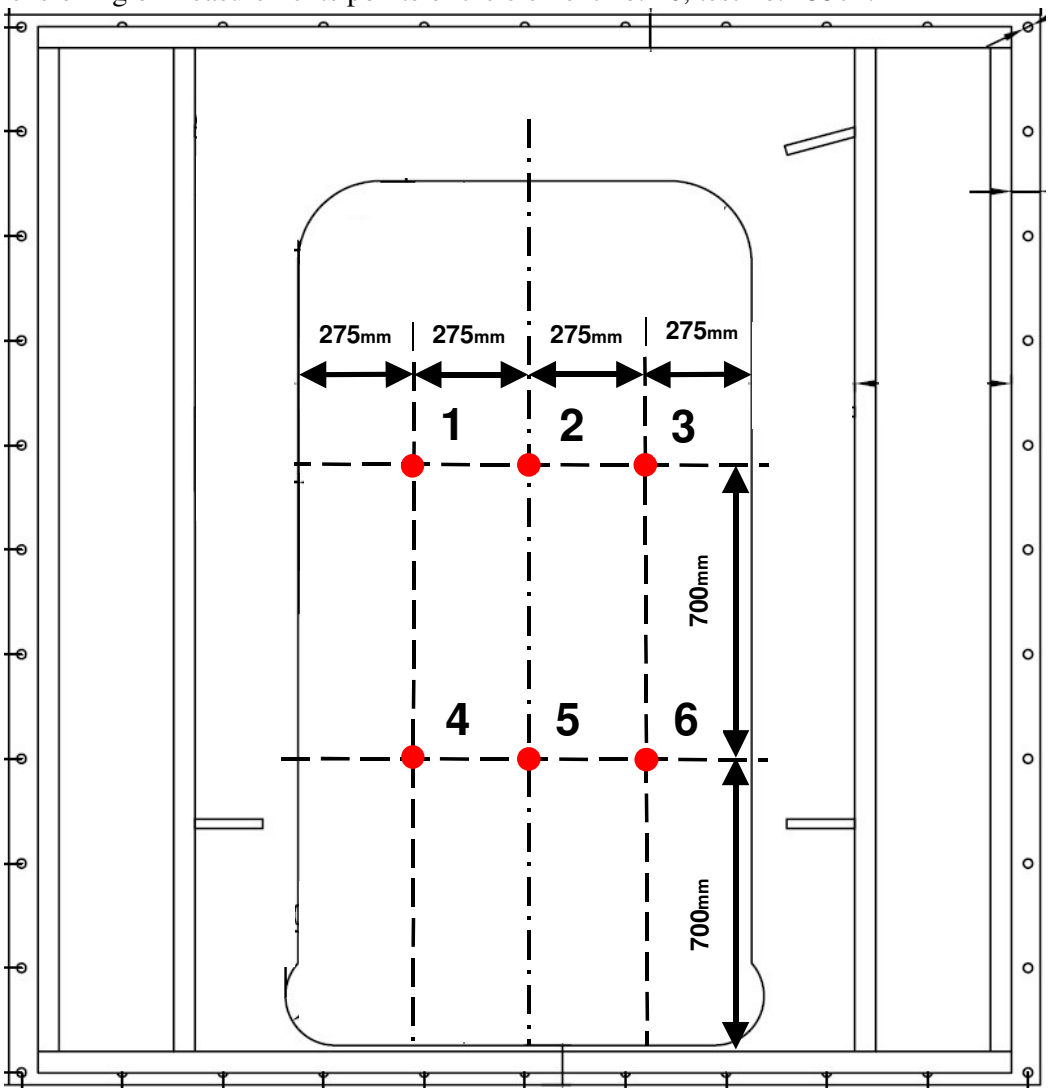


Fig. S1. Dimension plan of a measurement points.

Stand with installed test object no 10, test number 15572.

Fig. S2. Stand with installed object test.

Results of the test are presented on Fig. S3 to Fig. S20.

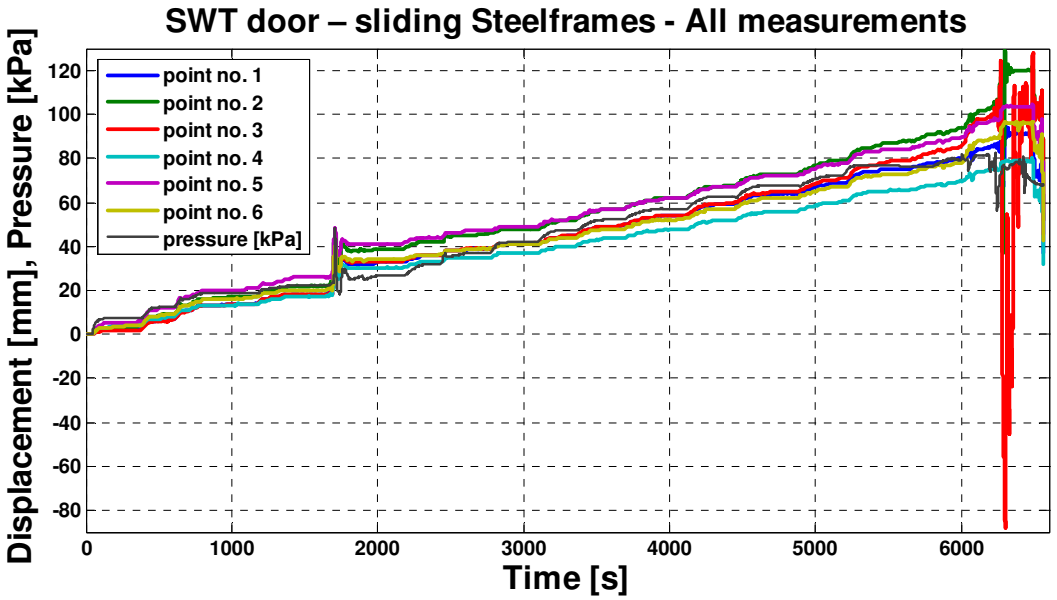


Fig. S3. Measurement results (full time history).

1st stage – pressure level p=7kPa

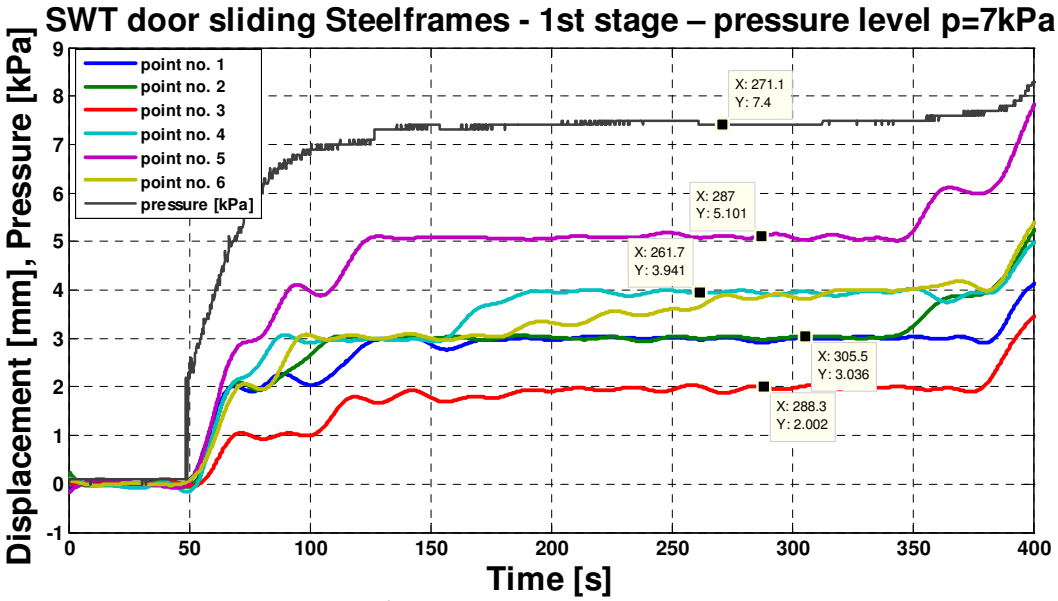


Fig. S4. 1st stage – pressure level p=7.4 kPa.

2nd stage – pressure level p=12.5 kPa

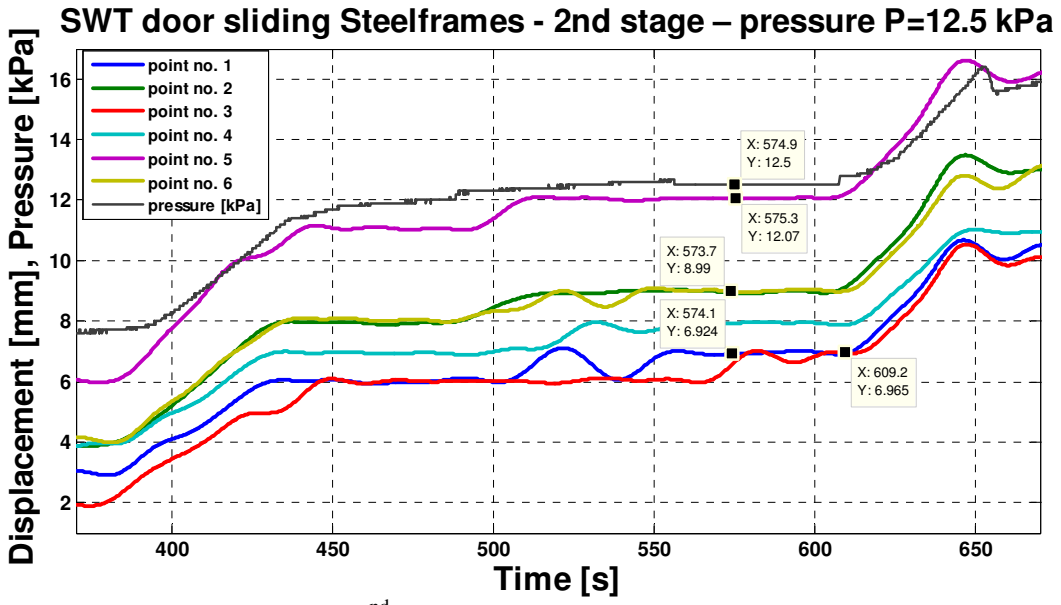


Fig. S5. 2nd stage – pressure level p=12.5 kPa.

3rd stage – pressure level p=18.6 kPa

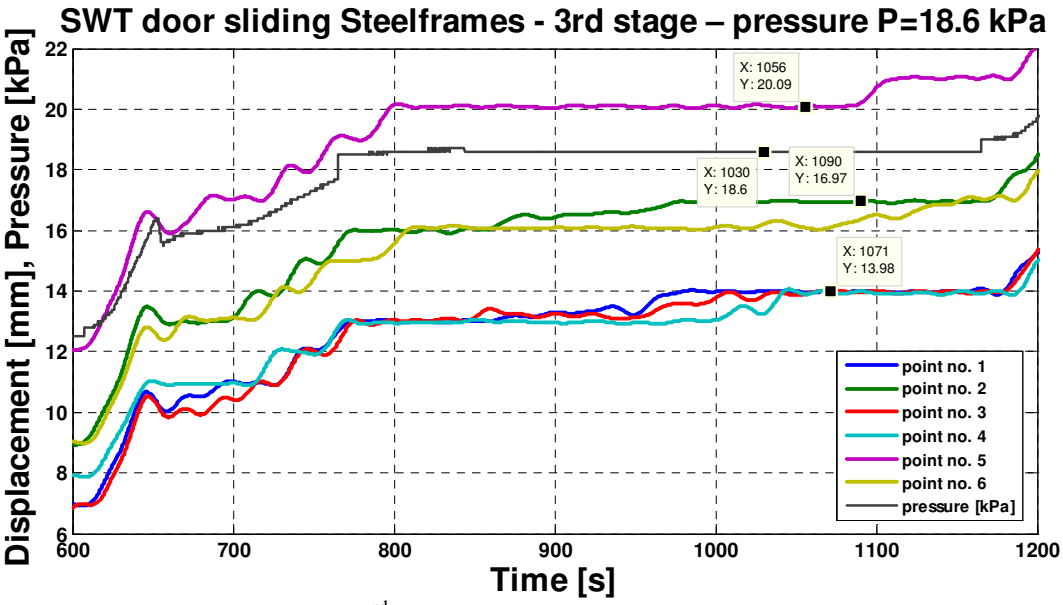


Fig. S6. 3rd stage – pressure level p=18.6 kPa.

4th stage – pressure level p=22 kPa

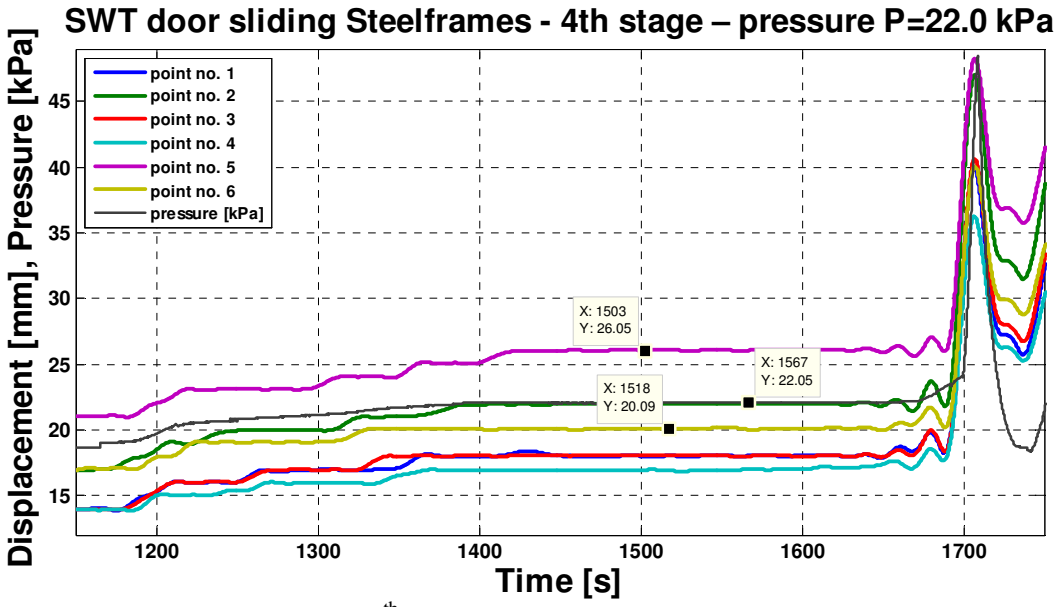


Fig. S7. 4th stage – pressure level p=22 kPa.

Damage the SWT sliding door

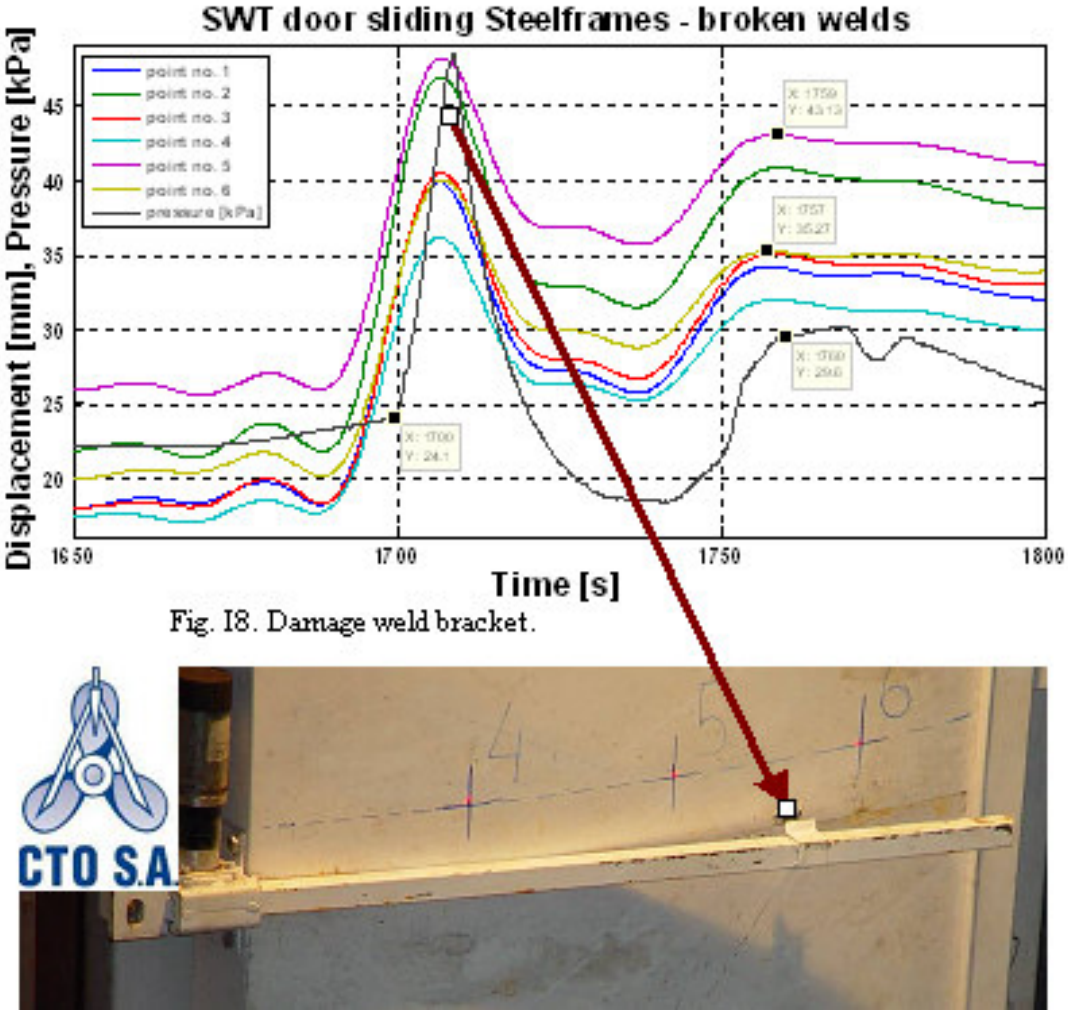


Fig. I8. Damage weld bracket.

Fig. S9. Damage weld bracket.

5th stage – pressure level p=26.8 kPa

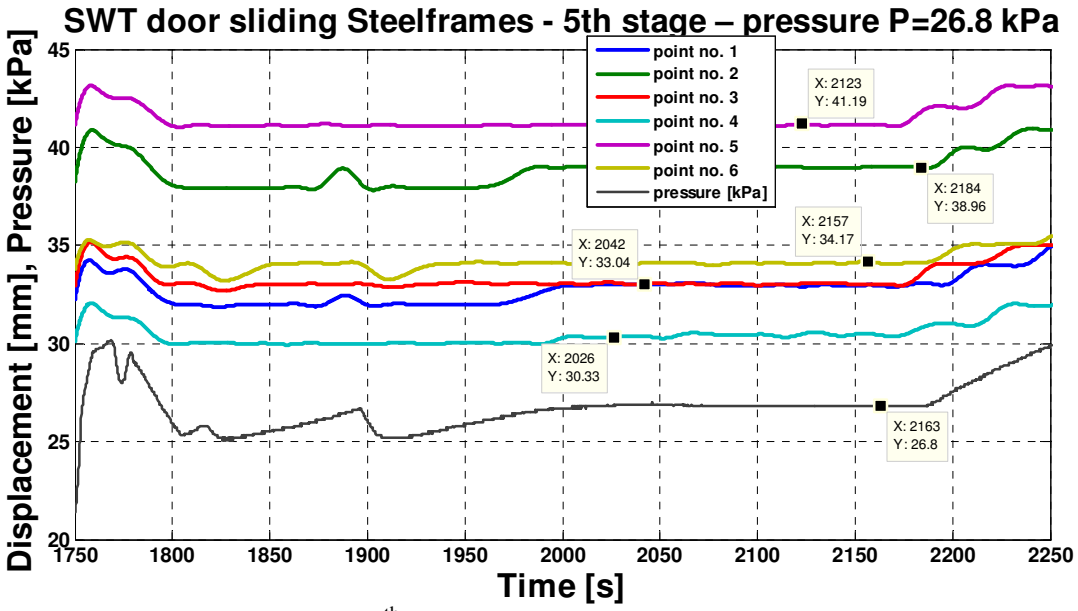


Fig. S10. 5th stage – pressure level p=26.8 kPa.

6th stage – pressure level p=32 kPa

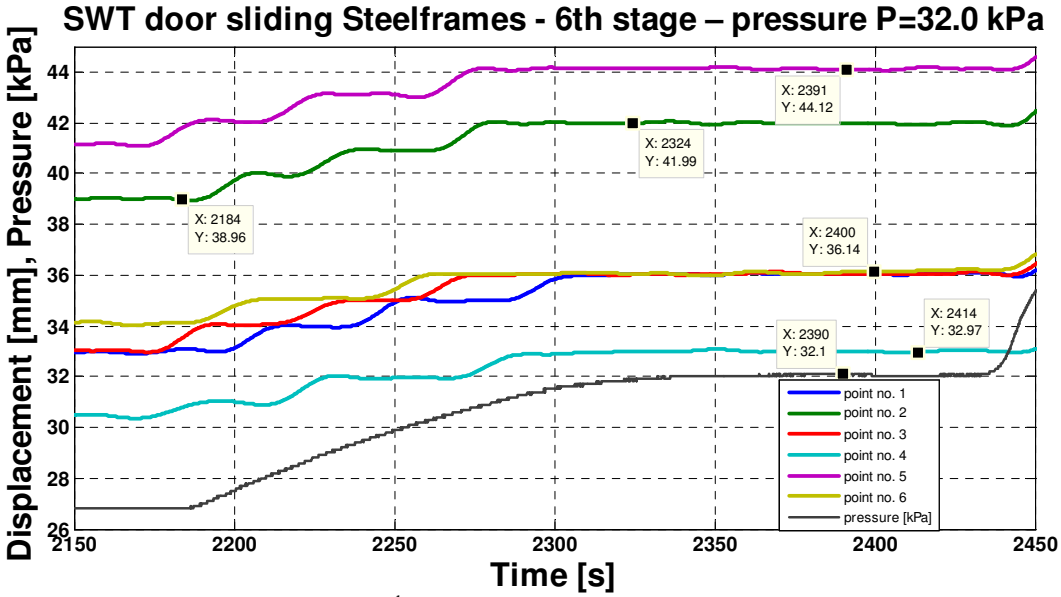


Fig. S11. 6th stage – pressure level p=32 kPa.

7th stage – pressure level p=37.2 kPa

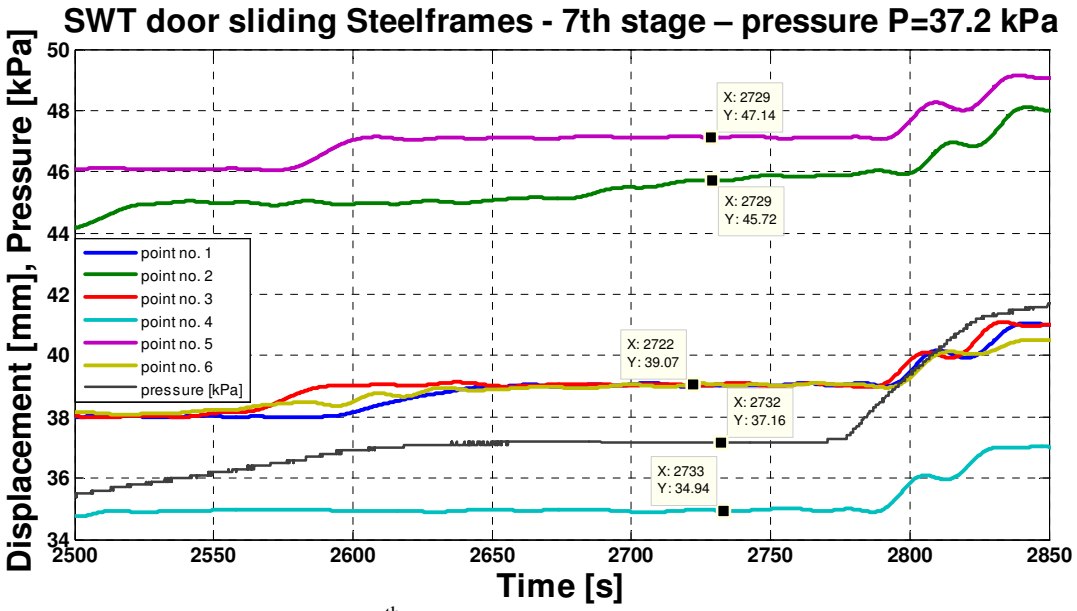


Fig. S12. 7th stage – pressure level p=37.2 kPa.

8th stage – pressure level p=42.1 kPa

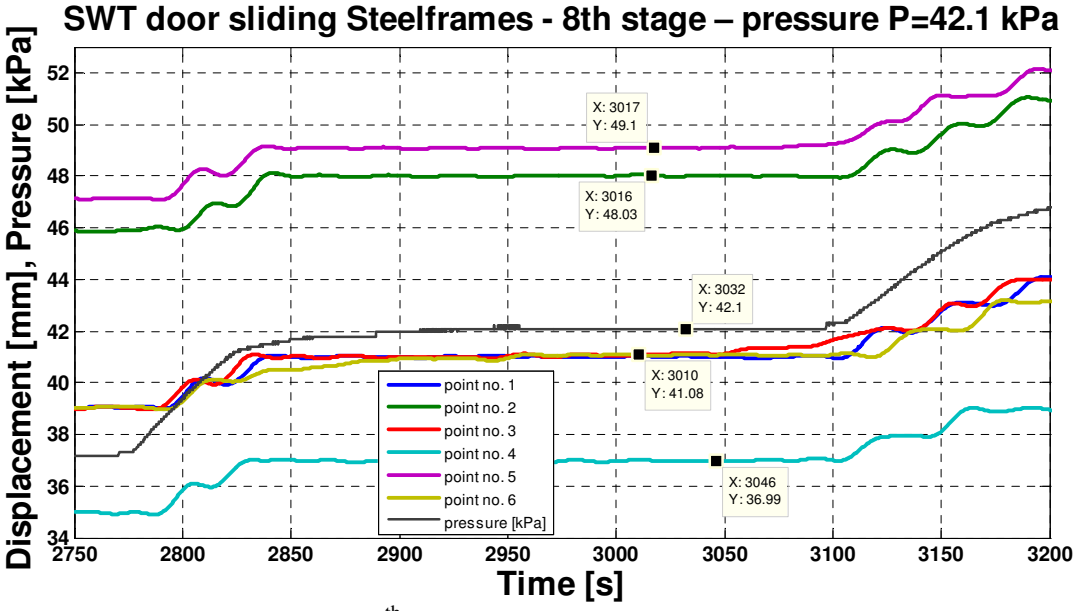


Fig. S13. 8th stage – pressure level p=42.1 kPa.

9th stage – pressure level p=47.2 kPa

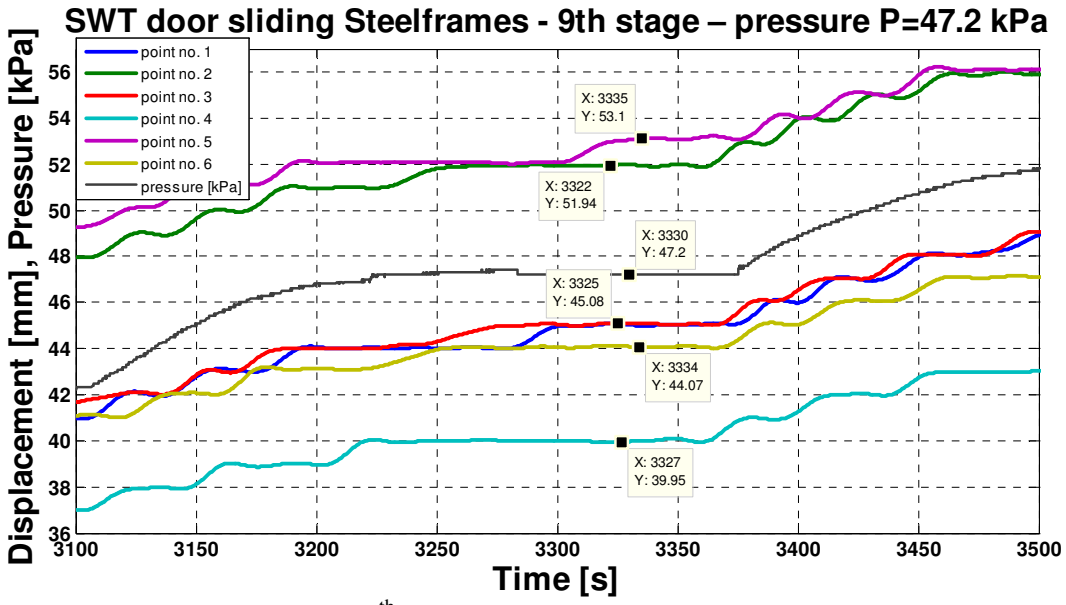


Fig. S14. 9th stage – pressure level p=47.2 kPa.

10th stage – pressure level p=52.2 kPa

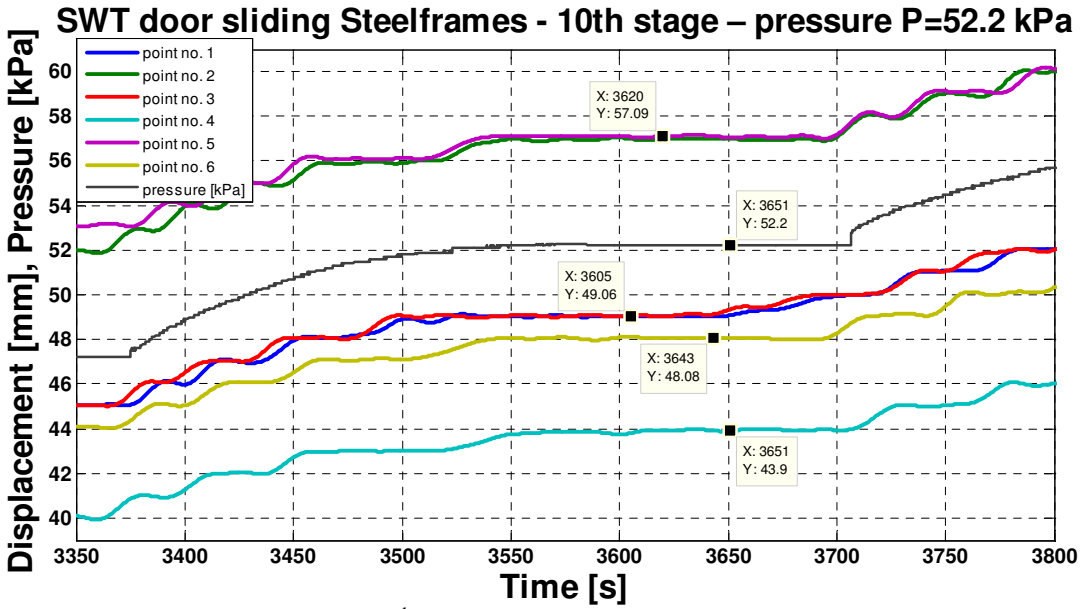


Fig. S15. 10th stage – pressure level p=52.2 kPa.

11th stage – pressure level p=57.2 kPa

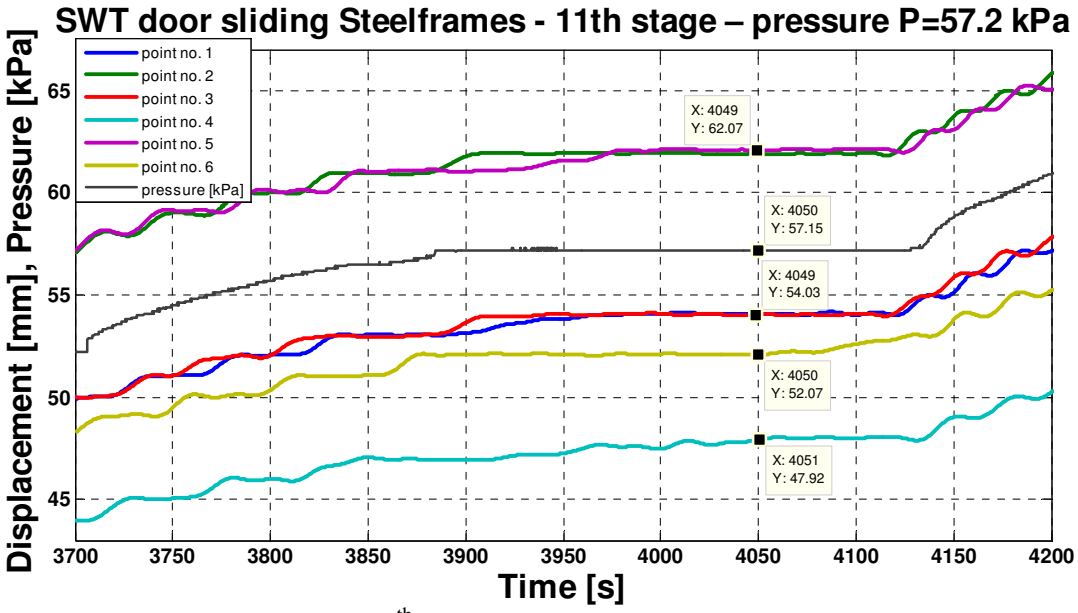


Fig. S16. 11th stage – pressure level p=57.2 kPa.

12th stage – pressure level p=62.5 kPa

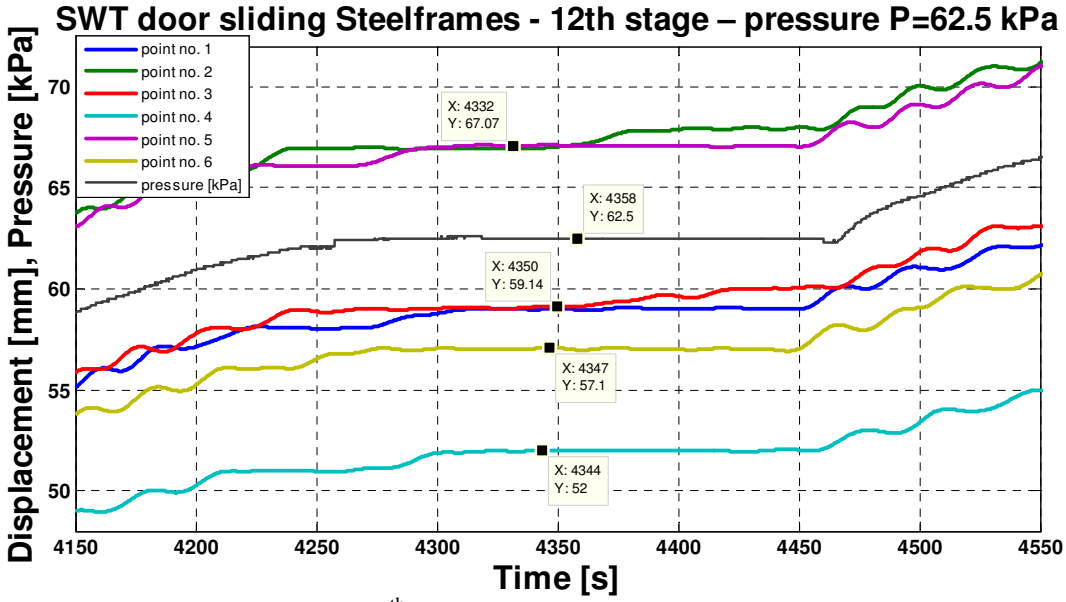


Fig. S17. 12th stage – pressure level p=62.5 kPa.

13th stage – pressure level p=67.5 kPa

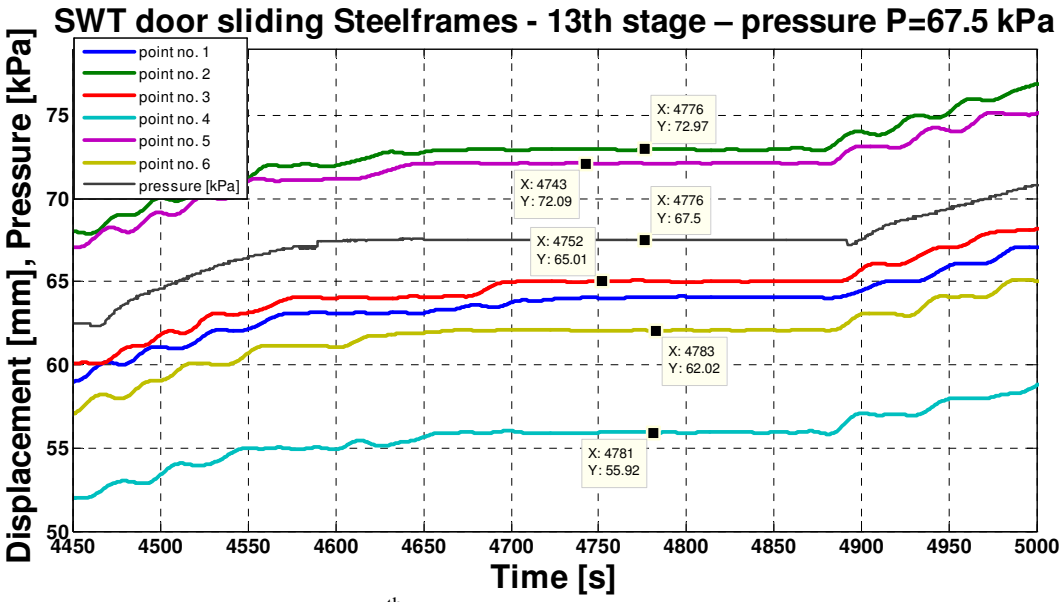


Fig. S18. 13th stage – pressure level p=67.5 kPa.

14th stage – pressure level p=72.2 kPa

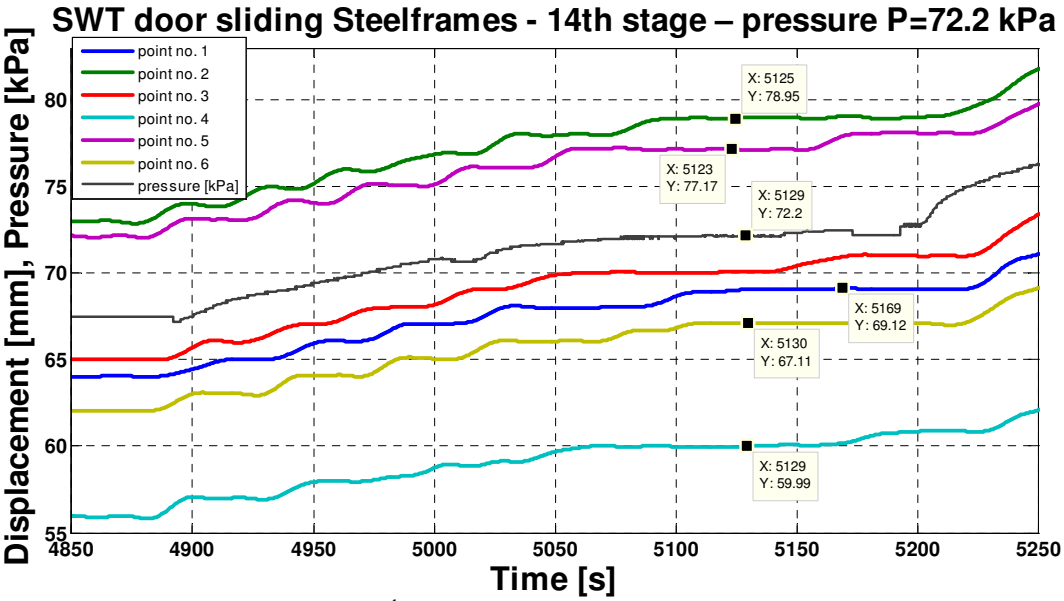


Fig. S19. 14th stage – pressure level p=72.2 kPa.

15th stage – pressure level p=76.7 kPa

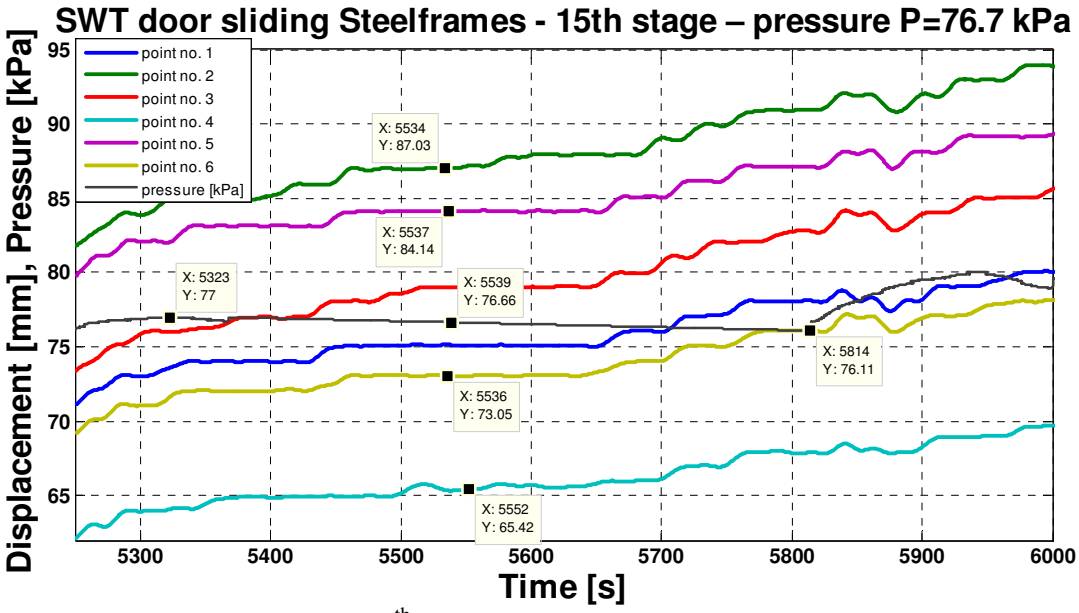


Fig. S20. 15th stage – pressure level p=76.7 kPa.

1th phase door damaged presentation on Fig. S21.

Fig. S21. 1th phase door damage.

16th stage – finish the test.

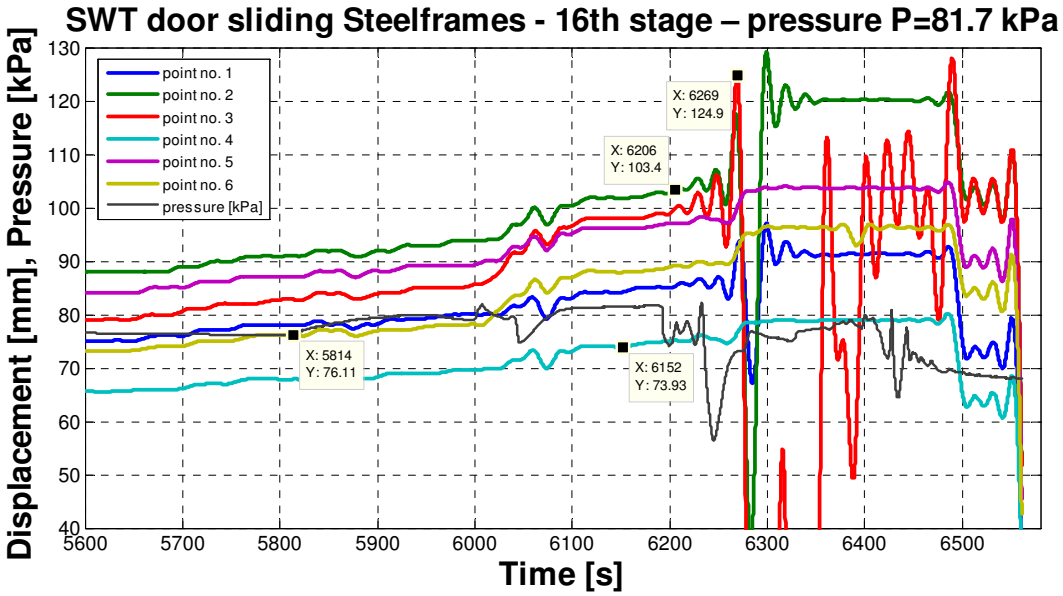


Fig. S22. Pressure level 81 kPa – finish the test.

Table TS.1. Displacement, leakage and pressure test results.

Tab. TS.1	Test results object no 10, test number 15572							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1	7,4	0,29	0,25	0,19	0,38	0,55	0,34	0,00
2	12,6	0,69	0,84	0,60	0,78	1,26	0,90	0,00
3	18,6	1,29	1,56	1,32	1,26	2,04	1,56	0,00
4	22,0	1,80	2,16	1,80	1,68	2,64	1,98	0,10
5	26,9	3,30	3,84	3,30	3,00	4,14	3,42	0,20
6	32,1	3,60	4,14	3,60	3,30	4,44	3,60	0,25
7	37,0	3,96	4,50	3,90	3,48	4,74	3,90	0,28
8	42,0	4,11	4,74	4,08	3,66	4,92	4,08	0,30
9	47,3	4,45	5,16	4,50	3,96	5,22	4,38	0,32
10	52,0	4,92	5,64	4,92	4,38	5,76	4,80	0,39
11	57,2	5,41	6,00	5,40	4,74	6,24	5,16	0,45
12	62,5	5,94	6,60	5,94	5,16	6,72	5,70	0,50
13	67,5	6,42	7,26	6,48	5,58	7,26	6,18	0,70
14	72,0	6,90	7,86	7,02	6,00	7,74	6,72	0,80
15	76,6	7,51	8,64	7,86	6,54	8,46	7,32	25,00
16	82,0	damage	damage	damage	damage	damage	damage	40

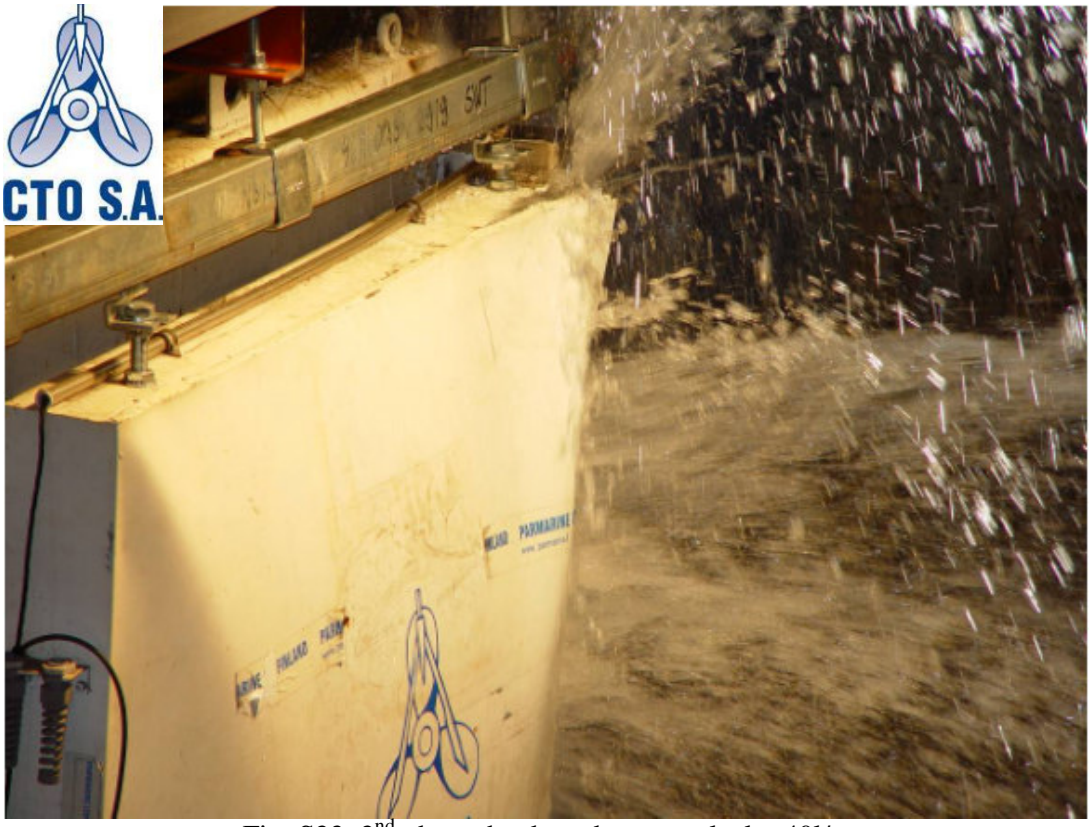


Fig. S23. 2nd phase the door damage – leak ~40l/s.

Fig. S24. Door damage.

Fig. S25. Door damage.

Fig. S26. Door damage.

Fig. S27. Door damage.

Fig. S28. Door damage.

Fig. S29. Door damage.

4.5 ELEMENTS TYPE: OTHER

t) Model no. 11; Window; test no 15645, (direction: "INTO the in-welded frame")

Test No. 15645, tested object no. 11.

Fig. T1. Stand with installed object test.

Fig. T2. Measuring points location.

Dimensioning of measurements points of the element no. 11.

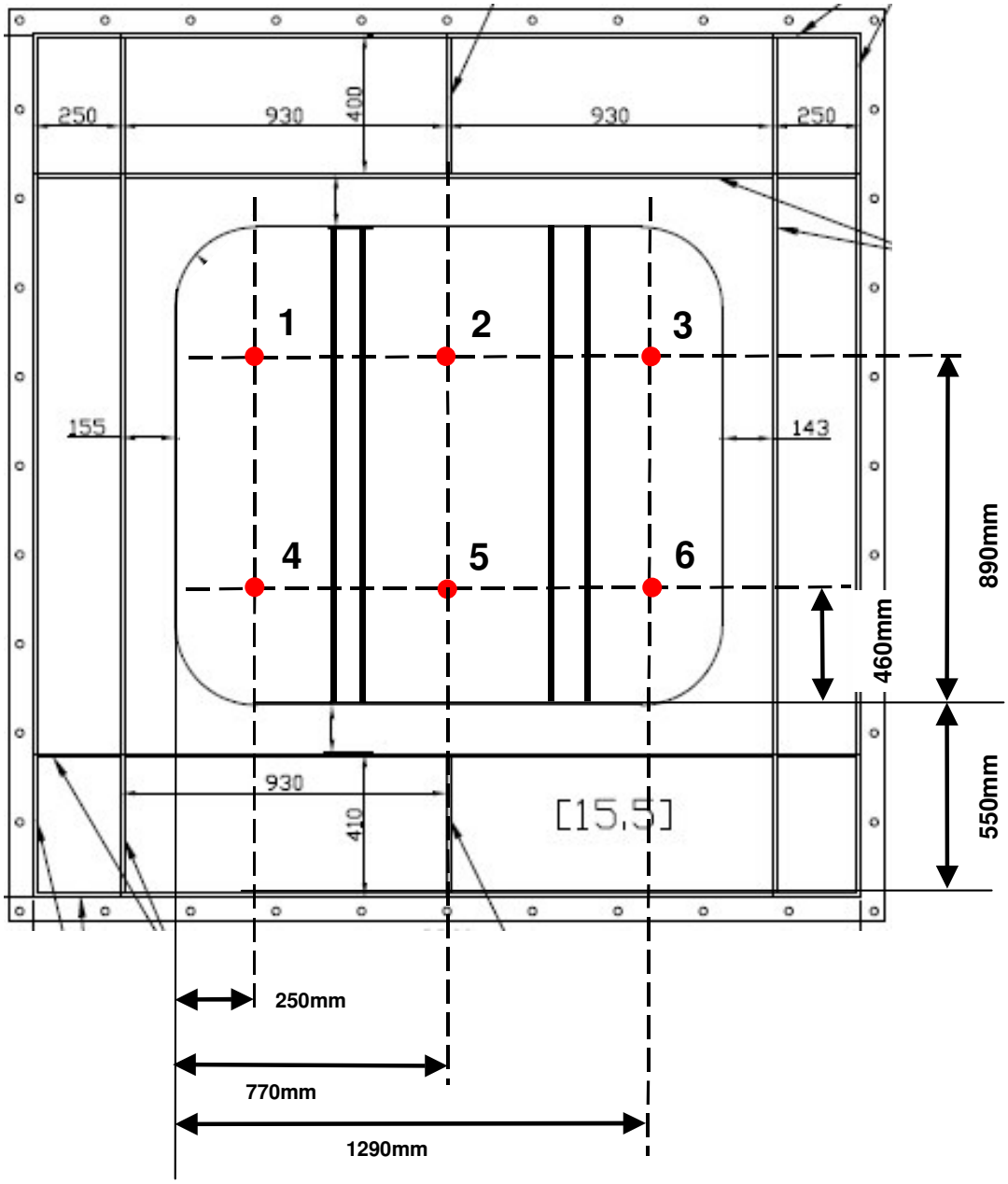


Fig. T3. Dimension plan of a measurement points.

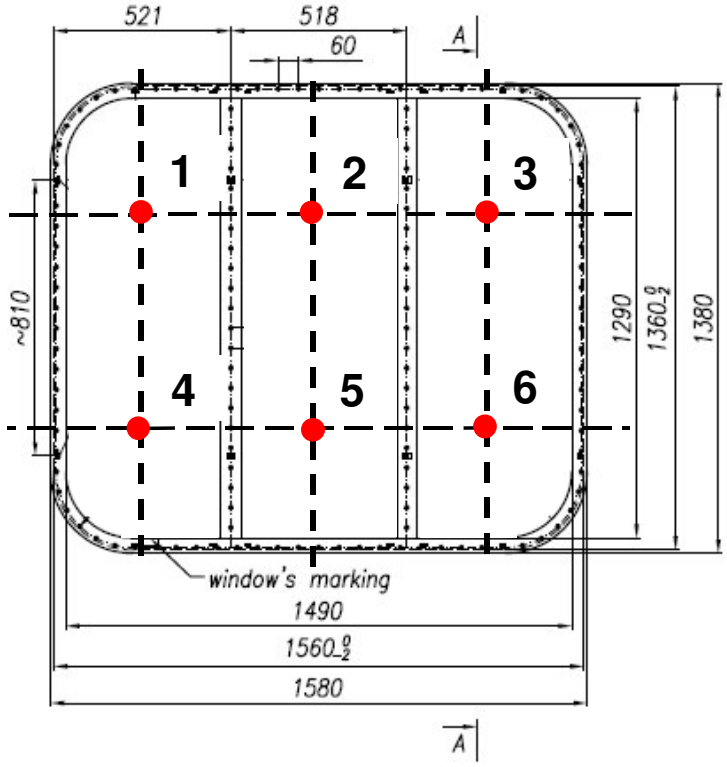


Fig. T4. Dimension plan of a measurement points

Results of the test are presented on Fig. T5 to Fig. T11.

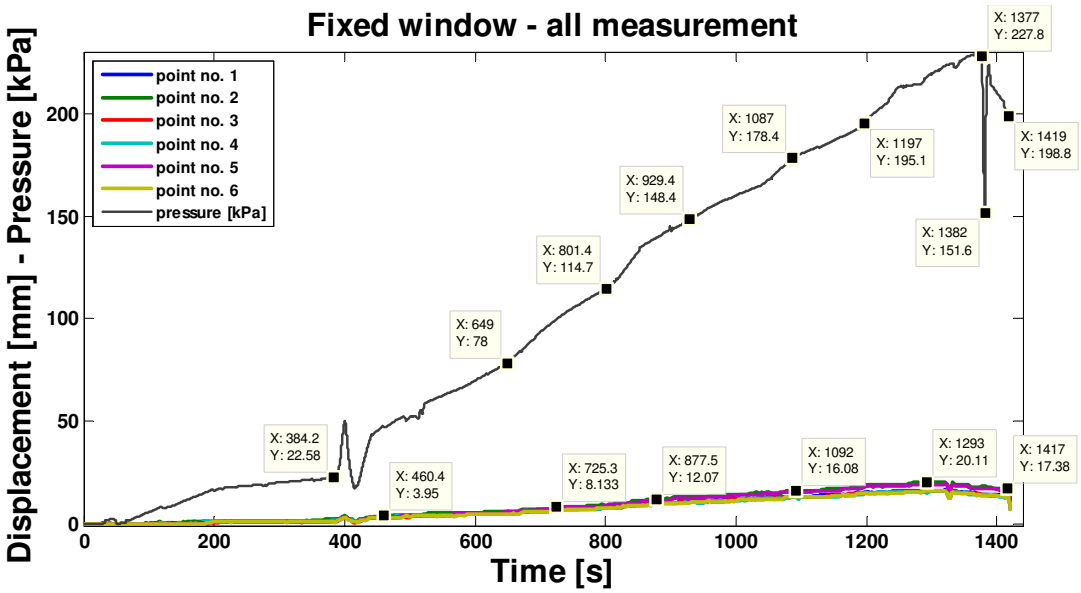


Fig. T5. Measurement results (full time history).

For a clear presentation of results, changed the scale of pressure. Results multiplied by a constant factor x10.

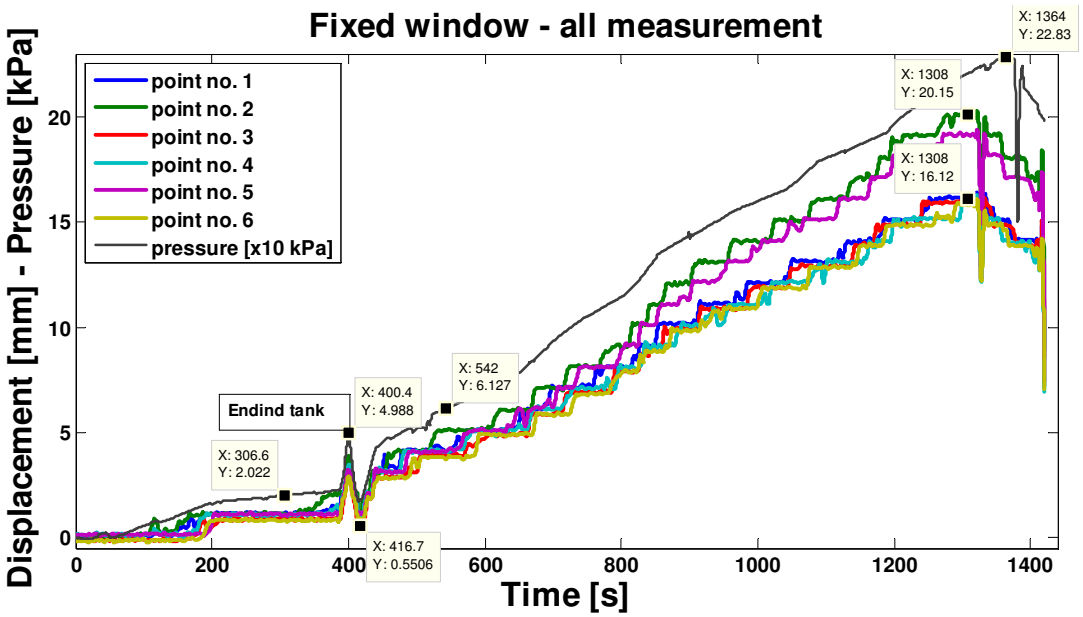


Fig. T6. Measurement results (full time history) with the revised scale.

1st stage – t_0 – t_{350} [s].

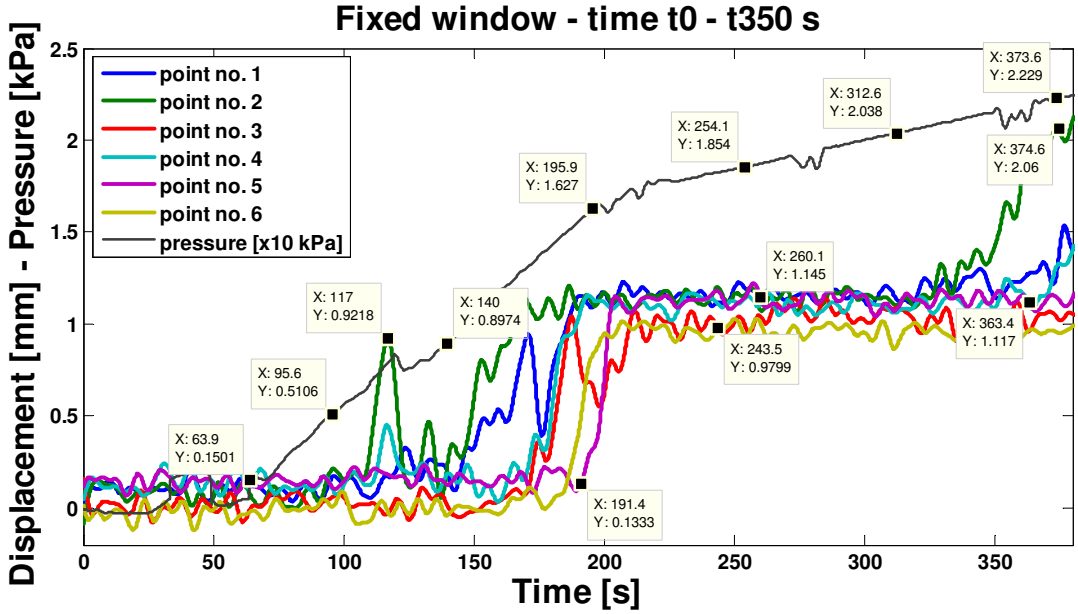


Fig. T7. 1st stage – t_0 – t_{350}, pressure p_0=0kPa to p_{350}=22kPa.

2nd stage t_{350} – t_{750}

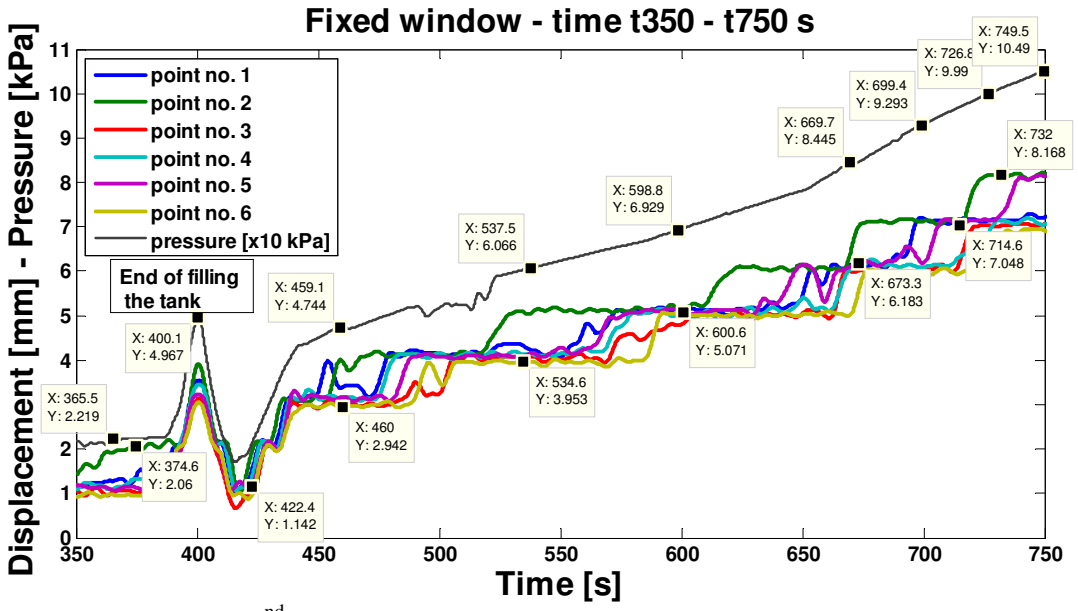


Fig. T8. 2nd stage t_{350} – t_{750} – pressure p_{350}=22kPa to p_{750}=105kPa.

3rd stage t_{750} – t_{1100}

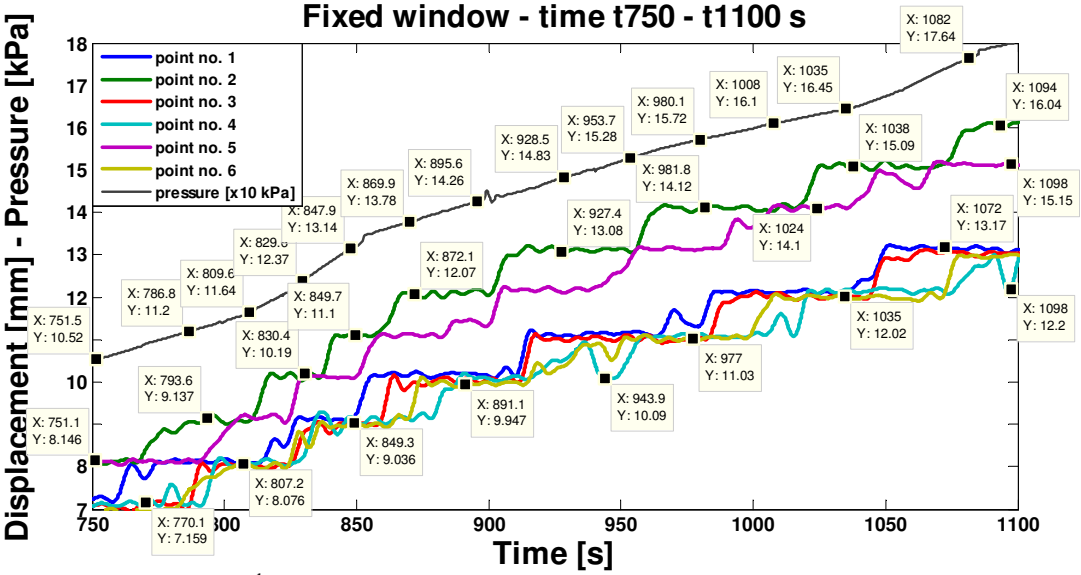


Fig. T9. 3rd stage t_{750} – t_{1100} – pressure p_{750}=105kPa to p_{1100}=180kPa.

4nd stage t_{1100} – t_{1430}

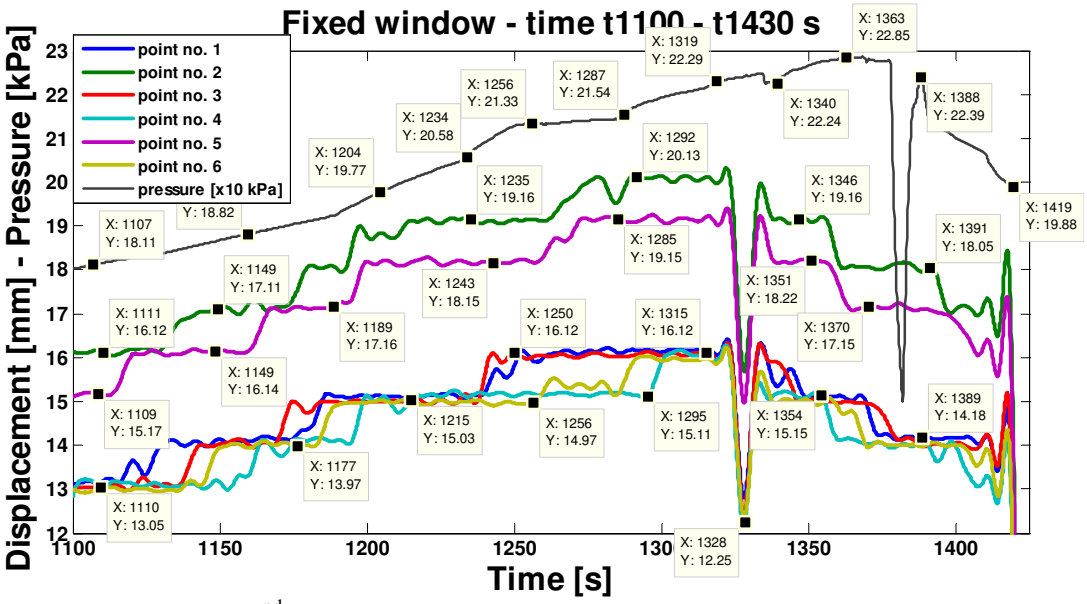


Fig. T10. 4nd stage t_{1100} – t_{1430} – pressure p_{1100}=180kPa to p_{1363}=228.5kPa.

Finish.

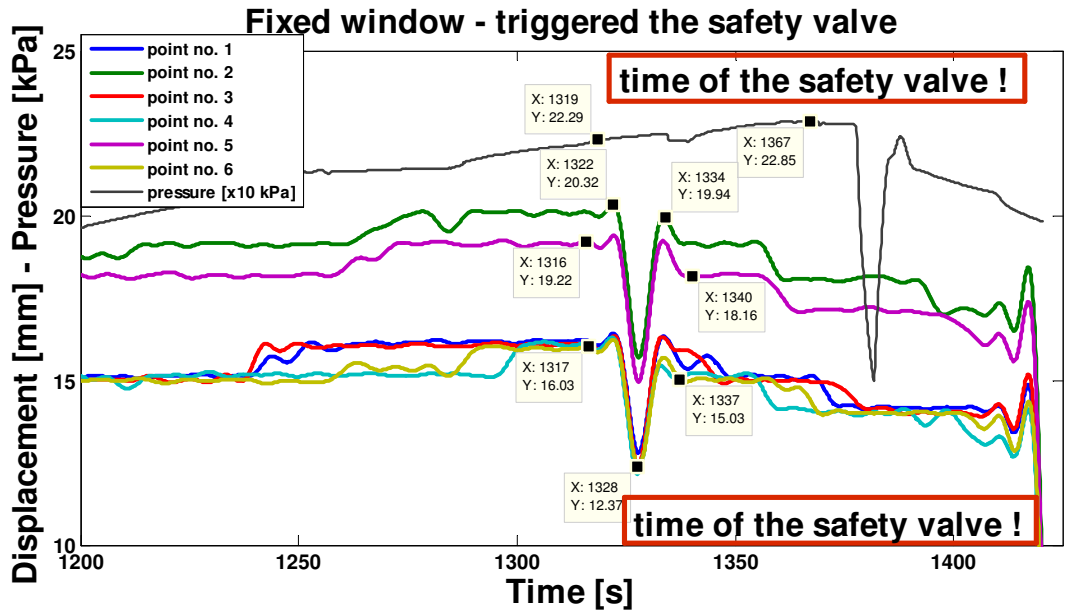


Fig. T11. Finish.

Table TT.1. Displacement, leakage and pressure test results.

Tab. TT.1	**Test results object no. 11, test number 15645**							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	18,5	~1,08	~1,08	~1,08	~0,98	~0,98	~0,98	0,0
2	22,3	1,34	2,06	0,97	1,34	0,97	0,97	0,0
3	50,3	4,14	4,14	3,21	4,14	4,14	2,96	0,0
4	69,3	5,07	5,07	4,78	5,07	5,07	5,07	0,0
5	95,0	7,05	7,05	5,97	6,14	7,05	5,97	0,0
6	99,9	7,05	8,16	7,05	7,05	7,05	6,85	0,0
7	123,7	9,04	10,19	9,04	9,04	10,19	9,04	0,0
8	157,9	12,02	14,12	11,88	11,03	13,08	11,03	0,0
9	204,0	15,03	19,16	15,03	15,03	18,15	15,03	0,0
10	222,9	16,12	20,11	16,12	16,12	19,15	16,12	0,0
11	228,5	**Triggered the safety valve**						**0,0**

Test photos.

Fig. T12. Window – no damage.

Fig. T13. Window – no damage.

Fig. T14. Window – no damage.

u) Model no. 12; Cross flooding hatch, type STXE; test no 15582, (direction: "INTO the door frame")

Test No. 15558, tested object no. 12.

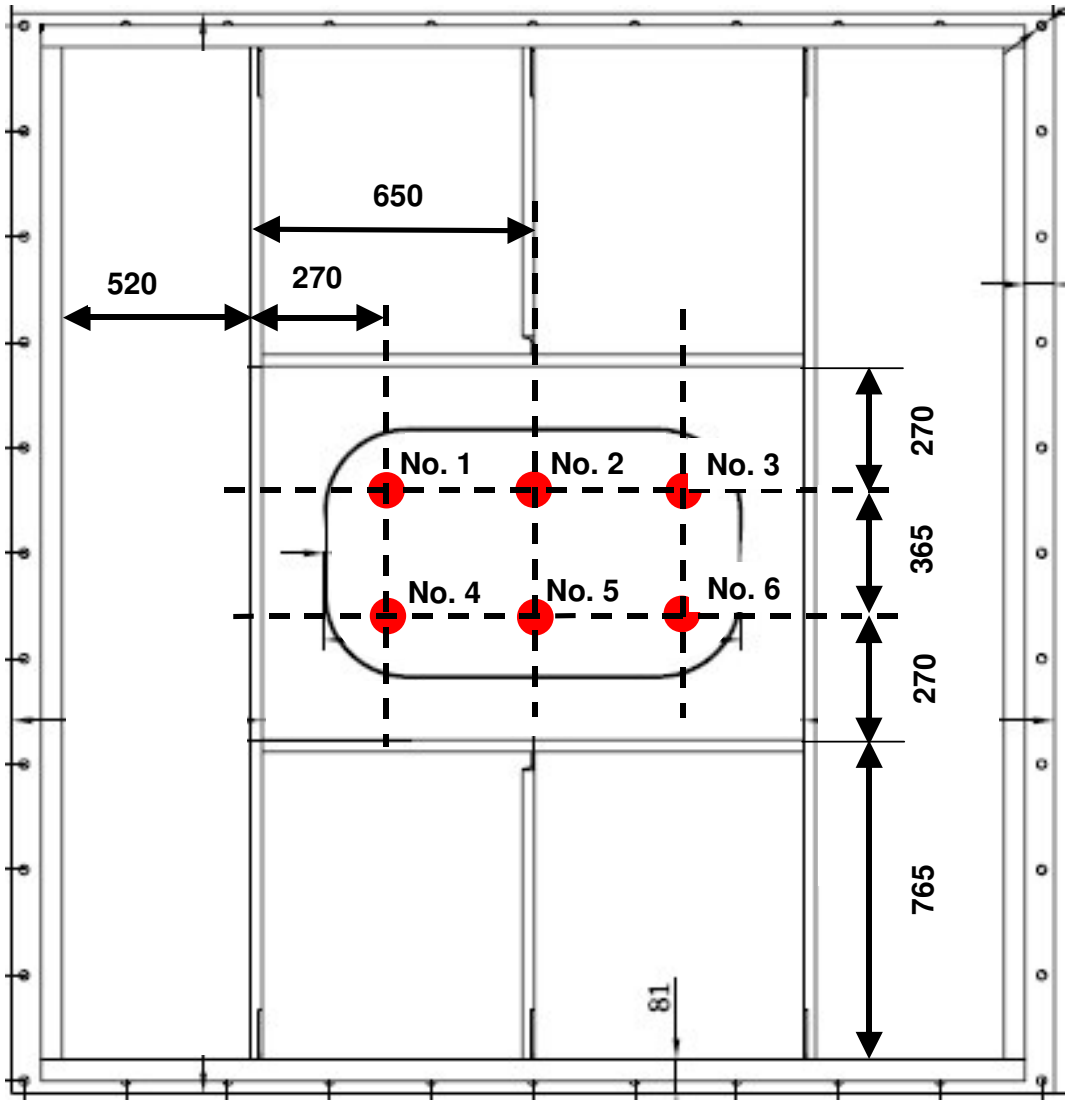


Fig. U1 . Dimension plan of a measurement points.

Stand with installed test object no. 12 test number 15558.

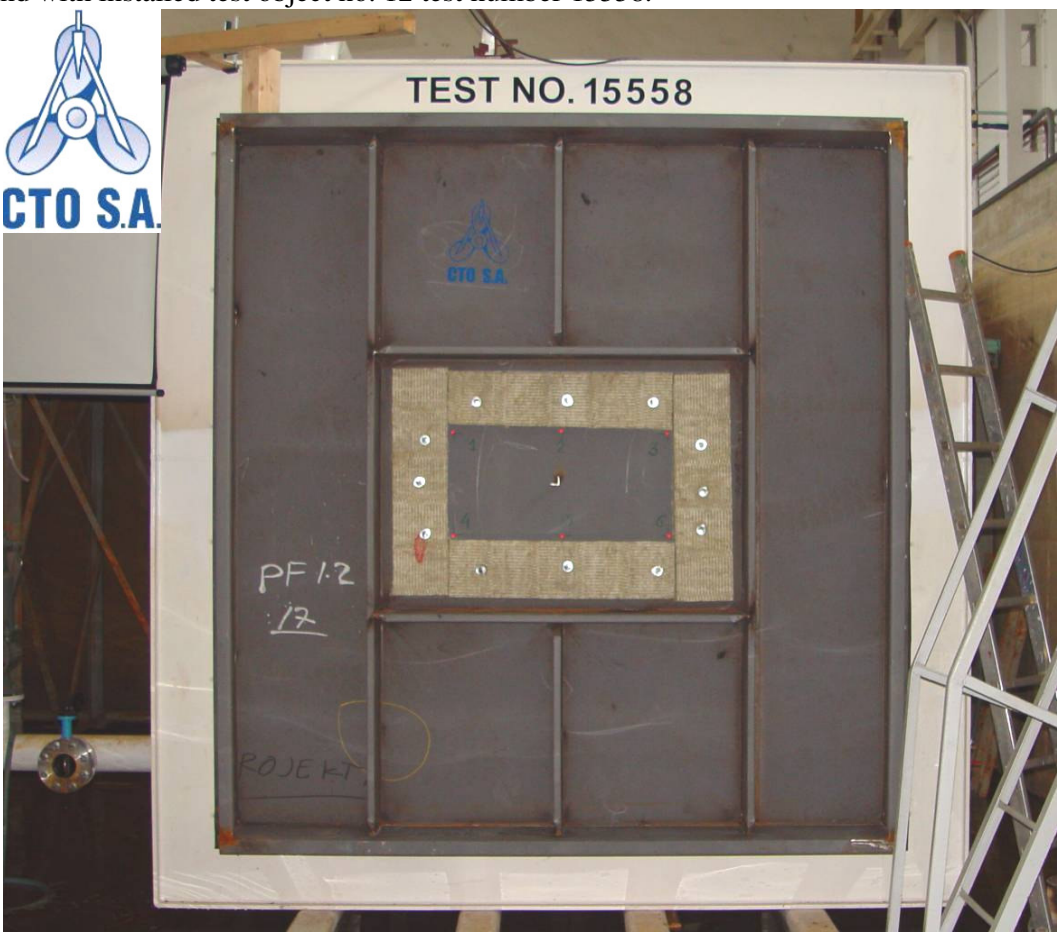


Fig. U2. Stand with installed test object no. 12 test number 15558.

Fig. U3. Measuring points location.

Results of the test are presented on Fig. U4 to Fig. U7.

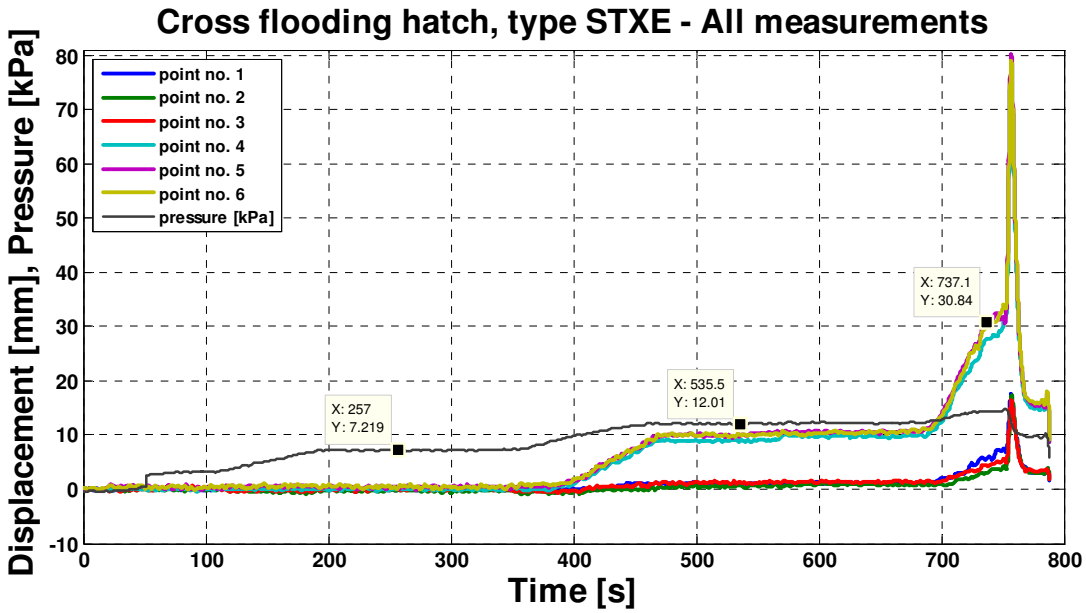


Fig. U4. Measurement results (full time history).

1th phase – Pressure level 7.3kPa- tank filling up.

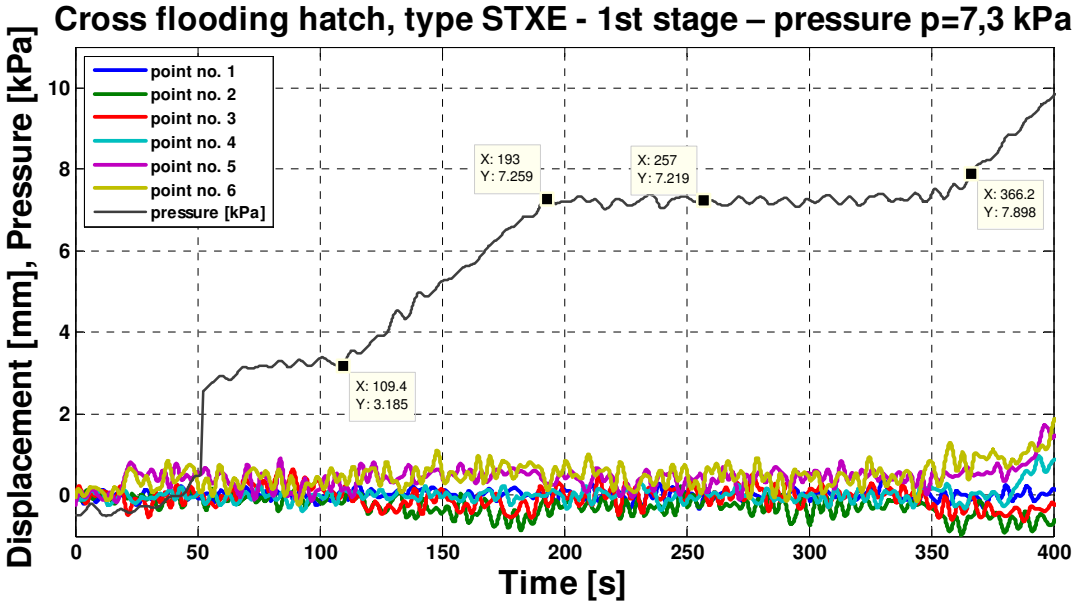


Fig. U5. Pressure level 7.3kPa - tank filling up.

2nd phase – pressure level p=12 kPa,

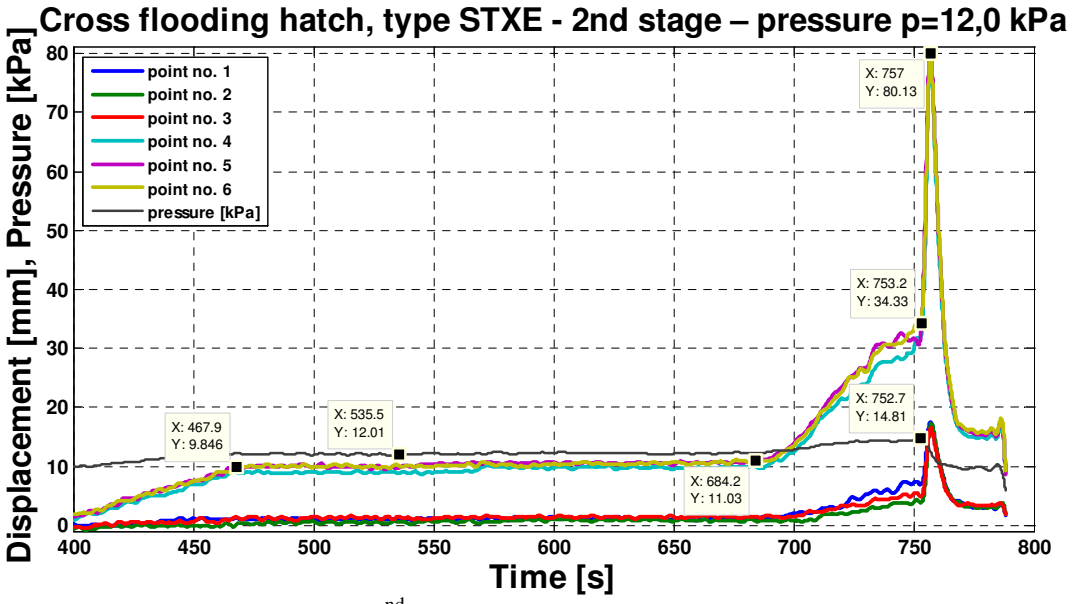


Fig. U6. 2nd phase – pressure level p=12 kPa.

3rd stage – finish

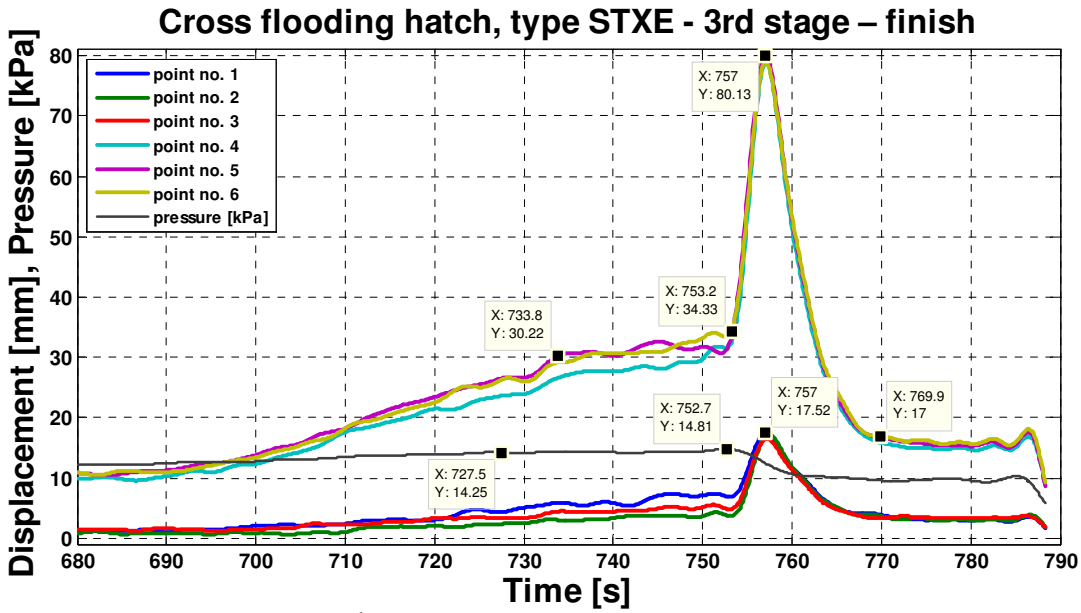


Fig. U7. 3rd stage – finish - pressure level – 14.8 kPa.

Table TU.1. Displacement, leakage and pressure test results.

Tab. TU.1	Test results object no. 12, test number 15558							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,0
1	7,2	0,00	0,00	0,00	0,00	0,00	0,00	0,0
2	12,2	1,39	0,92	1,34	9,79	10,25	10,65	~ 34 l/s
3	14,2	damage	damage	damage	damage	damage	damage	

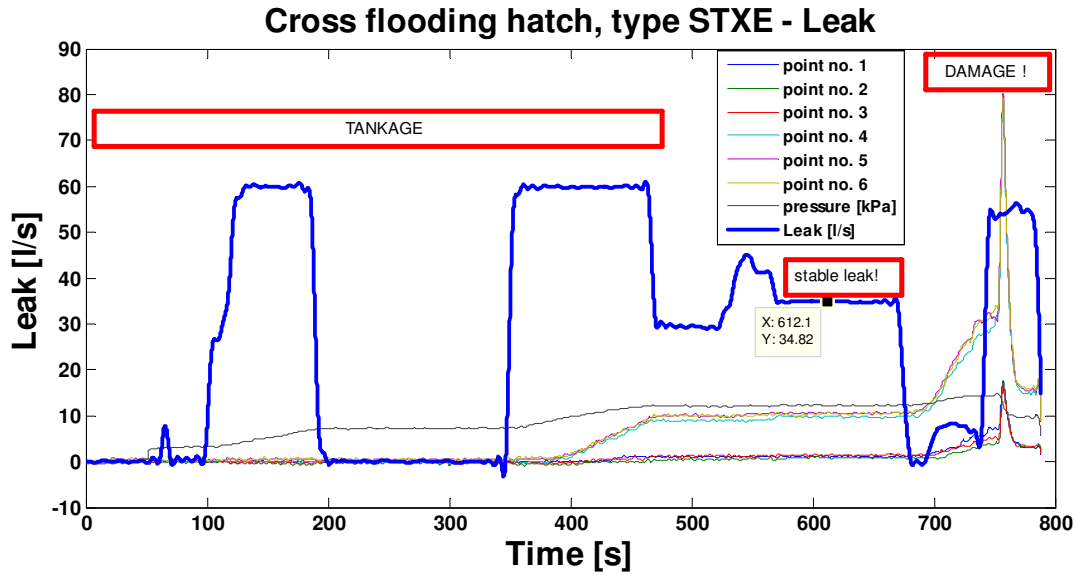


Fig. U8. Leak [l/s].

Test photos.

Fig. U9. Test object no. 12 damage, leak ~34 l/s = 2m^3/min.

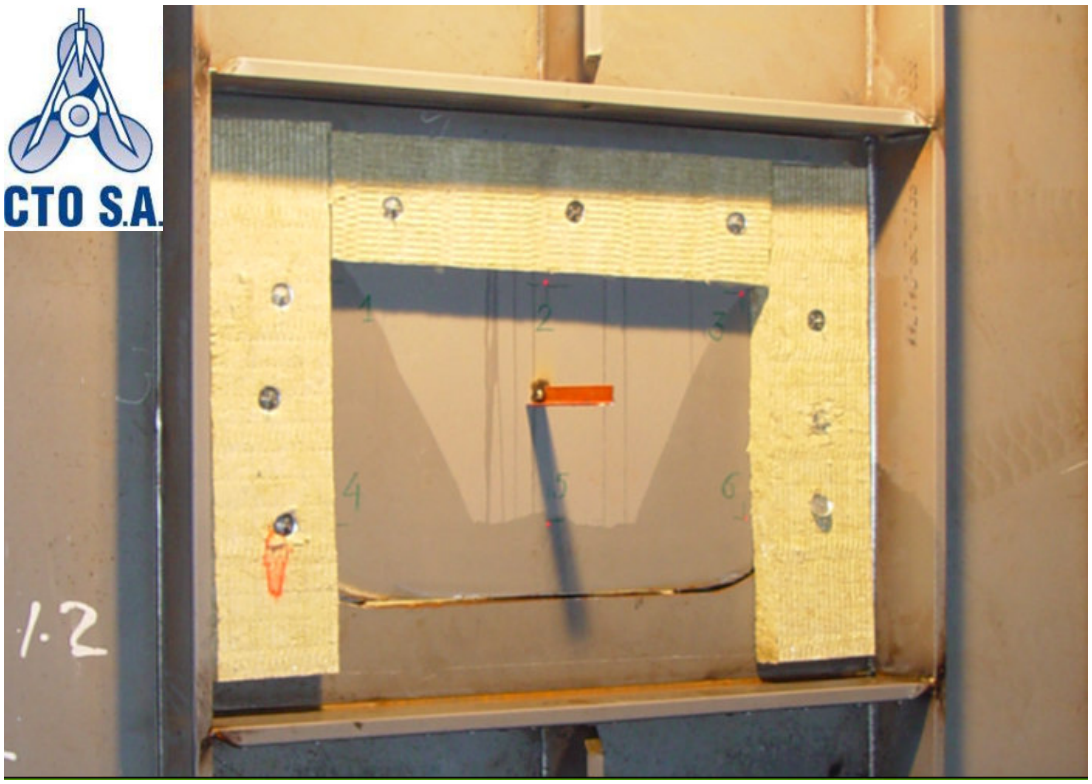


Fig. U10. Test object no. 12. damage

w) Model no. 13; Cross-flooding hatch; test no 15637, (direction: "OUT of the in-welded frame")

Test No. 15637, tested object no. 13.

Fig. W1. Stand with installed object test.

Dimensioning of measurements points of the element no. 13.

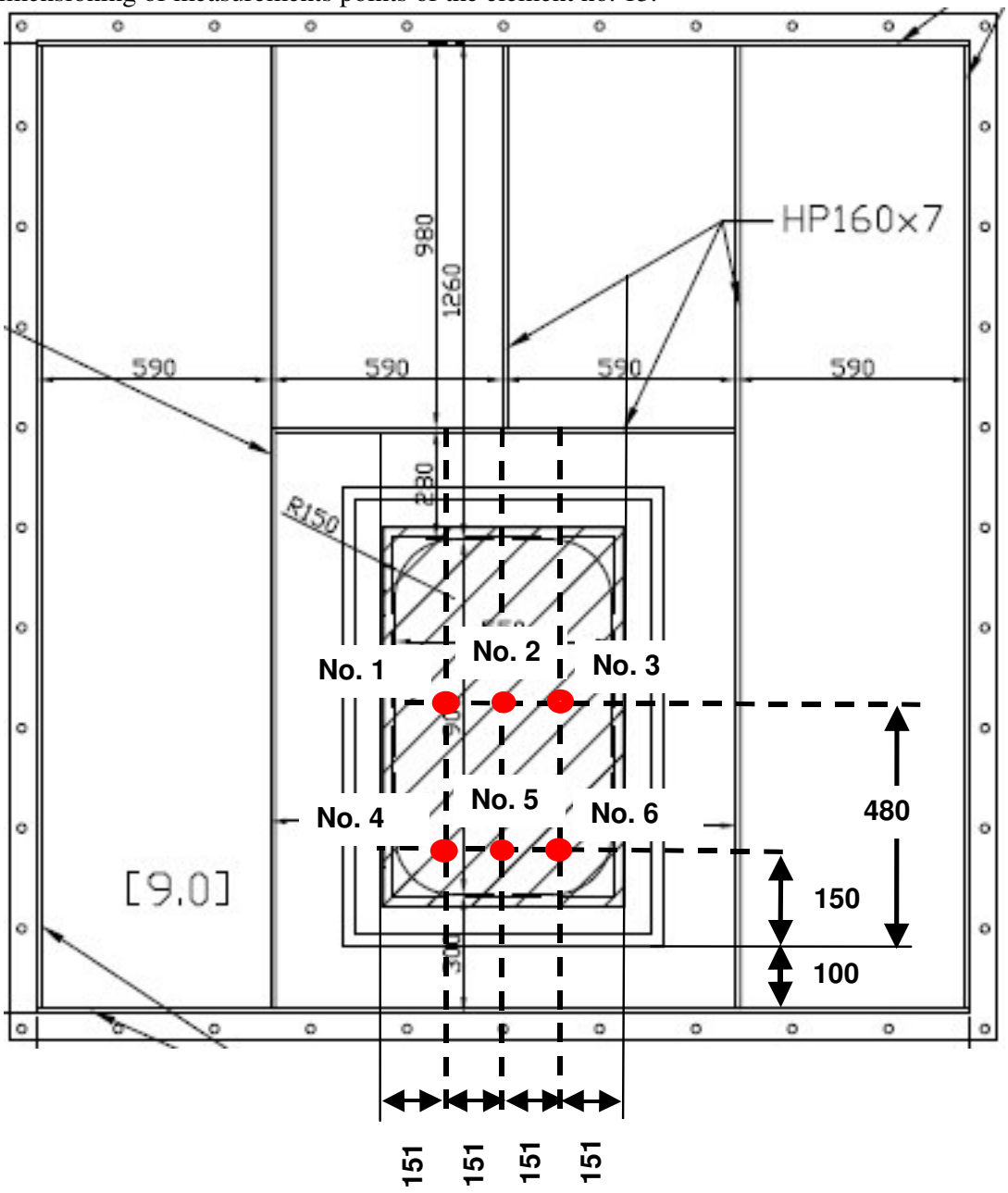


Fig. W2. Dimension plan of a measurement points.

The cross-flooding hatch has a broken lock which prevented it's closure. The lock operated only as self – locking latch.

Results of the test are presented on Fig. W3 to Fig. W5.

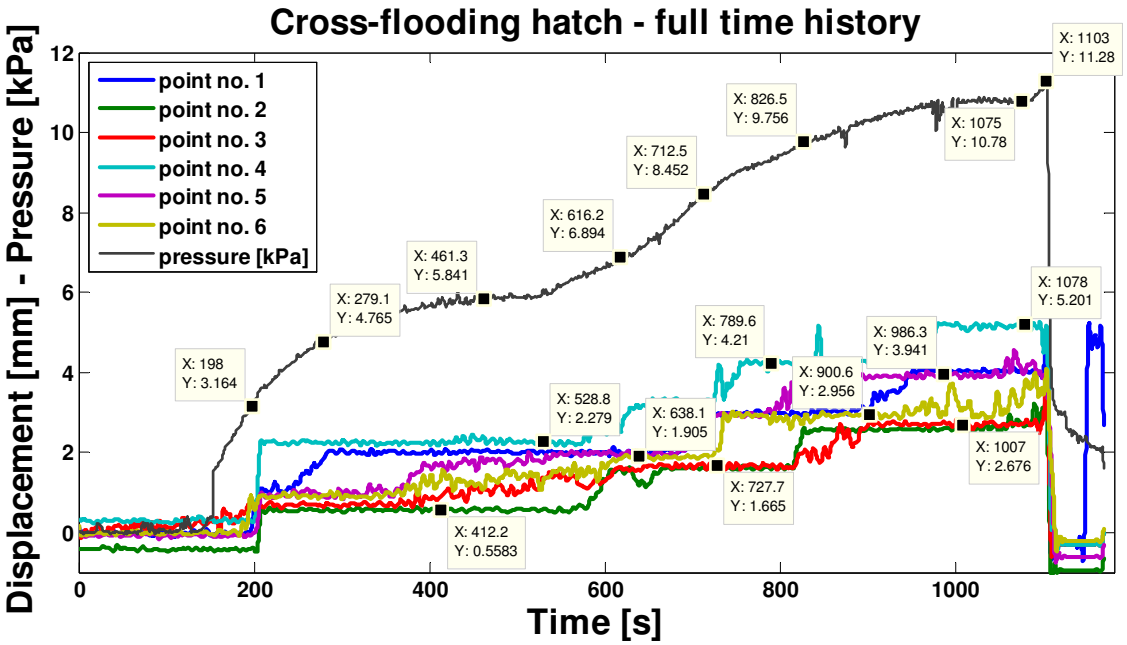


Fig. W3. Measurement results (full time history).

1th phase – tank filling up and pressure p=5,8 kPa.

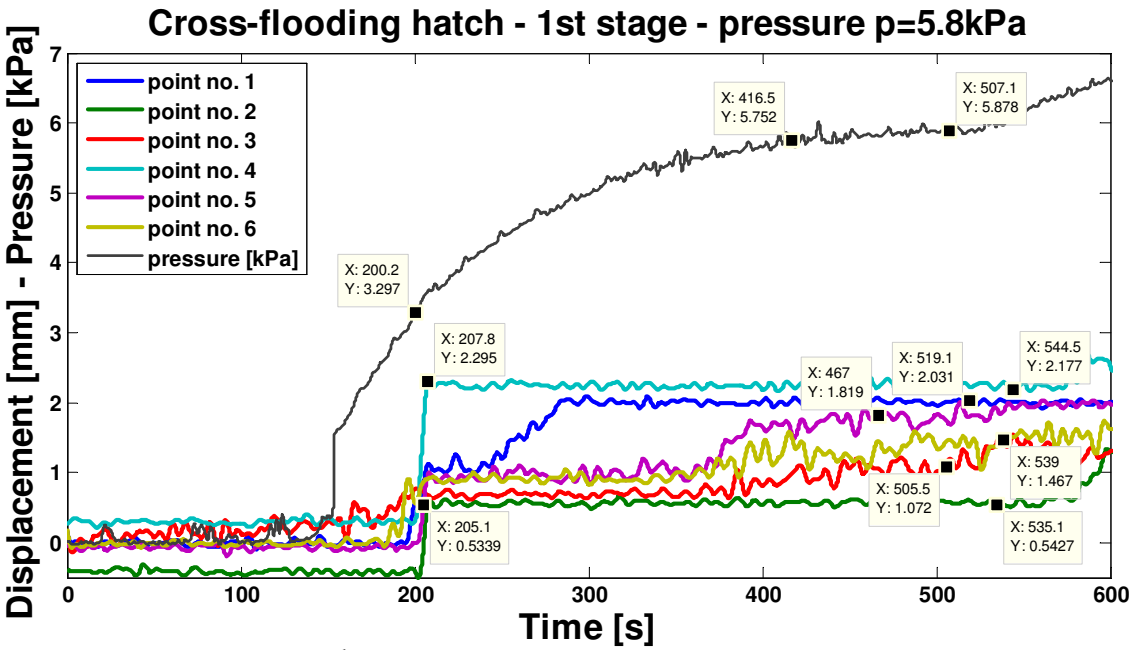


Fig. W4. 1th phase – tank filling up and pressure p=5,8 kPa.

2nd phase – pressure level p=11 kPa.

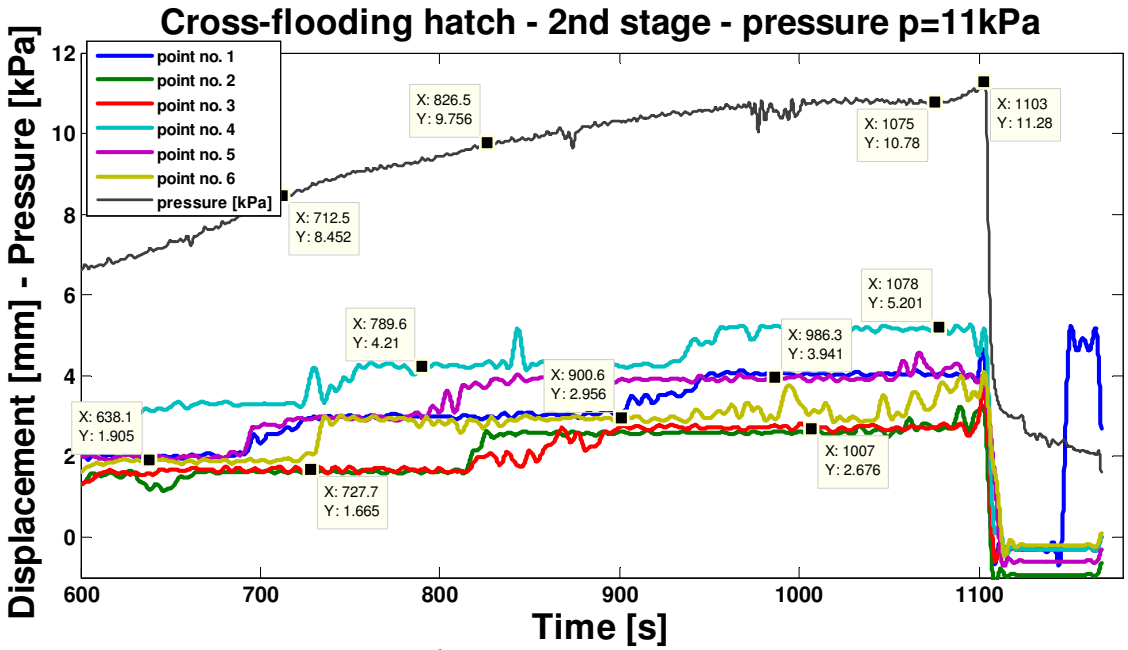


Fig. W5. 2nd phase – pressure level p=11 kPa.

Table TW.1. Displacement, leakage and pressure test results.

Tab. TW.1	Test results object no. 13, test number 15637							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,8	2,00	0,54	1,07	2,29	1,82	1,39	17,8
2	10,8	3,94	2,67	2,67	5,20	3,98	2,96	28,7
3	11,3	damage	damage	damage	damage	damage	damage	------

Test photos.

Fig. W6. Leak at pressure p=6 kPa.

Fig. W7. Leak at pressure p=9 kPa.

Fig. W8. Leak at pressure p=11 kPa.

Fig. W9. Cross-flooding hatch damage.

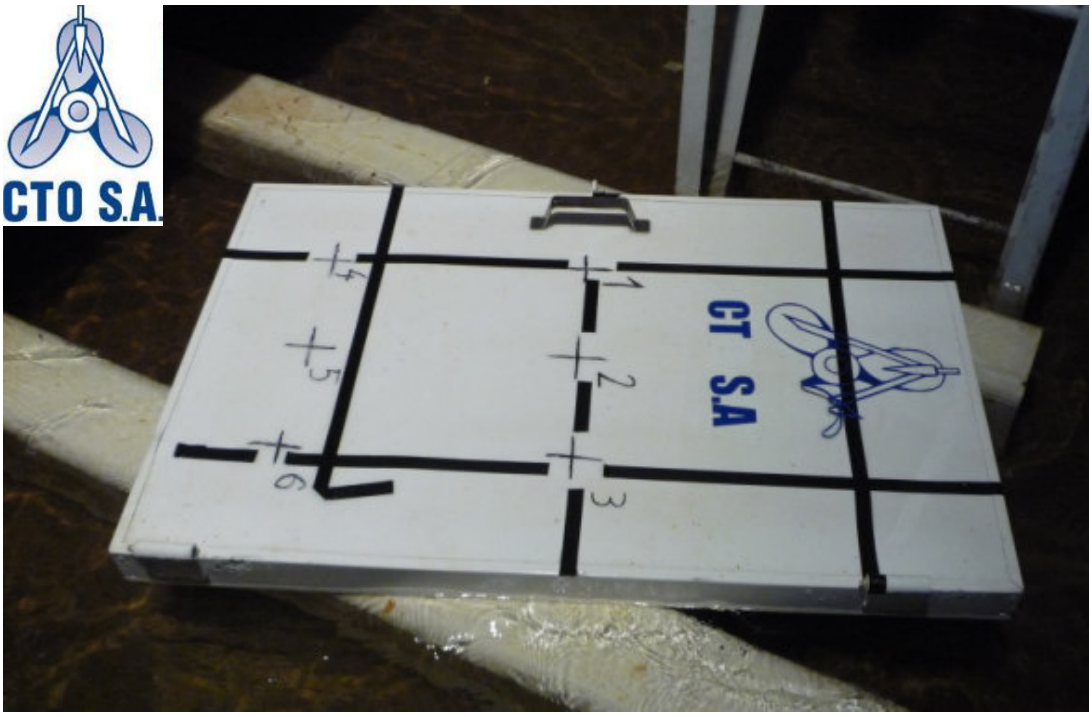


Fig. W10. Cross-flooding hatch damage.

Fig. W11. Cross-flooding hatch damage.

Fig. W12. Cross-flooding hatch damage.

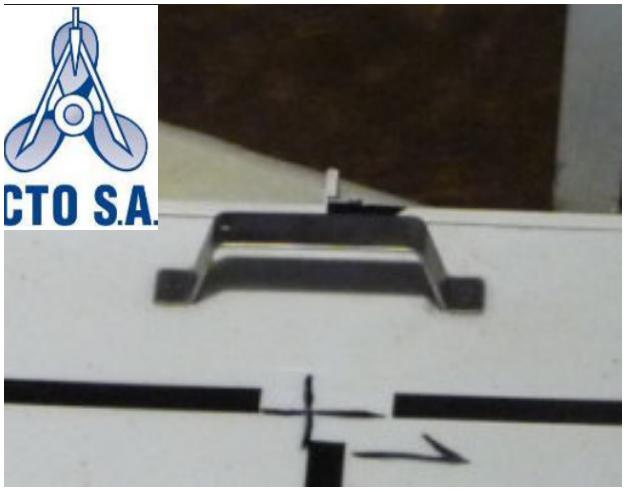


Fig. W13. Cross-flooding hatch damage.

Fig. W14. Cross-flooding hatch damage.

Fig. W15. Cross-flooding hatch damage.

5 SUMMARY

After performing all the test critical information are gathered in below table:

Table 5.1. Test end status and parameters maximum values (displacement, leak or pressure).

Tab. 5.1 Summary results

No object / no test	P [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s	Test end status
object 1,1 - **Sliding door;** direction "INTO the door frame". Area – 1,100mx2,070m=2,277 m^2, opening area after the test – about 98%.									
test 15628	12,8	damage	damage	damage	damage	damage	damage	------	damage
object 1,2 - Sliding door; direction "OUT the door frame". Area – 1,230mx2,070m=2,546 m^2, opening area after the test – about 50%.									
test 15630	10,8	damage	damage	damage	damage	damage	damage	------	damage
object 2,1 - **Hinged door;** direction "INTO the door frame". Area – 1,050mx2,070m=2,174 m^2, opening area after the test – about 8% + leak.									
Test 15634	22,6	damage	damage	damage	damage	damage	damage	------	damage
object 2,2 - **Hinged door;** direction "INTO the door frame". Area – 1,050mx2,070m=2,174 m^2, opening area after the test – about 4% + leak.									
test 15639	23,5	damage	damage	damage	damage	damage	damage	------	damage
object 2,3 - **Hinged door;** direction "INTO the door latch". Area – 1,050mx2,070m=2,174 m^2, opening area after the test – about 3% + leak.									
test 15632	11,5	9,21	8,98	5,98	18,5	16,22	7,50	96,1	critical flow
object 2,4 - **Hinged door;** direction "INTO the door latch". Area – 1,050mx2,070m=2,174 m^2, opening area after the test – only leak.									
test 15638	12,0	8,10	6,96	4,95	~10,4	~8,00	9,89	96,9	critical flow
object 3,1 - **A-60 double leaf hinged marine fire door;** direction "OUT the door frame". Area – 2,200x2,075=4,565 m^2, opening area after the test – only leak.									
test 15734	9,2	4,21	8,88	10,88	12,02	14,05	16,13	~90	critical flow
object 4 - **Door - single leaf;** direction "INTO the door frame". Area – 2,100mx1,000m=2,100 m^2, opening area after the test – 2% + leak.									
test 15732	22,0	34,23 damage	46,94 damage	47,92 damage	disturbance damage	disturbance damage	disturbance damage	~90	damage
object 5,1 - **B class joiner door – hinged, Steelframes for B-wall;** direction "OUT the door frame". Area – 2,300mx2,140m=4,922 m^2, contain door – 0,840mx2,100m=1,764 m^2, opening area after the test – about 1% + leak.									
test 15578	11,7	50,28	39,25	25,10	66,40	50,18	33,66	91,6	critical flow
object 5,2 - **B class joiner door – hinged, Steelframes for B-wall;** direction "INTO the door frame". Area – 2,300mx2,140m=4,922 m^2, contain door – 0,840mx2,100m=1,764 m^2, opening area after the test – about 15%.									
test 15574	12,3	damage	damage	damage	damage	damage	damage	------	damage
object 5,3 - **B class joiner door – hinged, Steelframes for B-wall;** direction "INTO the door frame". Area – 2,300mx2,140m=4,922 m^2, contain door – 0,840mx2,100m=1,764 m^2, opening area after the test – about 30%.									
test 15579	11,2	7,56 damage	8,67 damage	9,49 damage	6,71 damage	5,47 damage	8,43 damage	61,1 damage	damage
object 5,4 - **B class joiner door – hinged, Steelframes for B-wall;** direction "OUT the door frame". Area – 2,300mx2,140m=4,922 m^2, contain door – 0,840mx2,100m=1,764 m^2, opening area after the test – about 15%.									
test 15582	10,8	18,98 damage	14,94 damage	10,79 damage	29,45 damage	24,44 damage	17,61 damage	49,7 damage	damage

object 6 - **Cool Room sliding door;** direction "INTO the door wall" Area – 1,950mx1,100m=2,145 m^2, opening area after the test – about 1% + leak.									
test 15580	23,5	33,63	45,81	33,84	32,35	interferen	84,32	------	critical flow
object 8,1 - **B class Steelframes for cabin wall;** direction "INTO the panel wall". Area – 2,300mx2,140m=4,922 m^2, opening area after the test – about 5%.									
test 15569	14,2	damage	damage	damage	damage	damage	damage	damage	damage
object 8,2 - **B class Steelframes for cabin wall;** direction "INTO the wall with the frame structure" Area – 2,300mx2,140m=4,922 m^2, opening area after the test – about 10%.									
Test 15563	12,2	49,98 damage	66,77 damage	53,18 damage	72,26 damage	110,20 damage	73,94 damage	82,4 -----	Damage
object 9 - **B-Wall;** direction "OUT of the frame". Area – 2,300mx2,140m=4,922 m^2, opening area after the test – about 8%.									
test 15643	7,8	damage	damage	damage	damage	damage	damage	------	Damage
object 10 - **SWT door – sliding Steelframes;** direction "OUT the door frame". Area – 2,100mx1,100m=2,310 m^2, opening area after the test – about 3%.									
test 15572	82,0	damage	damage	damage	damage	damage	damage	40	damage
object 11 - **Window;** direction "INTO the in-welded frame". Area – 1,362mx1,562m=2,127 m^2, opening area after the test – 0%.									
test 15645	228,5	Safety valve triggered						0	critical pressure
object 12 - **Cross flooding hatch, type STXE;** direction "INTO the door frame". Area – 0,600mx1,000m=0,600 m^2, opening area after the test – about 5%.									
test 15558	14,2	damage	damage	damage	damage	damage	damage	------	damage
object 13 - **Cross flooding hatch;** direction "OUT of the in-welded frame". Area – 0,900mx0,550m=0,495 m^2, opening area after the test – 100%.									
test 15637	11,3	damage	damage	damage	damage	damage	damage	------	damage

One can specify four specimen groups, which were tested under pressure acting in both directions.

Group 1 - B-class joiner door – hinged,
object 5,1 - B class joiner door – hinged, Steelframes for B-wall; direction "**OUT the door frame"**.
object 5,4 - B class joiner door – hinged, Steelframes for B-wall; direction "**OUT the door frame"**.
object 5,2 - B class joiner door – hinged, Steelframes for B-wall; direction "**INTO the door frame".**
object 5,3 - B class joiner door – hinged, Steelframes for B-wall; direction "**INTO the door frame"**.

Group 2 - B-class Steelframes for cabin wall,
object 8,1 - B class Steelframes for cabin wall; direction "**the wall with the panel"**.
object 8,2 - B class Steelframes for cabin wall; direction "**INTO the wall with the frame structure".**

Group 3 - Sliding door

object 1,2 - Sliding door; direction "**OUT the door frame"**.
object 1,1 - Sliding door; direction "**INTO the door frame"**.

Group 4 - Hinged door.
object 2,3 - Hinged door; direction "**INTO the door latch"**.
object 2,4 - Hinged door; direction "**INTO the door latch"**.
object 2,1 - Hinged door; direction "**INTO the door frame"**.
object 2,2 - Hinged door; direction "**INTO the door frame"**.

In table 5.2 test results of specimens loaded in both directions were showed.

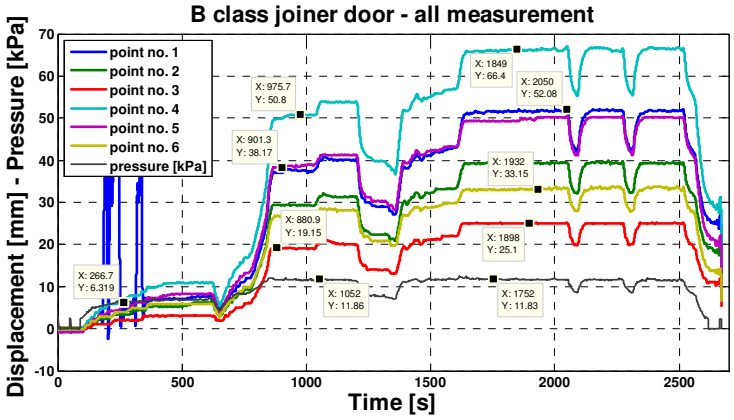
B-class joiner door – hinged,

pressuring of in the way of" OUT the door frame"

object no. 5,1, test number 15578

Tab. TB.1	Test results object no. 5,1, test number 15578							
Lp.	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
1	6,3	6,8	5,4	3,0	10,8	8,3	5,4	31,0
2	11,9	40,2	31,2	20,4	53,8	40,2	28,4	54,9
3	11,7	50,2	39,2	25,1	66,4	50,2	33,7	91,6

Table TB.1. Displacement, leakage and pressure test results.



Measurement results (full time history).

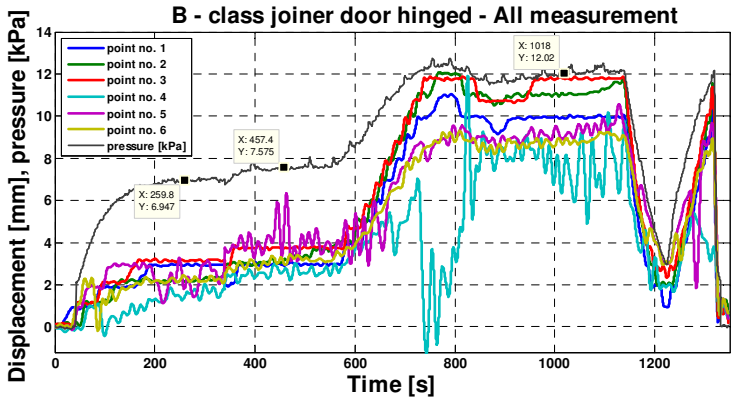
Table 5.2 Test results of specimens loaded in both directions

pressuring of in the way of "INTO the door frame"

object no. 5,2, test number 15574.

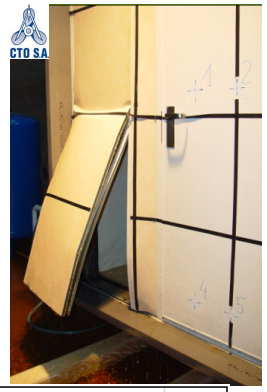
Tab. TC.1	Test results object no. 5,2, test number 15574							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
1	6,3	6,8	5,4	3,0	10,8	8,3	5,4	~20,5
2	11,9	40,2	31,2	20,4	53,8	40,2	28,4	~63,8
3	12,3	damage	damage	damage	damage	damage	damage	------

Table TC.1. Displacement, leakage and pressure test results.



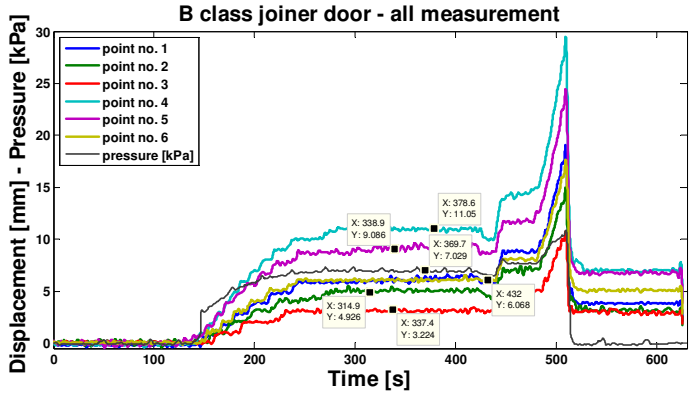
Measurement results (full time history).

object no. 5,4, test number 15582



Tab. TE.1	Test results object no. 5,4, test number 15582							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
1	7,0	5,8	4,9	3,2	11,1	9,1	6,1	30,4
2	10,8	19,0 damage	10,9 damage	10,7 damage	29,5 damage	24,4 damage	17,6 damage	49,7 damage

Table TE.1. Displacement, leakage and pressure test results.

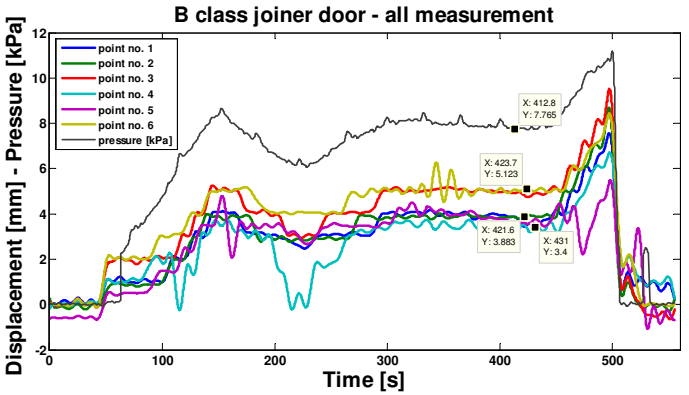


Measurement results (full time history).

object no. 5,3, test number 15579

Tab. TD.1	Test results object no. 5,3, test number 15579							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0
1	7,8	3,8	3,9	4,8	3,3	3,6	5,1	32,1
2	11,2	7,6 damage	8,7 damage	9,5 damage	6,7 damage	5,5 damage	8,4 damage	61,1 damage

Table TD.1. Displacement, leakage and pressure test results.



Measurement results (full time history).

B-class Steelframes for cabin wall,

pressuring of in the way of "INTO the wall with the panel"

object no. 8,1, test number15569.

Tab. TF.1 — Test results object no 8.1, test number 15569

Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	6,9	~9,00	~10,00	~8,50	~18,00	~21,00	~19,00	~2,5
2	11,4	~40,00	~49,00	~43,00	~62,00	~74,00	~64,00	~28
3	14,2	damage	damage	damage	damage	damage	damage	------

Table TF.1. Displacement, leakage and pressure test results.

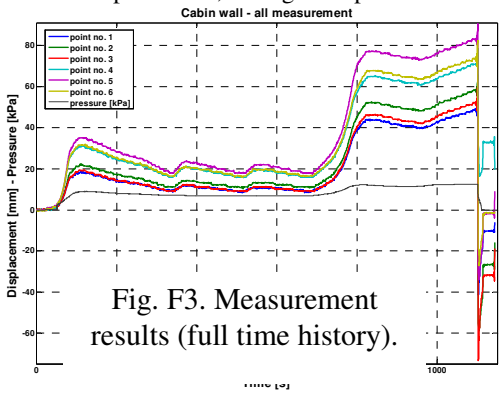
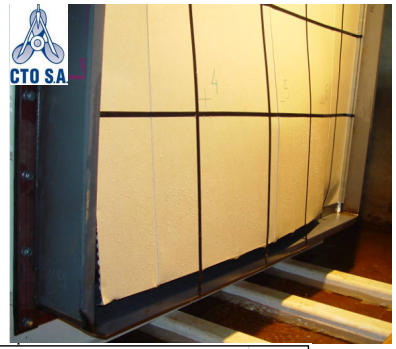


Fig. F3. Measurement results (full time history).

Measurement results (full time history).

pressuring of in the way of "INTO the wall with the wall frame"

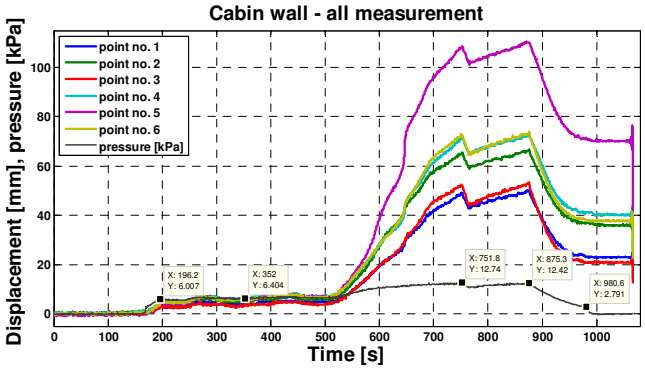
object no. 8,2, test number 15563.



Tab. TG.1 — Test results object no. 8.2, test number 15563

Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	6,0	5,37	3,89	2,29	5,08	4,21	4,62	34,7
2	12,7	46,83	63,05	49,01	69,00	106,23	69,36	64,4
3	12,2	49,98 damage	66,77 damage	53,18 damage	72,26 damage	110,20 damage	73,94 damage	82,4 ------

Table TG.1. Displacement, leakage and pressure test results.

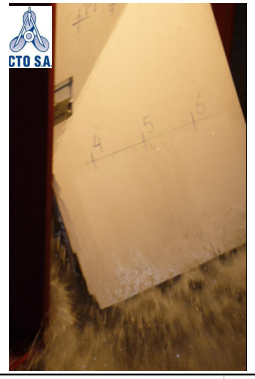


Measurement results (full time history).

Sliding door

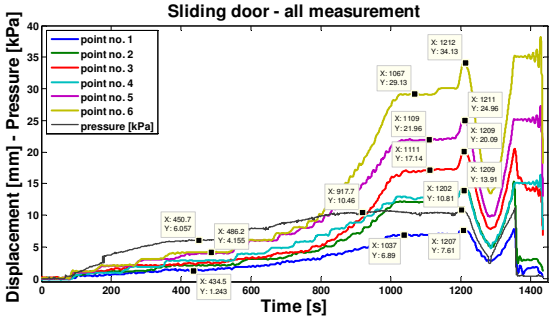
pressuring of in the way of "OUT the door frame"

object no. 1.2, test no 15630



Tab. TL.1	Test results object no. 1.2 test number 15630							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,98	1,41	2,15	2,25	2,91	3,10	4,02	44,83
2	10,57	6,80	12,07	17,00	12,91	21,90	29,11	48,67
3	10,81	damage	damage	damage	damage	damage	damage	------

Table TL.1. Displacement, leakage and pressure test results.



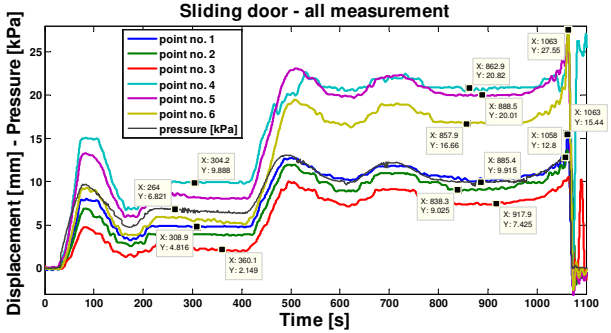
Measurement results (full time history).

pressuring of in the way of "INTO the door frame"

object no. 1.1, test no. 15628

Tab. TK.1	Test results object no. 1.1, test number 15628							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	6,72	4,82	3,90	2,25	9,89	8,23	5,81	8,68
2	10,0	10,54	9,00	7,42	20,94	20,01	16,67	49,42
3	12,8	damage	damage	damage	damage	damage	damage	------

Table TK.1. Displacement, leakage and pressure test results.



Measurement results (full time history).

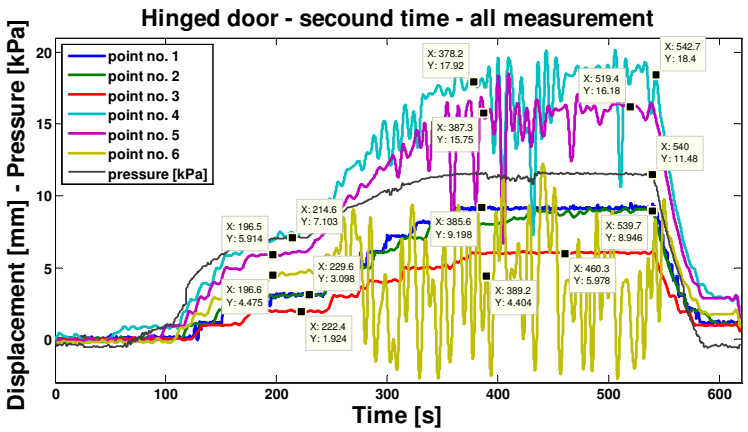
Hinged door

pressuring of in the way of "INTO the door latch"

object no 2.3, test no 15632

Tab. TM.1	Test results object no. 2,3, test number 15632							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	7,10	3,10	3,10	1,92	7,00	5,91	4,48	48,9
2	11,52	9,21	8,98	5,98	18,5	16,22	7,50	96,1
3	11,48	------	------	------	------	------	------	------

Table TM.1 Displacement, leakage and pressure test results.



Measurement results (full time history).

pressuring of in the way of "INTO the door frame"

object no 2.1, test no 15634

Tab. TN.1	Test results object no. 2,1, test number 15634							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,06	0,07	1,01	0,89	1,78	1,93	2,84	2,62
2	11,95	2,98	4,97	3,88	7,78	9,07	10,05	7,21
3	16,87	9,02	13,00	13,84	15,93	19,73	19,62	14,44
4	21,91	22,23	28,81	28,39	29,80	34,68	36,33	17,78
5	26,26	44,02	53,27	50,81	52,82	67,97	64,93	19,14
6	22,65	damage	damage	damage	damage	damage	damage	------

Table TN.1. Displacement, leakage and pressure test results.

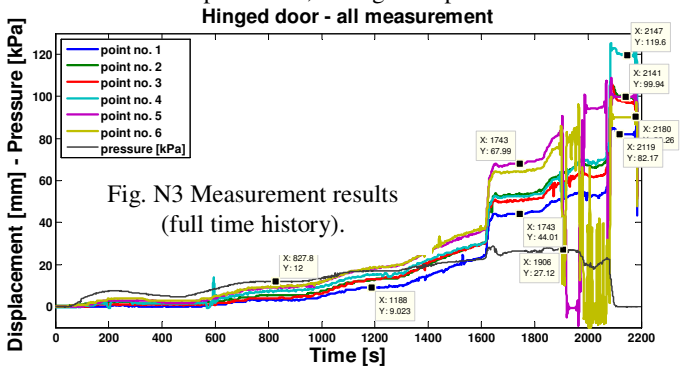


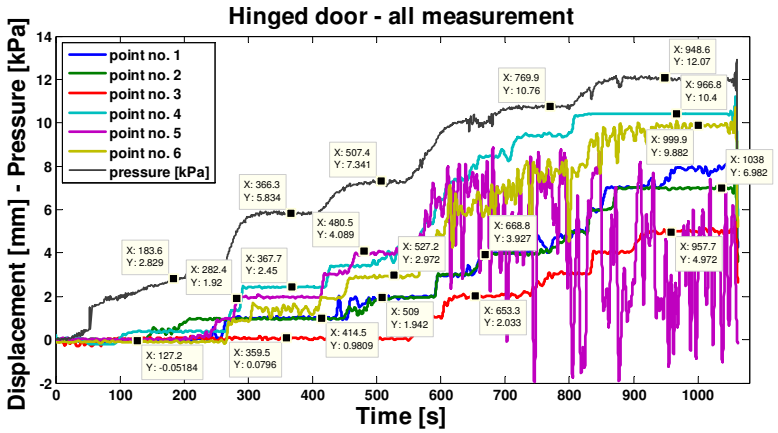
Fig. N3 Measurement results (full time history).

Measurement results (full time history).

object no 2.4, test no 15638

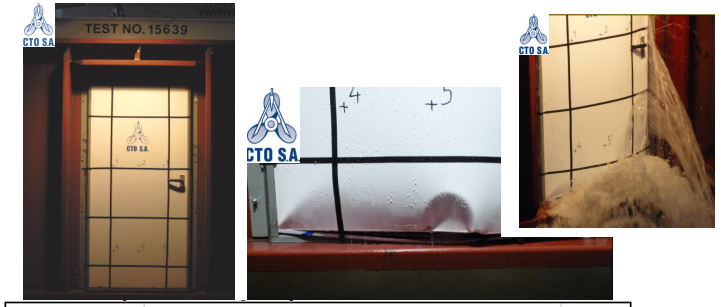
Tab. TP.1	Test results object no. 2.4, test number 15638							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,86	0,96	0,98	0,01	2,45	1,97	1,39	37,71
2	10,76	4,03	4,05	2,15	9,45	7,80	7,69	82,45
3	12,01	8,10	6,96	4,95	~10,4	~8,00	9,89	96,9

Table TP.1. Displacement, leakage and pressure test results.



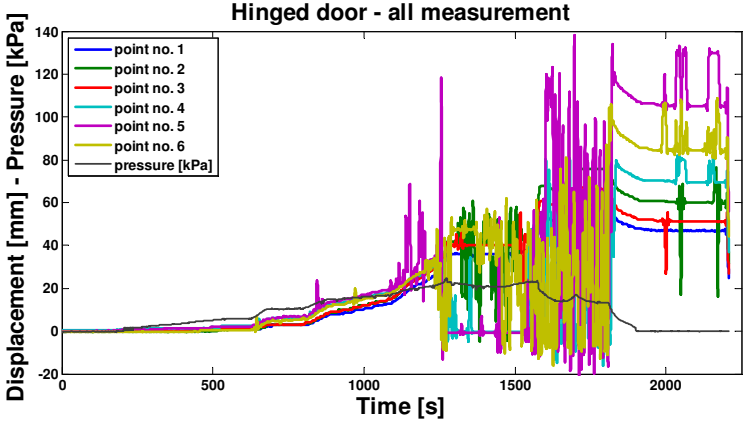
Measurement results (full time history).

object no. 2.2. test no 15639



Tab. TR.1	Test results object no. 2,2, test number 15639							
Lp	p [kPa]	Point no 1 [mm]	Point no 2 [mm]	Point no 3 [mm]	Point no 4 [mm]	Point no 5 [mm]	Point no 6 [mm]	Leak l/s
0	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0
1	5,87	1,18	0,98	0,81	1,60	1,91	0,98	34,76
2	10,60	5,43	2,96	2,81	5,44	6,73	6,04	27,19
3	16,85	12,19	13,85	12,84	16,53	18,30	17,06	48,82
4	23,22	36,13	42,07	39,85	-----	------	------	61,85
5	23,46	damage	damage	damage	damage	damage	damage	------

Table TR.1. Displacement, leakage and pressure test results.



Measurement results (full time history).

Conclusions – specimen comparison with both direction flooding loading

1.In case of **one leaf door** pressed against the door frame – specimen 5.2 and 5.3 – leak gaps between door and door frame were decreasing during water loading. The door wasn't subjected to displacement whereas wall structure which filled a space between door frame and outer frame has collapsed.

2. In case of **one leaf door** opened in out of the tank direction, during water loading leak pags between door and door frame were increasing (bottom part of the door was deforming). Locks and hinges have resisted water loading and have only been deformed. In all cases the locks wasn't destroyed hence the door didn't open. During testing of specimen 5.4 adjacent wall was damaged.

3. During testing, specimens 8.1 and 8.2 have been damaged in similar way as described above and in both specimens testing bottom part of the wall was damaged. As a result of this displacement wall has slide from the frame.

4. Sliding door 1.1 and 1.2 have been damaged with pressure corresponding to H = 1,28 H_2O for 1.1 and H = 1,08m H_2O for 1.2.

5. For Specimens 2.3 and 2.4, which were opened in out of the tank direction, large leak gaps were observed and after reaching critical leakage around 96 l/s the tank reached a water height H = 1,2 m H_2O. This phenomena has not caused any significant door deformation.

6. In case of specimen 2.1 and 2.2, which were pressed against the door frame, leak gaps was changing only in small range. After reaching maximum **water flooding efficiency** 96 l/s, the tank reached a water height H = 2,26 m H_2O for 2.1 and H = 2,35 H_2O for 2.2. For pressure p =22 kPa acting on a bottom part of a door, door significant deformation occurred which caused big leak gaps.

General conclusions:

7. Majority of specimens, where adjacent wall element was used, have been damaged and no higher pressure then H ~ 1,5 do 2,0 H_2O could be achieved.

8. The most watertight specimen was a window specimen 11, where maximum water pressure 228.5 kPa was achieved and no deformations or leakage was observed.

9. The biggest leakage was observed at specimen 3.1 - A-60 double leaf hinged marine fire door, where reaching maximum water flooding efficiency one has reached a pressure value only 9,15 kPa = 0,915 mH_2O.