Comparative Tests with Laminated Safety Glass Panes and Polycarbonate Panes at the Federal Highway Research Institute (BASt)

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Leverkusen, Germany, 22 November 2011

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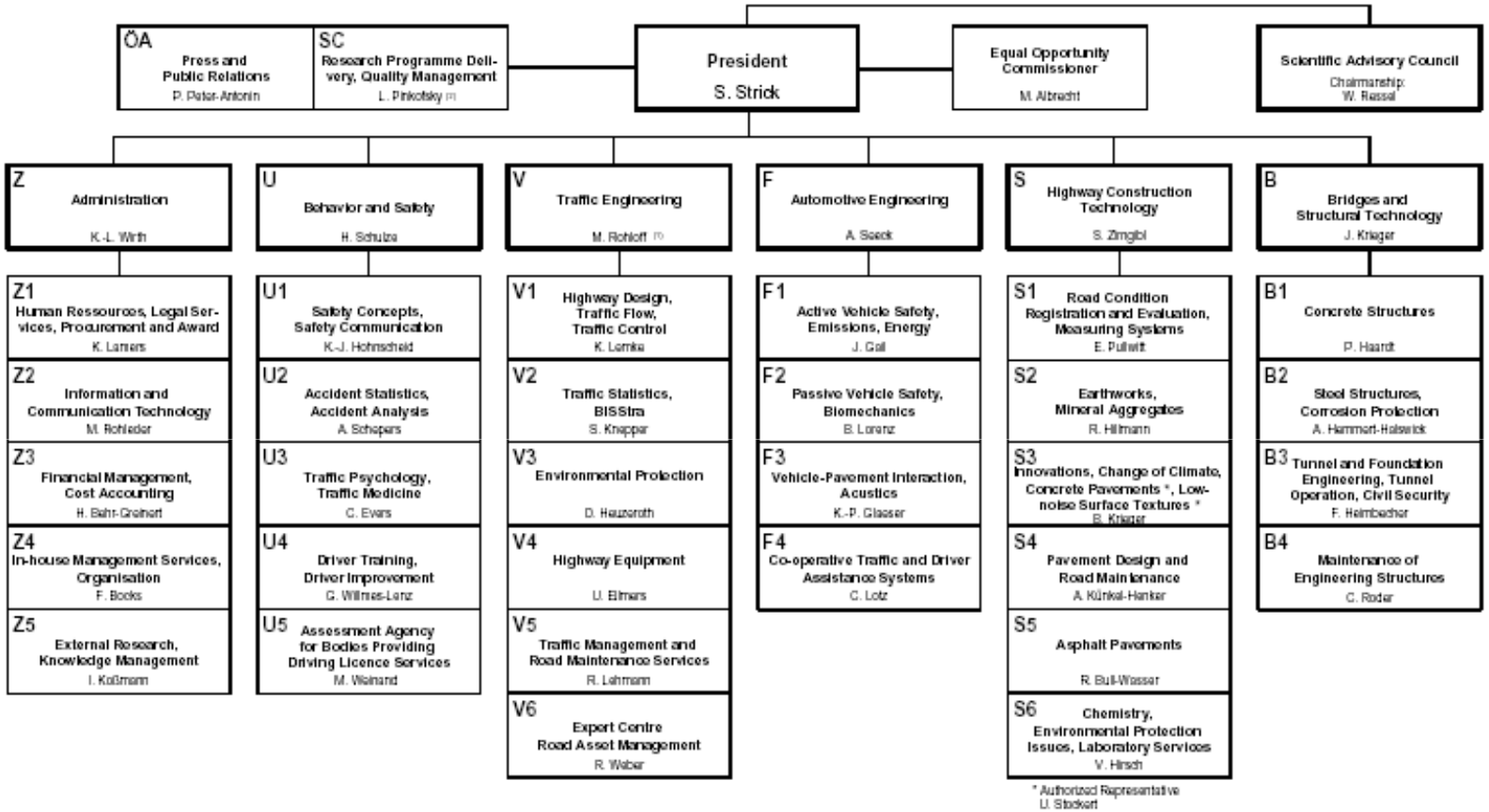
Federal Highway Research Institute (BASt)

- Technical and Scientific Research Institute
- Founded in 1951
- Located since 1983 in Bergisch Gladbach-Bensberg near Cologne
- Responsible to the Federal Ministry of Transport, Building and Urban Affairs (BMVBS)
- Approximately 400 Employees
- Place of Training and Education

Responsibilities

- Scientifically Sound Decision Support on Technical Issues and Questions of Traffic Policy for the Ministry
- Drawing up of Regulations and Standards at National and European Level

Federal Highway Research Institute (BASt) Organisation Chart



(1) Deputy to the President
(2) also Research Commissioner

Date: November 2011

Bundesanstalt fuer Straßenwesen (BASt)
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Terms of Reference – Section F2

- Passive safety of vehicles and vehicle components, protection criteria, compatibility
- Biomechanics, dummy development
- Tests at the crash test facility
- Contribute to the international activities, in particular EEVC, ESV, EU- and ECE-committees
- Euro NCAP - Passive safety

Head of Section: Dipl.-Ing. Bernd Lorenz

- **Section F2 is active in all international groups working in the field of passive safety regulations**
  - European Enhanced Vehicle-safety Committee (EEVC)
  - Expert Group of the United Nations on Passive Vehicle Safety (UN/ECE/GRSP)
  - International Harmonised Research Activities (IHRA)

- **For the research activities BASt is equipped with modern testing facilities**
  - Crash test facility
  - Vehicle component test facilities (i.e. pedestrian safety, interior head form testing)
  - Component test stands
  - Dummy and sensor calibration equipment

- **A substantial proportion of the research activities are financed by European projects and industry contracts**

Test Facilities

Crash Test Facility:

- all legally required tests
- all accident reconstructions
- all tests on road equipment
- max. test velocity 120 km/h
- max. vehicle mass 3,5t

Test Facilities

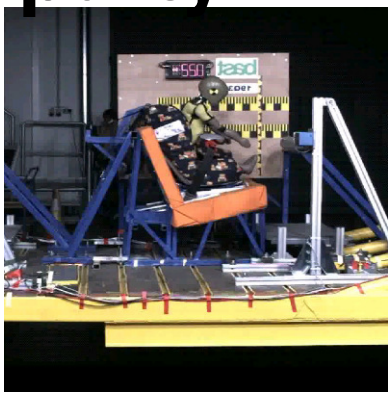
Hydrobrake:

- sledtests
- payload up to 2 t
- max. decelaration 60g
- max. testspeed 64km/h

Projekts: own, for EU, for third party

Euro NCAP

Compatibility in car to car impact



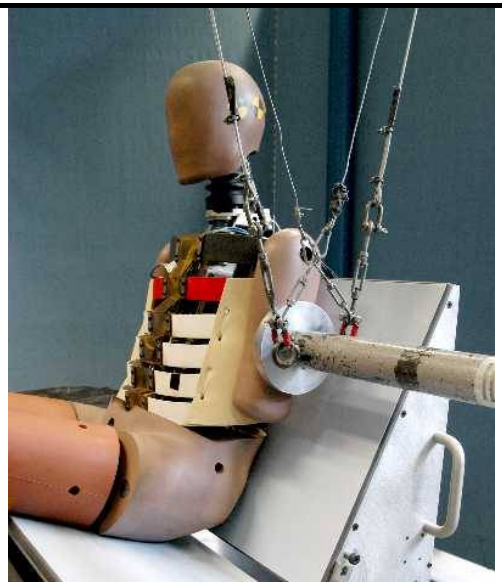
child seats

Calibration of dummies, sensors

Tests pedestrian protection

Approval of road equipment

BGS Böhme & Gehring GmbH



- Cooperation partner of the Federal Highway Research Institute (BASt) for
  - Dummy and Sensor Certifications
  - Pedestrian Protection Testing
- Founded in 1986
- 15 full-time employees, ca. 6 part-time students
- Located in Bergisch Gladbach, Germany
- Operator of BASt‘s Dummy Certification Laboratory
  - Crashdummy Certification, Inspection, Maintenance, Instrumentation work, Test preparation, etc.
  - All Dummy Types incl. BioRid, WorldSid, Q-Series
  - Transducer Calibrations

- Operator of BASt's Vehicle Component Testing Facility
  - Pedestrian Protection
  - Interior Headform Testing (FMH)
  - Other impact and drop tests

- Working on Pedestrian Protection topics for BASt since 1992:
  - Research activities
  - Development of test procedures (EEVC WG 10 and WG 17, Euro NCAP, …)
  - Participation in working groups (e.g. Euro NCAP Pedestrian Protection group)
  - Homologation and NCAP Testing
  - Testing for third parties

BGS Böhme & Gehring GmbH

- Development and Distribution
  - Test Equipment
  - Special Tools
- Seminars / Workshops
  - Dummy Basics, Handling, Certification, Usage
  - Pedestrian Protection Testing Procedures
- Annual PraxisConference Pedestrian Protection

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  - **Overview**
  - **Test Setups**
  - **Investigated Factors**

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- Conclusions

Motivation

Federal Ministry
of Transport, Building
and Urban Development

- The Federal Highway Research Institute was tasked by the Federal Ministry of Transport, Building and Urban Development (BMVBS) to perform tests in order to answer the following questions:

- Does the use of plastic windscreens in vehicles lead to a higher injury risk for vulnerable road users, especially for pedestrians?

- Can the current test procedure (Phantom head drop test) on the approval of glazing according to UN regulation Nr. 43 be used for plastic glazing? Which modifications or extensions might be necessary?

Test Programme - Overview

Executed Tests:

- 18 Drop Tests with Adult Headform
- 12 Drop Tests with Phantom Headform
- 15 Vehicle Impact Tests with Laminated Safety Glass Panes (VSG)
- 22 Vehicle Impact Tests with Polycarbonate Panes (PC)
- 12 Vehicle Impact Tests with Laminated Poly-carbonate Panes (L-PC)

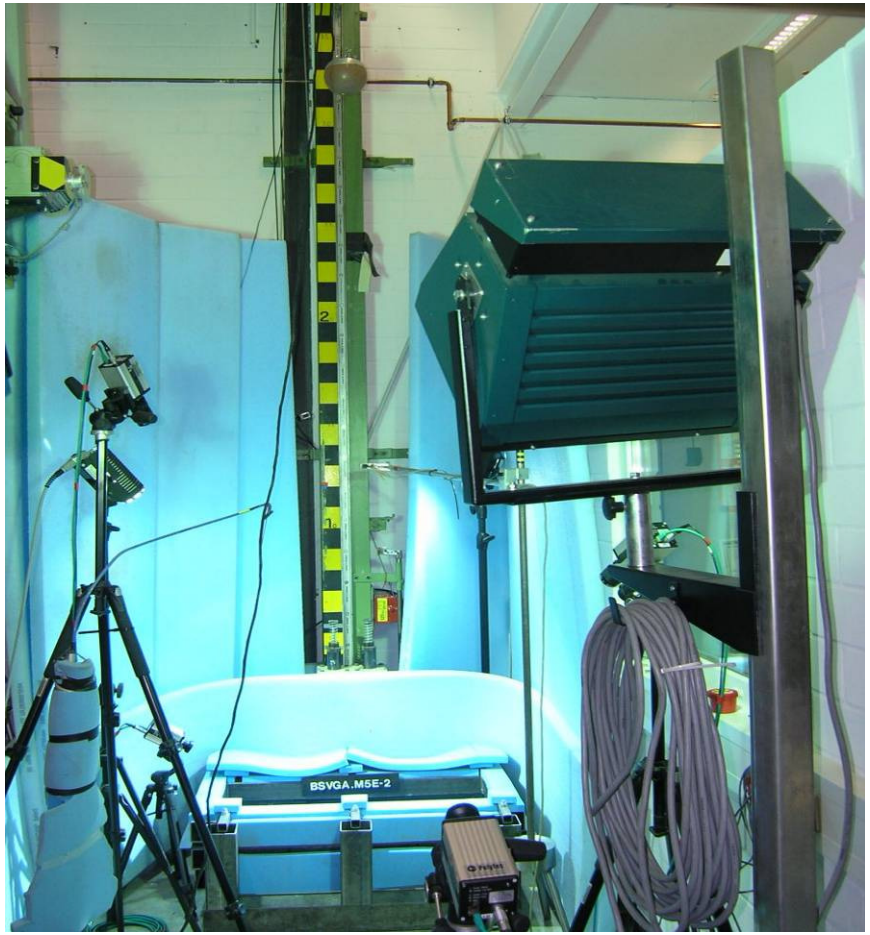
Total:

- 30 Drop Tests
- 49 Vehicle Impact Tests

Test Programme

18 Drop Tests with Adult Headform

- Mass: 4,5 kg, Drop Height: 3 m
- Investigated Factors:
  - Material (VSG vs. PC)
  - Fixation (adhesive vs. clamping)
  - PC-pane thickness (5 mm vs. 8 mm)
  - Frame dimension (500 x 1000 mm vs. 570 x 1170 mm)



Test Programme

12 Drop Tests with Phantom Headform

- Mass: 10 kg, Drop Height: 3 m
- 8 mm PC panes
- Frame according to UN R43
- Investigated Factors:
  - High Temperature (110°)
  - Low Temperature (-18°)

  - [Material (VSG vs. PC)]

Test Programme

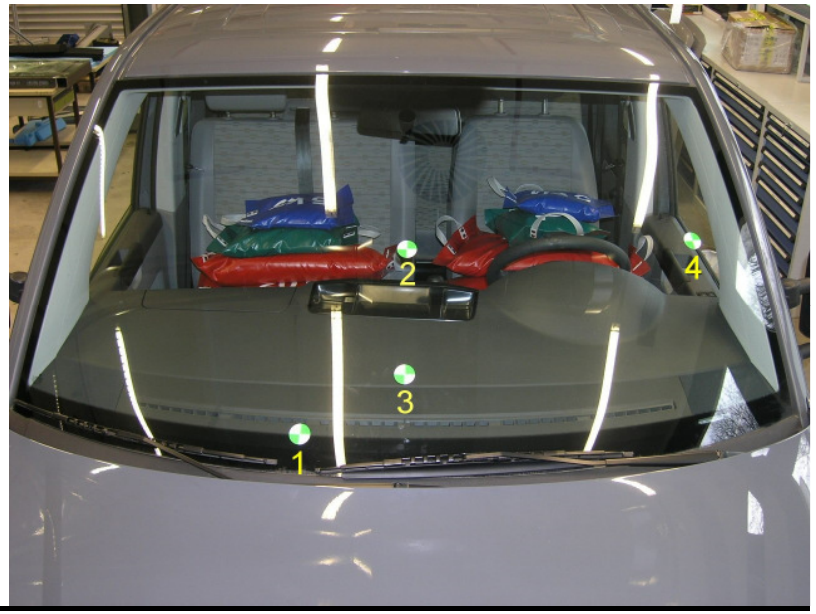
49 Vehicle Impact Tests

- 15 Vehicle Impact Tests with Laminated Glazing Panes (VSG)
- 22 Vehicle Impact Tests with Polycarbonate Panes (PC)
- 12 Vehicle Impact Tests with Laminated Polycarbonate Panes (L-PC)

Test Programme

49 Vehicle Impact Tests

- Investigated Factors:
  - Material (VSG vs. PC)
  - PC pane thickness (5 mm / 6 mm / 8 mm)
  - PC pane construction (monolithic vs. laminated)
    - (L-PC: 3 mm PC/1,2 mm foil/3 mm PC)
  - Test point position
    - 1 = Windscreen base
    - 2 = Glazing without structure within range
    - 3 = Glazing with underlying structure
    - 4 = Next to A-pillar (100 mm distance)
  - Impact Angle (35° vs. 28°)



Vehicle Impact Tests

Impact Angle: 35° vs. 28° to the horizontal

- 35°: Impact angle acc. to R(EC)78/2009; industry raised concerns about VW T5 windscreen angle being representative.
- 28°: The difference of 7° was determined as an average difference between the windscreen angle of the T5 and current sedan vehicles.

Test Programme - General

- Impactor certification before test series according to Regulation (EC) 631/2009 (Adult Headform) and DIN 52310 Part 2 (Phantom Headform), respectively
- Use of damped accelerometers for adult headform
- Photographic documentation
  - Pre test
  - Post test
- High speed video documentation
  - At least two views per test
- Tests with adhesive: Drying time at least 24 hours between application and test
- Calculation of resultant accelerations and HIC values according to Regulation (EC) 631/2009

$$HIC = \left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)dt\right]^{2,5}(t_2 - t_1)$$

- Three tests with each test setup (unless otherwise stated in this presentation)

Test Programme – Flat Panes

- Mass Comparison

Pane Type	Dimension [mm]	Mass [kg]
VSG 4,5 mm (2,1 outer pane, 1,6 inner pane)	1100 x 500 (1170 x 570)	5.5 (6.7)
PC 5 mm	1170 x 570	4.1
PC 6 mm	1170 x 570	4.8
PC 8 mm	1170 x 570	6.3

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Results - Overview

- Drop Tests

Cons. No.	Test No.	Repetition	Impactor	Support Structure	Impact Position	Material	Thickness	Fixation	Temperature	Imp. Angle	HIC	Mean	CV
1	BSVGA-V5A-1	1	Adult Head 4,5 kg	Base Frame	center	VSG	5 mm	Adhesive	RT	90°	473,7	339,6	47,8
2	BSVGA-V5A-2	2	Adult Head 4,5 kg	Base Frame	center	VSG	5 mm	Adhesive	RT	90°	158,9		
3	BSVGA-V5A-3	3	Adult Head 4,5 kg	Base Frame	center	VSG	5 mm	Adhesive	RT	90°	386,2		
4	BSVGA-M5A-1	1	Adult Head 4,5 kg	Base Frame	center	PC	5 mm	Adhesive	RT	90°	672,8	666,5	1,9
5	BSVGA-M5A-2	2	Adult Head 4,5 kg	Base Frame	center	PC	5 mm	Adhesive	RT	90°	651,6		
6	BSVGA-M5A-3	3	Adult Head 4,5 kg	Base Frame	center	PC	5 mm	Adhesive	RT	90°	675,2		
7	BSVGA-M5E-1	1	Adult Head 4,5 kg	Base Frame	center	PC	5 mm	Clamping	RT	90°	851,6	863,7	1,3
8	BSVGA-M5E-2	2	Adult Head 4,5 kg	Base Frame	center	PC	5 mm	Clamping	RT	90°	867,0		
9	BSVGA-M5E-3	3	Adult Head 4,5 kg	Base Frame	center	PC	5 mm	Clamping	RT	90°	872,6		
10	BSVGA-M8A-1	1	Adult Head 4,5 kg	Base Frame	center	PC	8 mm	Adhesive	RT	90°	1081,2	1104,6	2,6
11	BSVGA-M8A-2	2	Adult Head 4,5 kg	Base Frame	center	PC	8 mm	Adhesive	RT	90°	1095,6		
12	BSVGA-M8A-3	3	Adult Head 4,5 kg	Base Frame	center	PC	8 mm	Adhesive	RT	90°	1137,0		
13	BSVEA-M8E-1	1	Adult Head 4,5 kg	ECE Frame	center	PC	8 mm	Clamping	RT	90°	897,8	907,2	2,3
14	BSVEA-M8E-2	2	Adult Head 4,5 kg	ECE Frame	center	PC	8 mm	Clamping	RT	90°	930,8		
15	BSVEA-M8E-3	3	Adult Head 4,5 kg	ECE Frame	center	PC	8 mm	Clamping	RT	90°	892,9		
16	BSVEA-M8A-1	1	Adult Head 4,5 kg	ECE Frame	center	PC	8 mm	Adhesive	RT	90°	776,8	806,6	3,4
17	BSVEA-M8A-2	2	Adult Head 4,5 kg	ECE Frame	center	PC	8 mm	Adhesive	RT	90°	829,8		
18	BSVEA-M8A-3	3	Adult Head 4,5 kg	ECE Frame	center	PC	8 mm	Adhesive	RT	90°	813,2		
19	BSVEPM8E-LT1	1	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	-18°	90°	851,1	883,5	10,8
20	BSVEPM8E-LT2	2	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	-18°	90°	990,8		
21	BSVEPM8E-LT3	3	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	-18°	90°	808,7		
22	BSVEPM8E-NT1	1	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	RT	90°	773,0	778,9	3,9
23	BSVEPM8E-NT2	2	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	RT	90°	751,7		
24	BSVEPM8E-NT3	3	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	RT	90°	811,9		
25	BSVEPM8E-HT1	1	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	110°	90°	919,8	857,6	7,2
26	BSVEPM8E-HT2	2	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	110°	90°	796,6		
27	BSVEPM8E-HT3	3	Phantom Head	ECE Frame	center	PC	8 mm	Clamping	110°	90°	856,4		
28	BSVEP-V5E-1	1	Phantom Head	ECE Frame	center	VSG	5 mm	Clamping	RT	90°	2624,2	1640,3	80,8
29	BSVEP-V5E-2	2	Phantom Head	ECE Frame	center	VSG	5 mm	Clamping	RT	90°	132,5		
30	BSVEP-V5E-3	3	Phantom Head	ECE Frame	center	VSG	5 mm	Clamping	RT	90°	2164,3		

Tests with phantom head to VSG glazing showed large scatter. Maybe resulting from error in data acquisition system.

Results - Overview

- Vehicle Tests (1)

Cons. No.	Test No.	Repetition	Impactor	Support Structure	Impact Position	Material	Thickness	Fixation	Temperature	Imp. Angle	HIC	Mean	CV
31	BSVFA-V1-1	1	Adult Head 4,5 kg	T5	1	VSG	5 mm	Adhesive	RT	35°	1196,9	1089,2	13,6
32	BSVFA-V1-2	2	Adult Head 4,5 kg	T5	1	VSG	5 mm	Adhesive	RT	35°	1150,1		
33	BSVFA-V1-3	3	Adult Head 4,5 kg	T5	1	VSG	5 mm	Adhesive	RT	35°	920,5		
34	BSVFA-V2-1	1	Adult Head 4,5 kg	T5	2	VSG	5 mm	Adhesive	RT	35°	600,0	550,7	21,4
35	BSVFA-V2-2	2	Adult Head 4,5 kg	T5	2	VSG	5 mm	Adhesive	RT	35°	635,7		
36	BSVFA-V2-3	3	Adult Head 4,5 kg	T5	2	VSG	5 mm	Adhesive	RT	35°	416,4		
37	BSVFA-V3-1	1	Adult Head 4,5 kg	T5	3	VSG	5 mm	Adhesive	RT	35°	642,4	611,6	7,6
38	BSVFA-V3-2	2	Adult Head 4,5 kg	T5	3	VSG	5 mm	Adhesive	RT	35°	558,0		
39	BSVFA-V3-3	3	Adult Head 4,5 kg	T5	3	VSG	5 mm	Adhesive	RT	35°	634,5		
40	BSVFA-V4-1	1	Adult Head 4,5 kg	T5	4	VSG	5 mm	Adhesive	RT	35°	407,6	398,9	34,0
41	BSVFA-V4-2	2	Adult Head 4,5 kg	T5	4	VSG	5 mm	Adhesive	RT	35°	259,0		
42	BSVFA-V4-3	3	Adult Head 4,5 kg	T5	4	VSG	5 mm	Adhesive	RT	35°	530,1		
43	BSVFA-V4-28-1	1	Adult Head 4,5 kg	T5	4	VSG	5 mm	Adhesive	RT	28°	187,0	195,8	4,0
44	BSVFA-V4-28-2	2	Adult Head 4,5 kg	T5	4	VSG	5 mm	Adhesive	RT	28°	202,3		
45	BSVFA-V4-28-3	3	Adult Head 4,5 kg	T5	4	VSG	5 mm	Adhesive	RT	28°	198,1		
46	BSVFA-M1-1	1	Adult Head 4,5 kg	T5	1	PC	5 mm	Adhesive	RT	35°	1667,1	1545,2	7,7
47	BSVFA-M1-2	2	Adult Head 4,5 kg	T5	1	PC	5 mm	Adhesive	RT	35°	1537,8		
48	BSVFA-M1-3	3	Adult Head 4,5 kg	T5	1	PC	5 mm	Adhesive	RT	35°	1430,6		
49	BSVFA-M2-1	1	Adult Head 4,5 kg	T5	2	PC	5 mm	Adhesive	RT	35°	196,9	196,9	
50		[1])	Adult Head 4,5 kg	T5	2	PC	5 mm	Adhesive	RT	35°			
51			Adult Head 4,5 kg	T5	2	PC	5 mm	Adhesive	RT	35°			
52	BSVFA-M3-1	1	Adult Head 4,5 kg	T5	3	PC	5 mm	Adhesive	RT	35°	835,1	726,2	13,4
53	BSVFA-M3-2	2	Adult Head 4,5 kg	T5	3	PC	5 mm	Adhesive	RT	35°	695,4		
54	BSVFA-M3-3	3	Adult Head 4,5 kg	T5	3	PC	5 mm	Adhesive	RT	35°	648,0		
55	BSVFA-M4-1	1	Adult Head 4,5 kg	T5	4	PC	5 mm	Adhesive	RT	35°	909,5	840,1	11,0
56	BSVFA-M4-2	2	Adult Head 4,5 kg	T5	4	PC	5 mm	Adhesive	RT	35°	735,3		
57	BSVFA-M4-3	3	Adult Head 4,5 kg	T5	4	PC	5 mm	Adhesive	RT	35°	875,6		

[1]) Tests not performed because of enormous rebound of the impactor.
No further test with PC glazing on impact pos. 2 was performed

Results - Overview

- Vehicle Tests (2)

Cons. No.	Test No.	Repetition	Impactor	Support Structure	Impact Position	Material	Thickness	Fixation	Temperature	Imp. Angle	HIC	Mean	CV
58	BSVFA-M1-6-1	1	Adult Head 4,5 kg	T5	1	PC	6 mm	Adhesive	RT	35°	1315,1	1315,1	
59	2)		Adult Head 4,5 kg	T5	1	PC	6 mm	Adhesive	RT	35°			
60			Adult Head 4,5 kg	T5	1	PC	6 mm	Adhesive	RT	35°			
61	BSVFA-M3-6-1	1	Adult Head 4,5 kg	T5	3	PC	6 mm	Adhesive	RT	35°	645,8	645,8	
62	2)		Adult Head 4,5 kg	T5	3	PC	6 mm	Adhesive	RT	35°			
63			Adult Head 4,5 kg	T5	3	PC	6 mm	Adhesive	RT	35°			
64	BSVFA-M4-6-1	1	Adult Head 4,5 kg	T5	4	PC	6 mm	Adhesive	RT	35°	731,4	731,4	
65	2)		Adult Head 4,5 kg	T5	4	PC	6 mm	Adhesive	RT	35°			
66			Adult Head 4,5 kg	T5	4	PC	6 mm	Adhesive	RT	35°			
67	BSVFA-M1-8-1	1	Adult Head 4,5 kg	T5	1	PC	8 mm	Adhesive	RT	35°	1289,1	1222,9	5,0
68	BSVFA-M1-8-2	2	Adult Head 4,5 kg	T5	1	PC	8 mm	Adhesive	RT	35°	1168,2		
69	BSVFA-M1-8-3	3	Adult Head 4,5 kg	T5	1	PC	8 mm	Adhesive	RT	35°	1211,5		
70	BSVFA-M3-8-1	1	Adult Head 4,5 kg	T5	3	PC	8 mm	Adhesive	RT	35°	659,9	676,2	2,2
71	BSVFA-M3-8-2	2	Adult Head 4,5 kg	T5	3	PC	8 mm	Adhesive	RT	35°	687,9		
72	BSVFA-M3-8-3	3	Adult Head 4,5 kg	T5	3	PC	8 mm	Adhesive	RT	35°	680,9		
73	BSVFA-M4-8-1	1	Adult Head 4,5 kg	T5	4	PC	8 mm	Adhesive	RT	35°	794,6	750,0	7,6
74	BSVFA-M4-8-2	2	Adult Head 4,5 kg	T5	4	PC	8 mm	Adhesive	RT	35°	685,5		
75	BSVFA-M4-8-3	3	Adult Head 4,5 kg	T5	4	PC	8 mm	Adhesive	RT	35°	770,0		
76	BSVFA-MV1-7-1	1	Adult Head 4,5 kg	T5	1	L-PC	7,2 mm	Adhesive	RT	35°	1089,5	1124,0	3,0
77	BSVFA-MV1-7-2	2	Adult Head 4,5 kg	T5	1	L-PC	7,2 mm	Adhesive	RT	35°	1156,5		
78	BSVFA-MV1-7-3	3	Adult Head 4,5 kg	T5	1	L-PC	7,2 mm	Adhesive	RT	35°	1126,1		
79	BSVFA-MV3-7-1	1	Adult Head 4,5 kg	T5	3	L-PC	7,2 mm	Adhesive	RT	35°	777,1	846,1	8,7
80	BSVFA-MV3-7-2	2	Adult Head 4,5 kg	T5	3	L-PC	7,2 mm	Adhesive	RT	35°	837,5		
81	BSVFA-MV3-7-3	3	Adult Head 4,5 kg	T5	3	L-PC	7,2 mm	Adhesive	RT	35°	923,7		
82	BSVFA-MV4-7-1	1	Adult Head 4,5 kg	T5	4	L-PC	7,2 mm	Adhesive	RT	35°	892,4	883,6	1,6
83	BSVFA-MV4-7-2	2	Adult Head 4,5 kg	T5	4	L-PC	7,2 mm	Adhesive	RT	35°	866,8		
84	BSVFA-MV4-7-3	3	Adult Head 4,5 kg	T5	4	L-PC	7,2 mm	Adhesive	RT	35°	891,6		
85	BSVFA-MV4-28-1	1	Adult Head 4,5 kg	T5	4	L-PC	7,2 mm	Adhesive	RT	28°	855,4	848,9	0,7
86	BSVFA-MV4-28-2	2	Adult Head 4,5 kg	T5	4	L-PC	7,2 mm	Adhesive	RT	28°	844,1		
87	BSVFA-MV4-28-3	3	Adult Head 4,5 kg	T5	4	L-PC	7,2 mm	Adhesive	RT	28°	847,2		

2) Tests not performed because the first results from tests with 6 mm PC glazing were comparable with 5 mm and/or 8 mm PC material.

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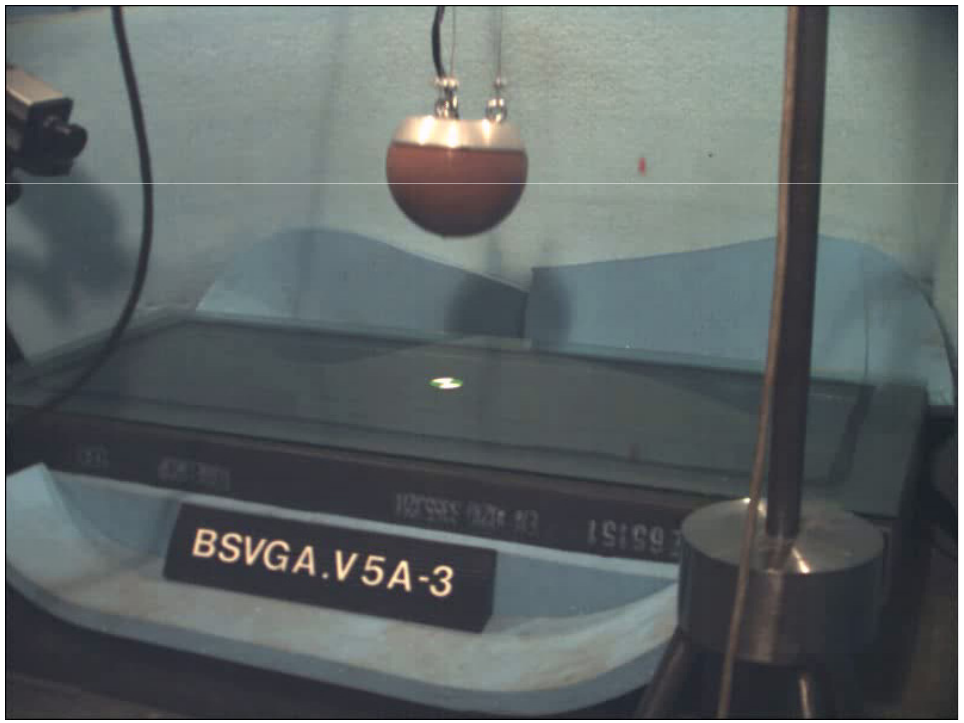
Drop Tests with Adult Headform

- Sample videos:

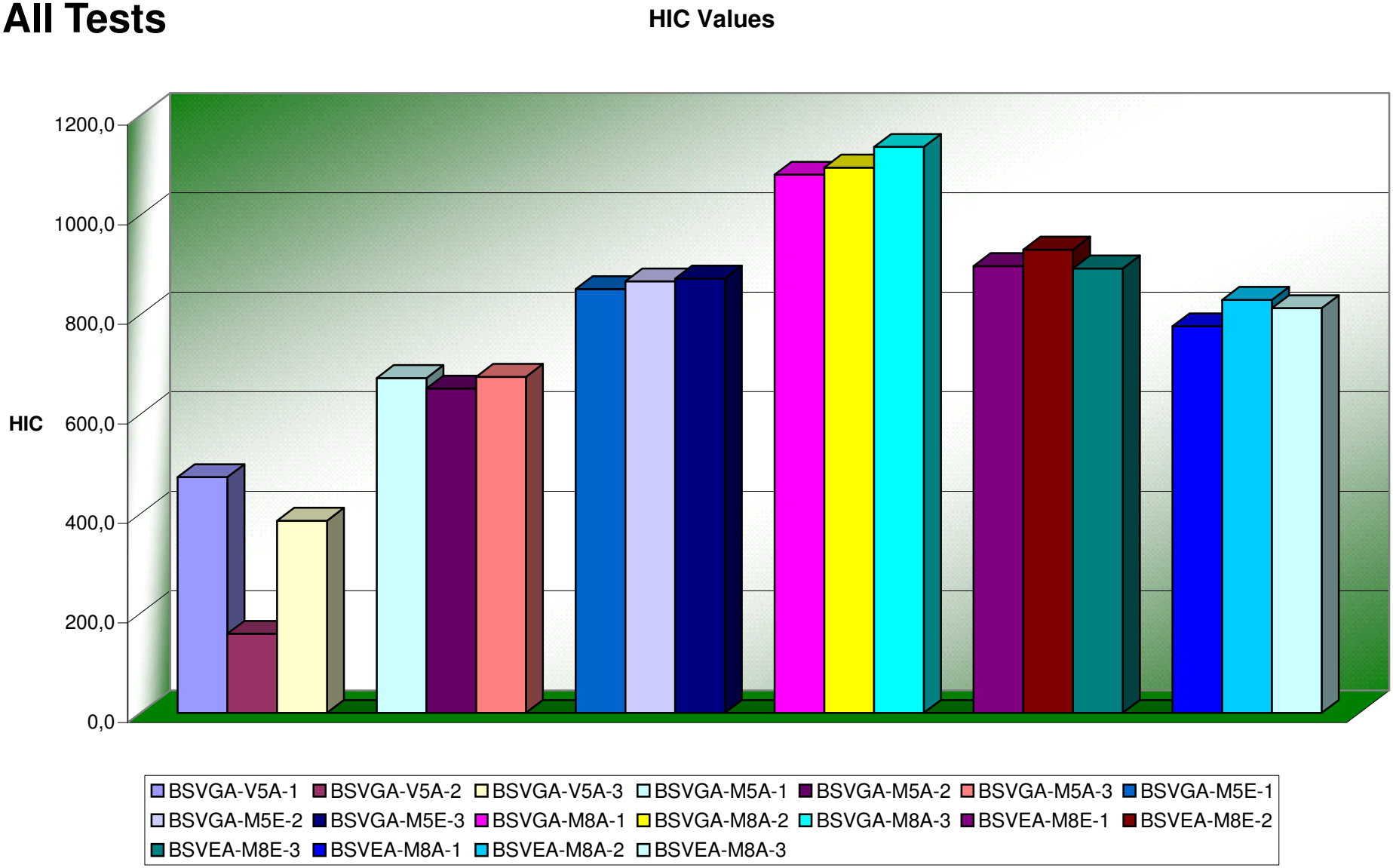
8 mm PC glazing

VSG glazing



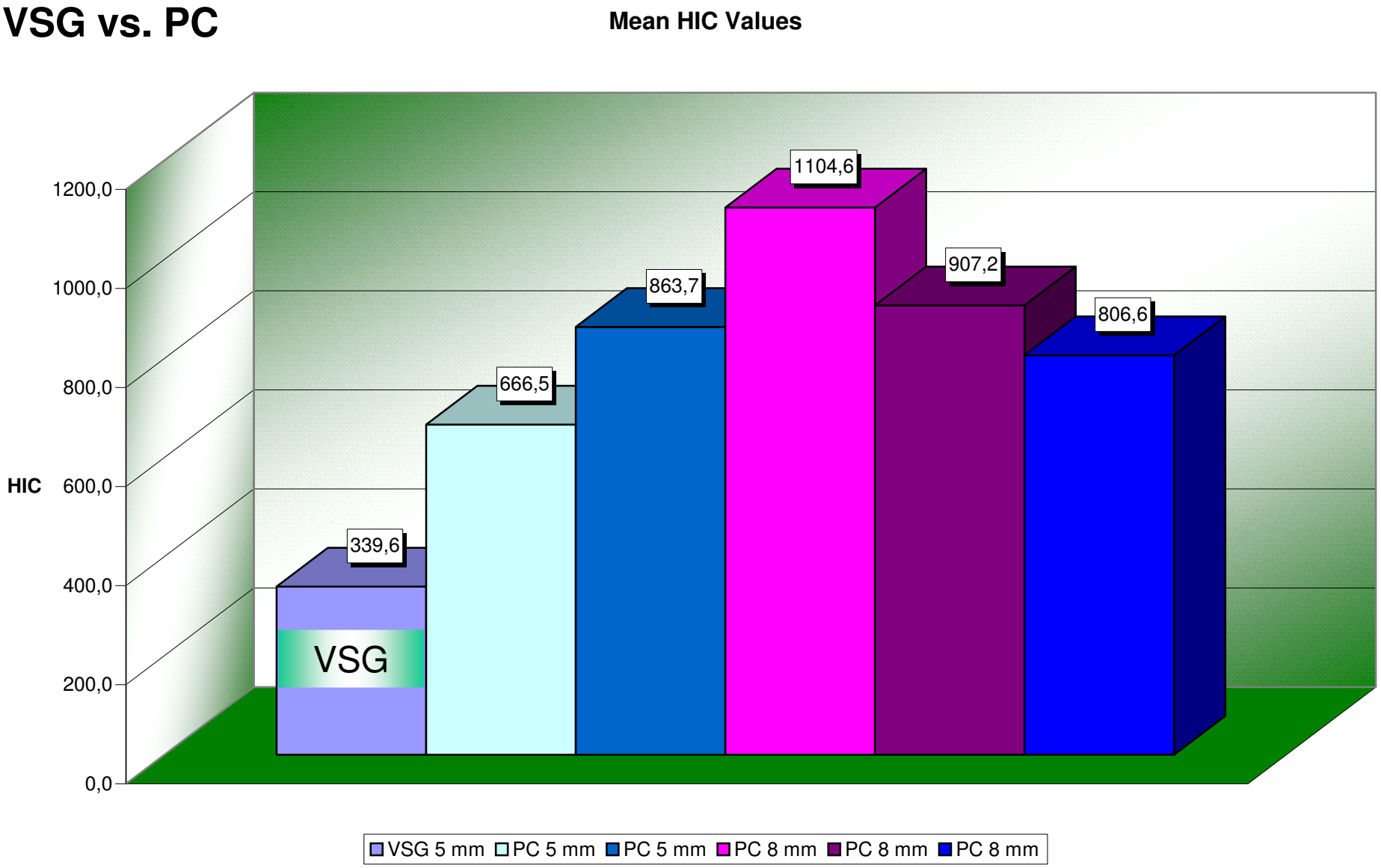
Drop Tests with Adult Headform

All Tests



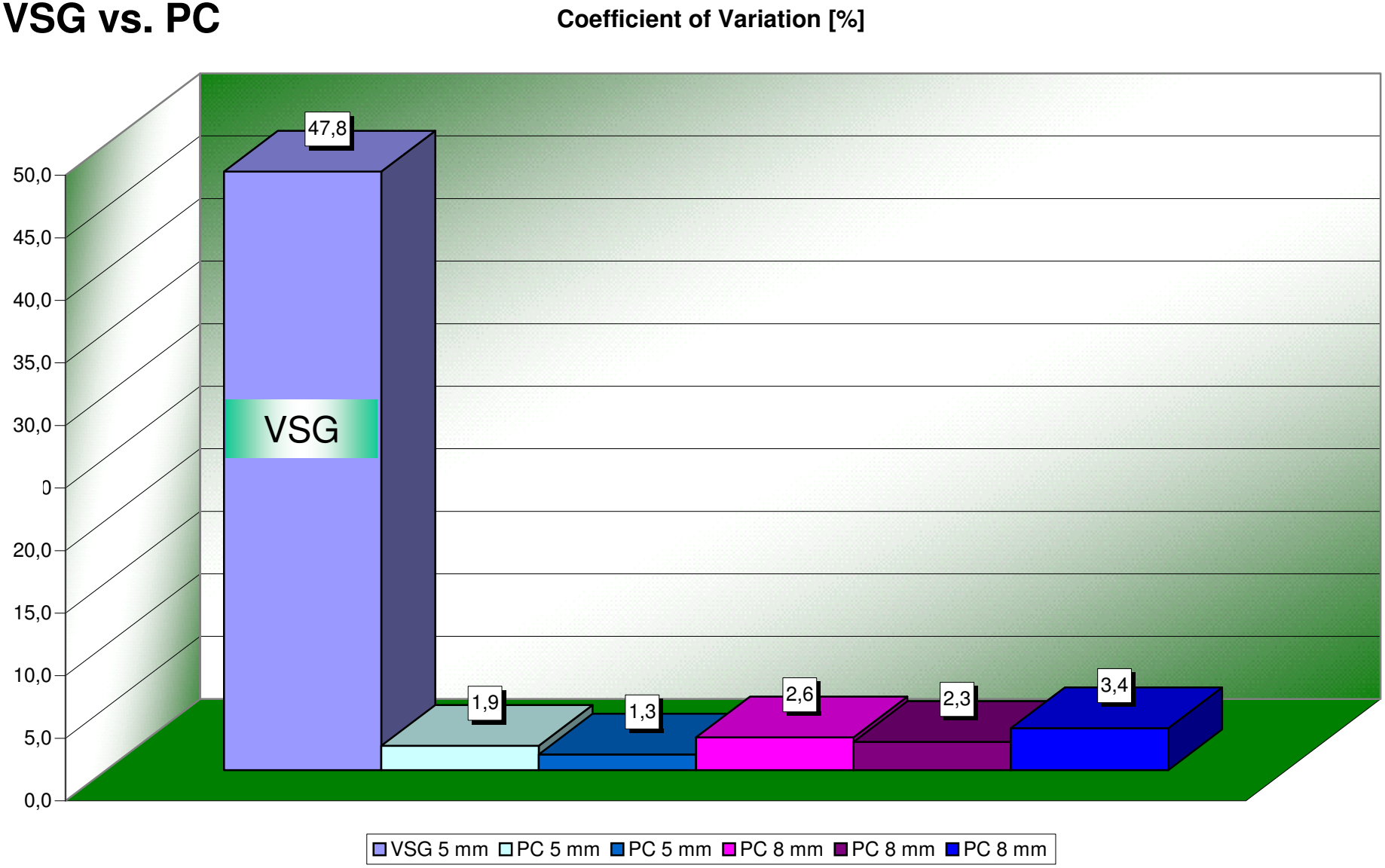
Drop Tests with Adult Headform

VSG vs. PC



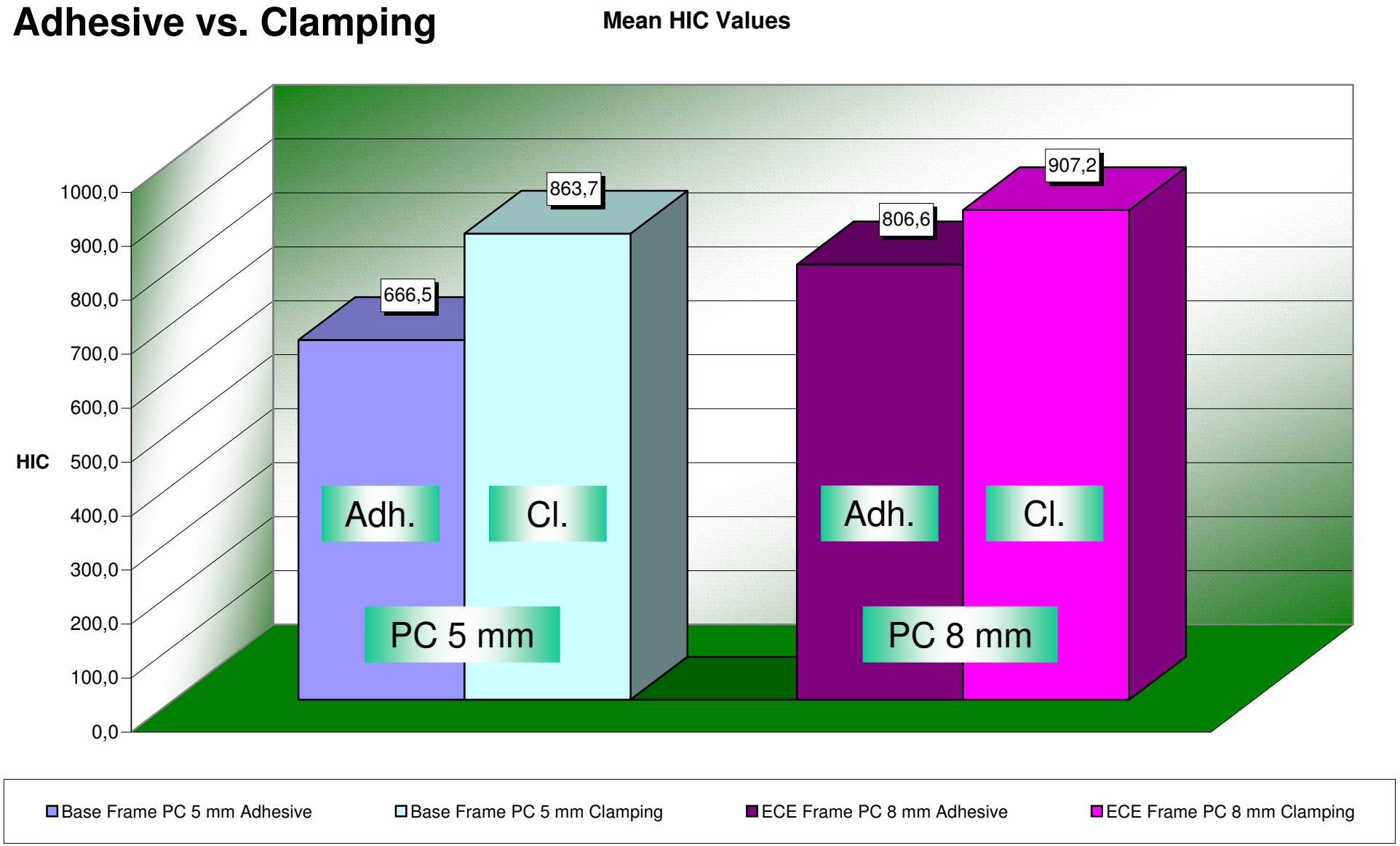
Drop Tests with Adult Headform

VSG vs. PC



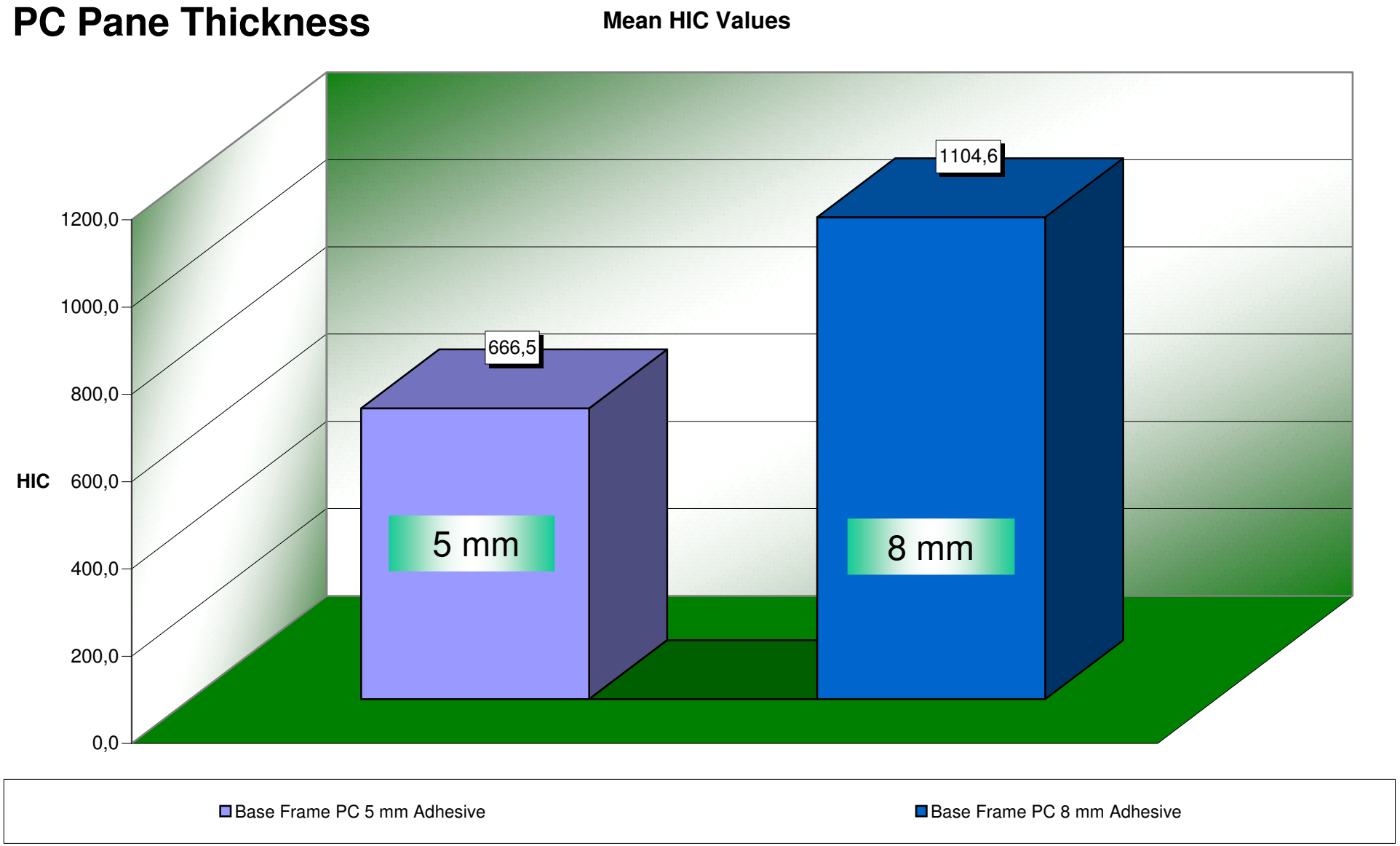
Drop Tests with Adult Headform

Adhesive vs. Clamping



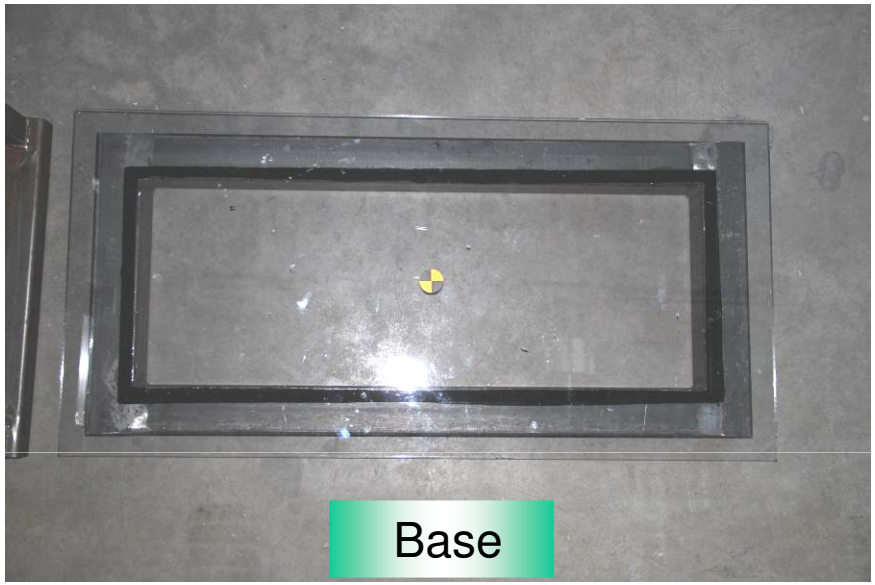
Drop Tests with Adult Headform

PC Pane Thickness

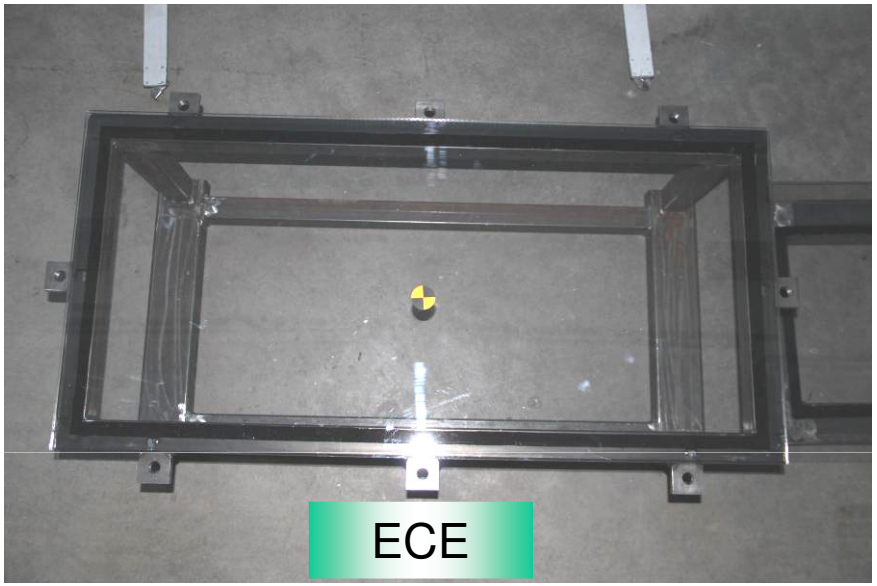


Drop Tests with Adult Headform

Frame Dimensions



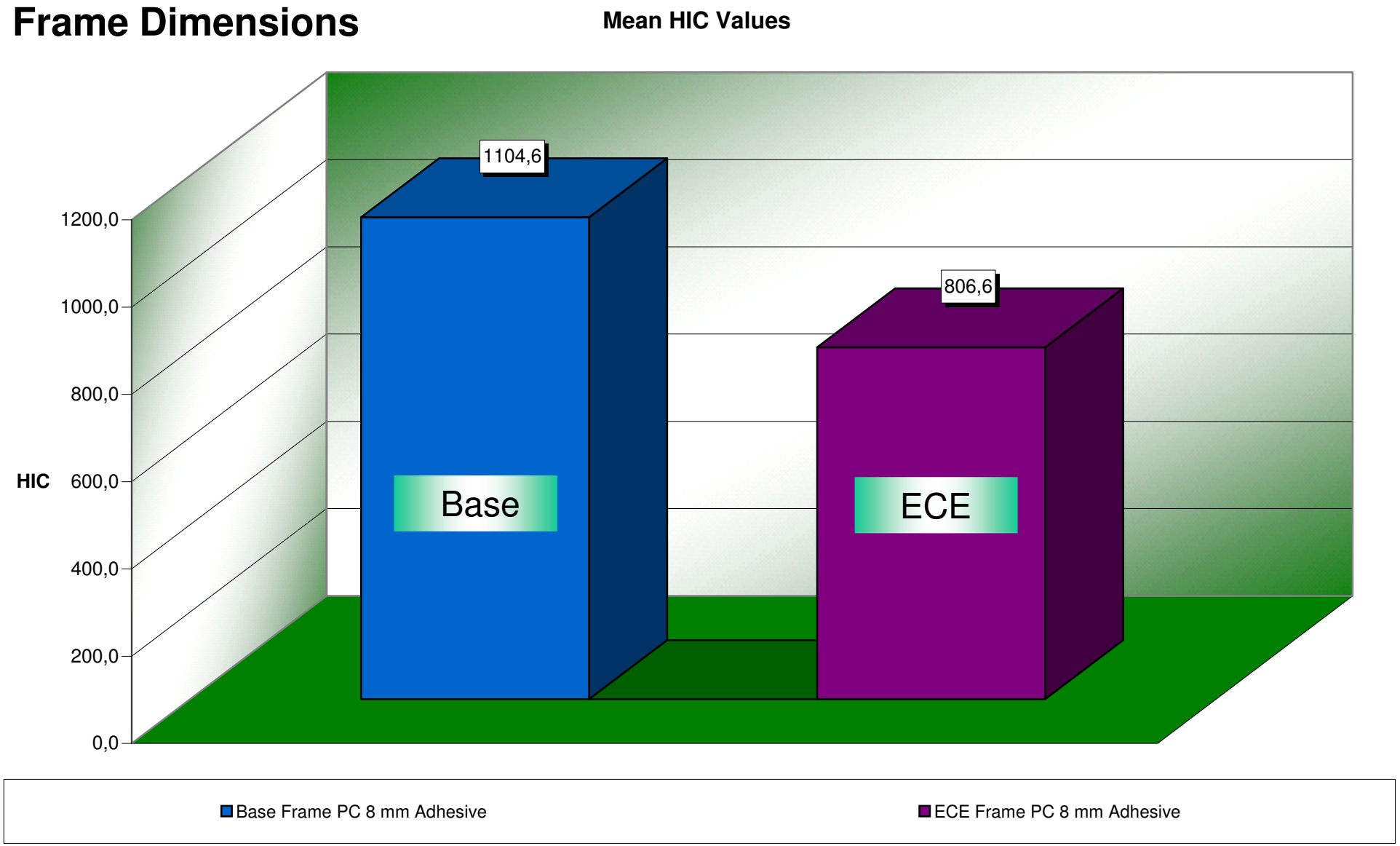
500 x 1000 mm



570 x 1170 mm

Drop Tests with Adult Headform

Frame Dimensions



Drop Tests with Adult Headform

- No visible damage of the PC panes
- HIC Values significantly higher with PC glazing
- Higher scatter with glass panes
- Clamping of PC panes lead to higher HIC results than bonding
- HIC increases with thickness of PC panes
- Frame dimensions according to UN R 43 lead to lower HIC results
- Current Requirement according to UN R 43 (HIC 1000 with Phantom head) was met in tests with ECE frame

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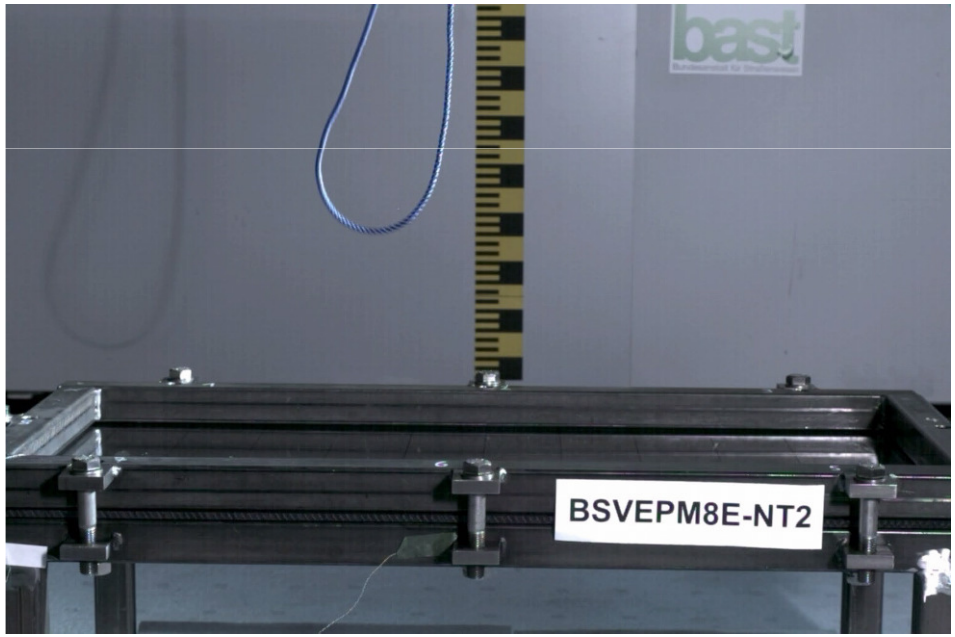
  - Vehicle Tests
- Conclusions

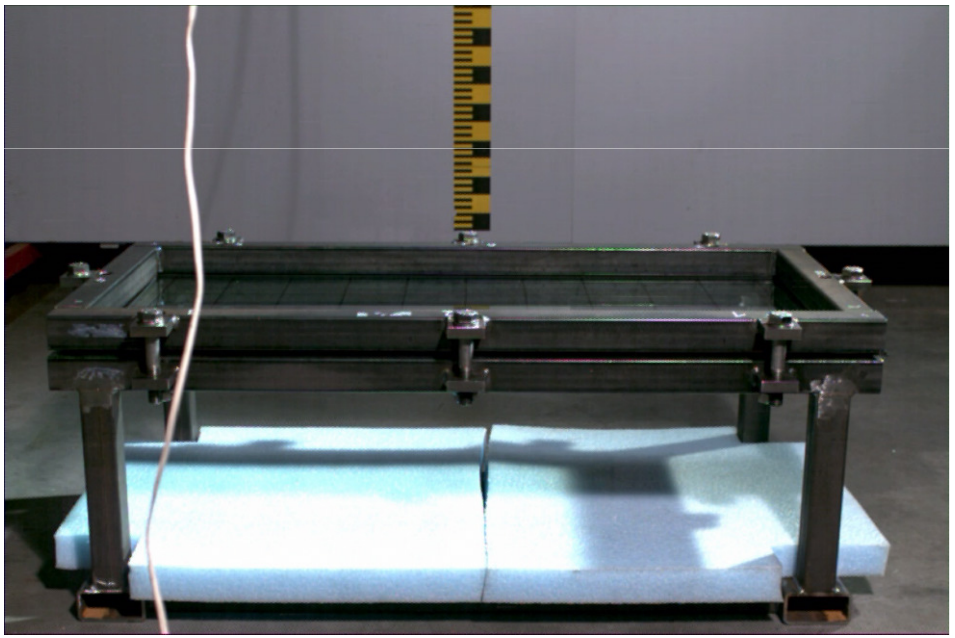
Drop Tests with Phantom Headform

- Sample videos:

8 mm PC glazing

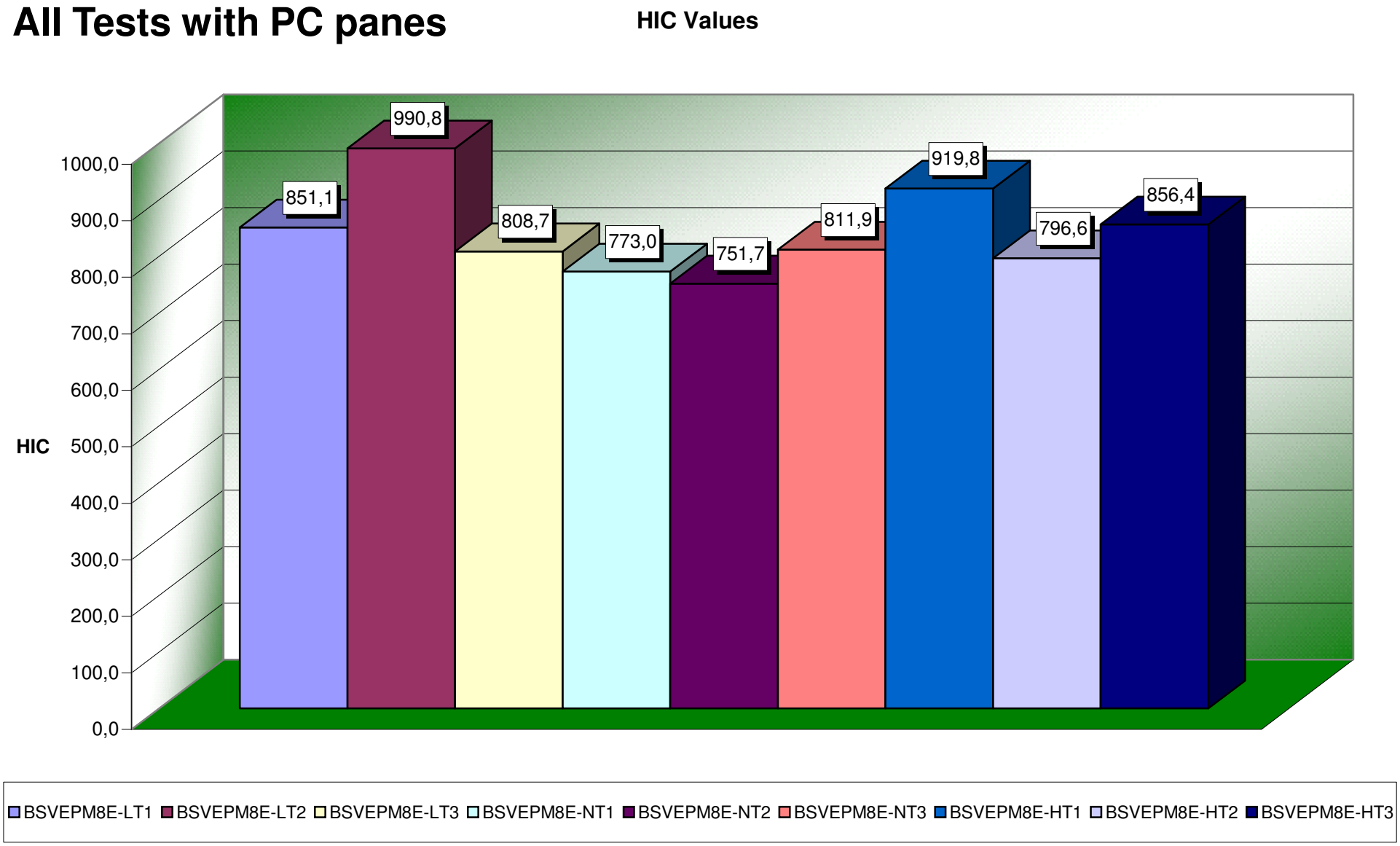


VSG glazing



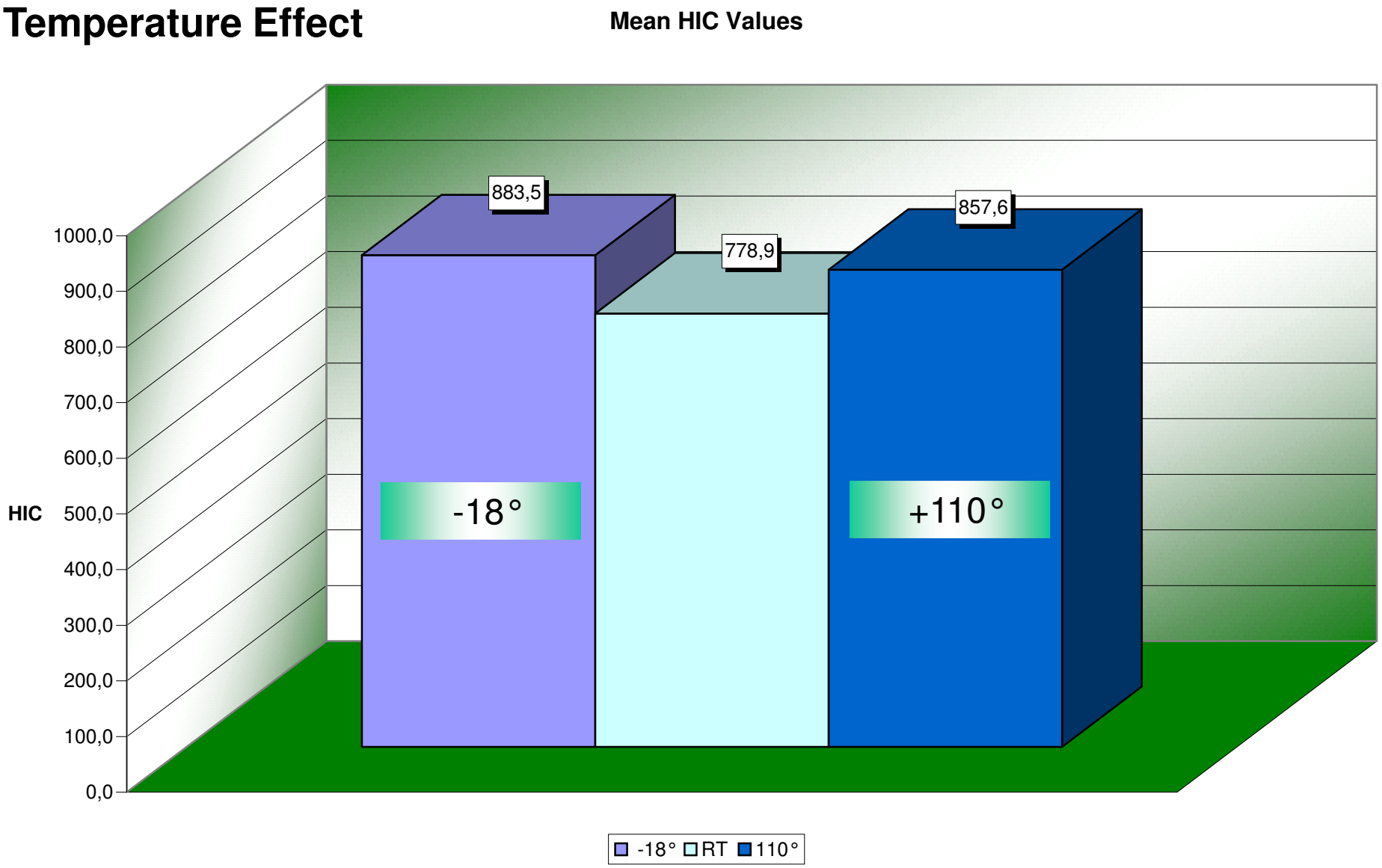
Drop Tests with Phantom Headform

All Tests with PC panes



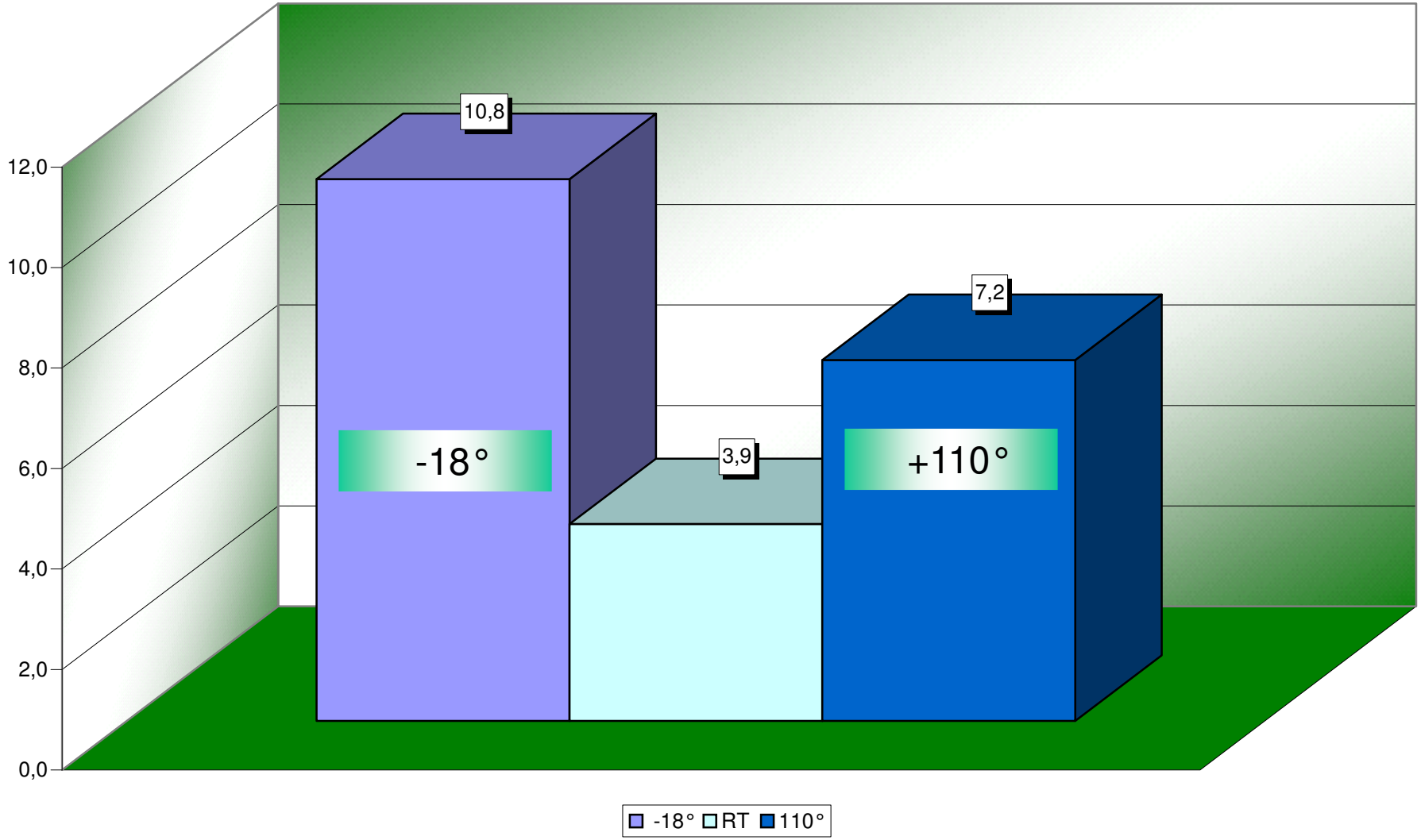
Drop Tests with Phantom Headform

Temperature Effect



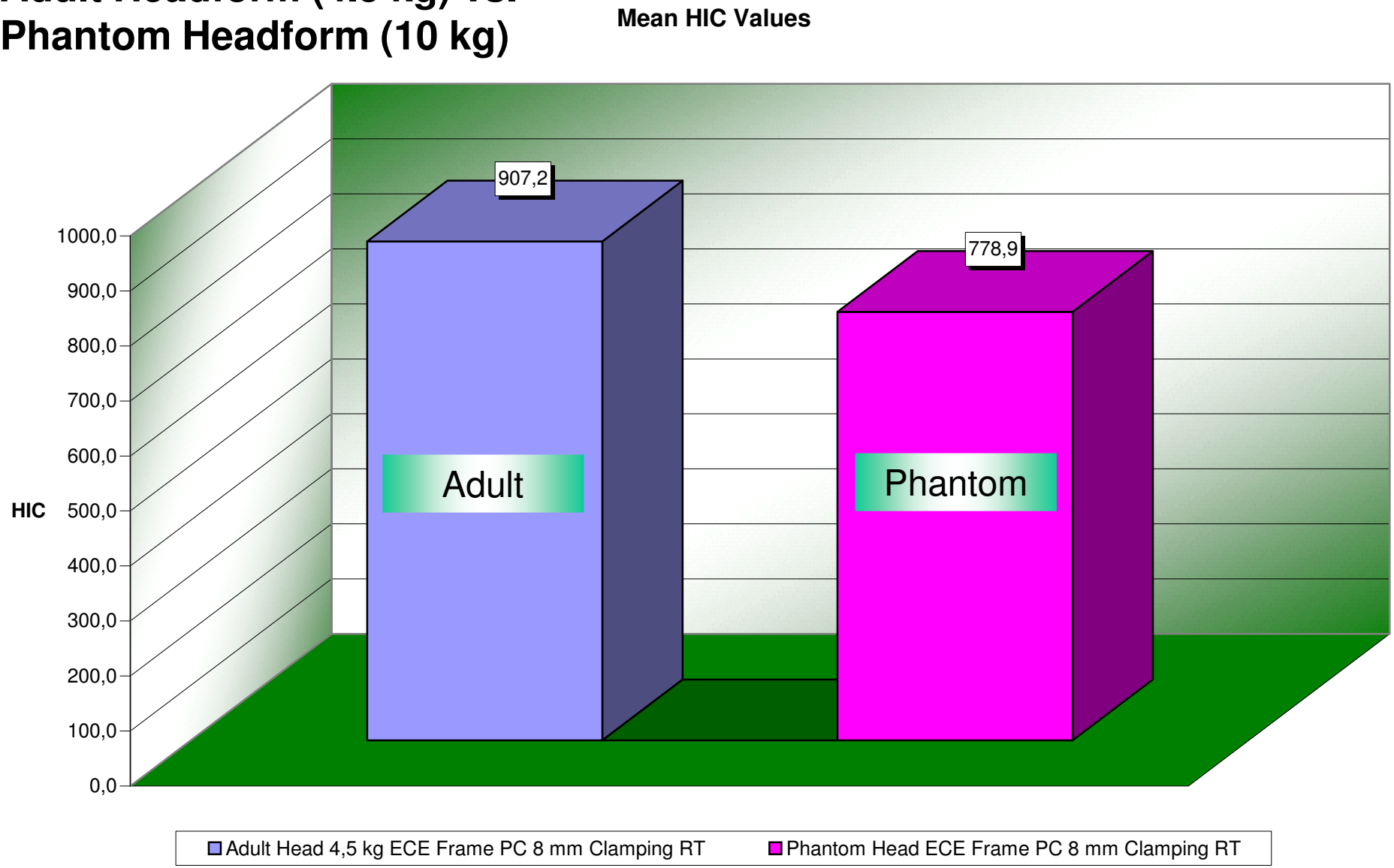
Drop Tests with Phantom Headform

Temperature Effect



Drop Tests – Comparison

Adult Headform (4.5 kg) vs. Phantom Headform (10 kg)



Summary 2:

Drop Tests with Phantom Headform

- No visible damage of the PC panes
- HIC values seem to increase with lower and higher temperature
- Scatter in high and low temperature test results too high to rely on tendency
- Scatter increases in tests with low and high temperature
- These observations may also result from the rubber properties because the whole test setup was preconditioned (except headform). This represents more realistic situations, not laboratory conditions.
- High temperature (110°) was chosen due to the laboratory capabilities. At lower temperatures (e.g. 40°C) no tests were performed because no significant influence was expected.
- Comparison between drop tests with Adult headform and Phantom headform on 8 mm PC pane show higher results in adult headform test

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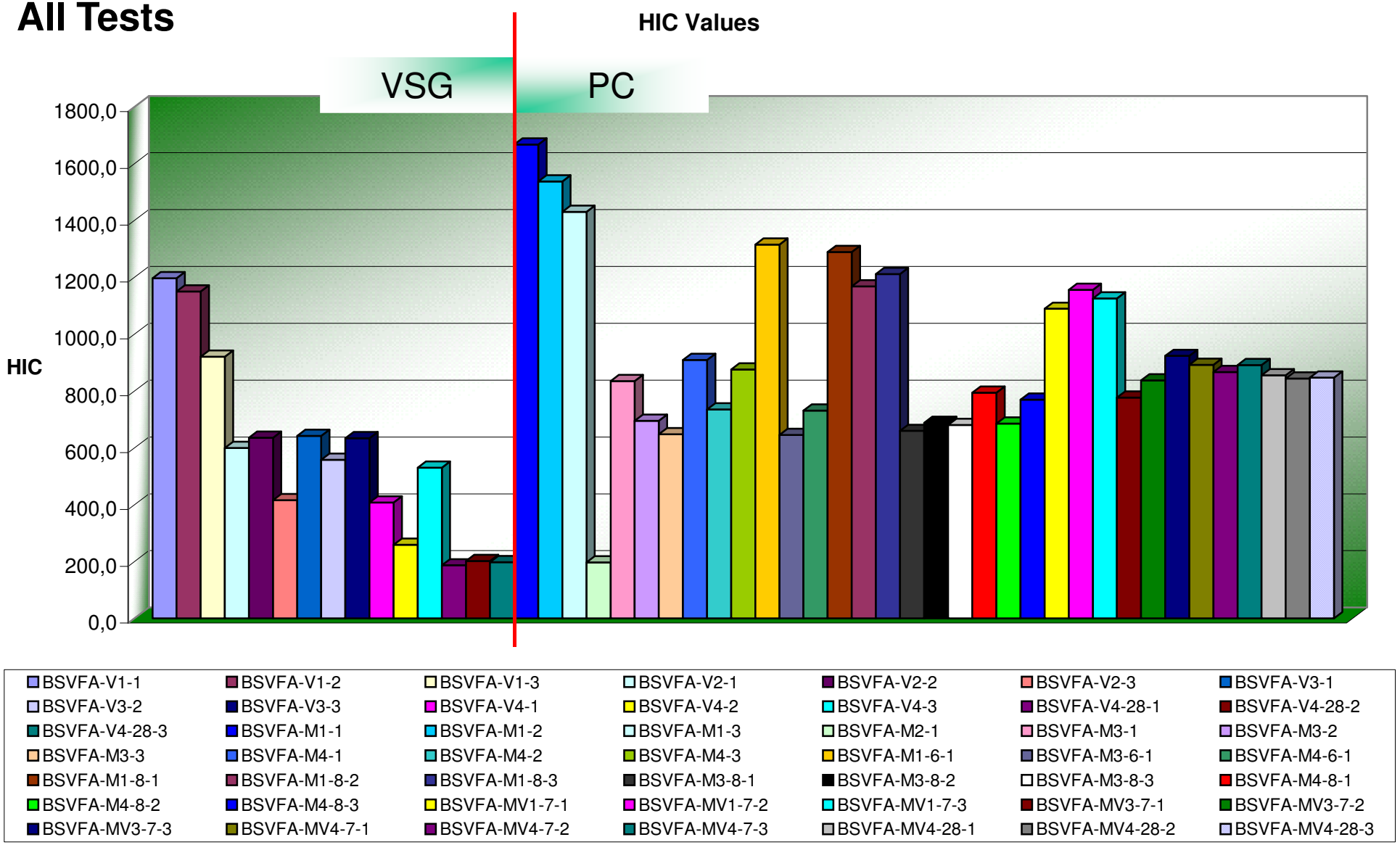
Vehicle Impact Tests

All Tests



All Tests

- Three tests were performed with each test setup, except
  - Tests with PC glazing on impact location 2, because of the extensive rebound of the headform along with a very low hic value in the first test.
  - Tests with 6 mm PC glazing, because the results were comparable with 5 mm and/or 8 mm PC material. However, the results of the single tests with the 6 mm PC panes are included in the following diagrams

- In the following comparison diagrams, the tests with 28° impact angle are excluded

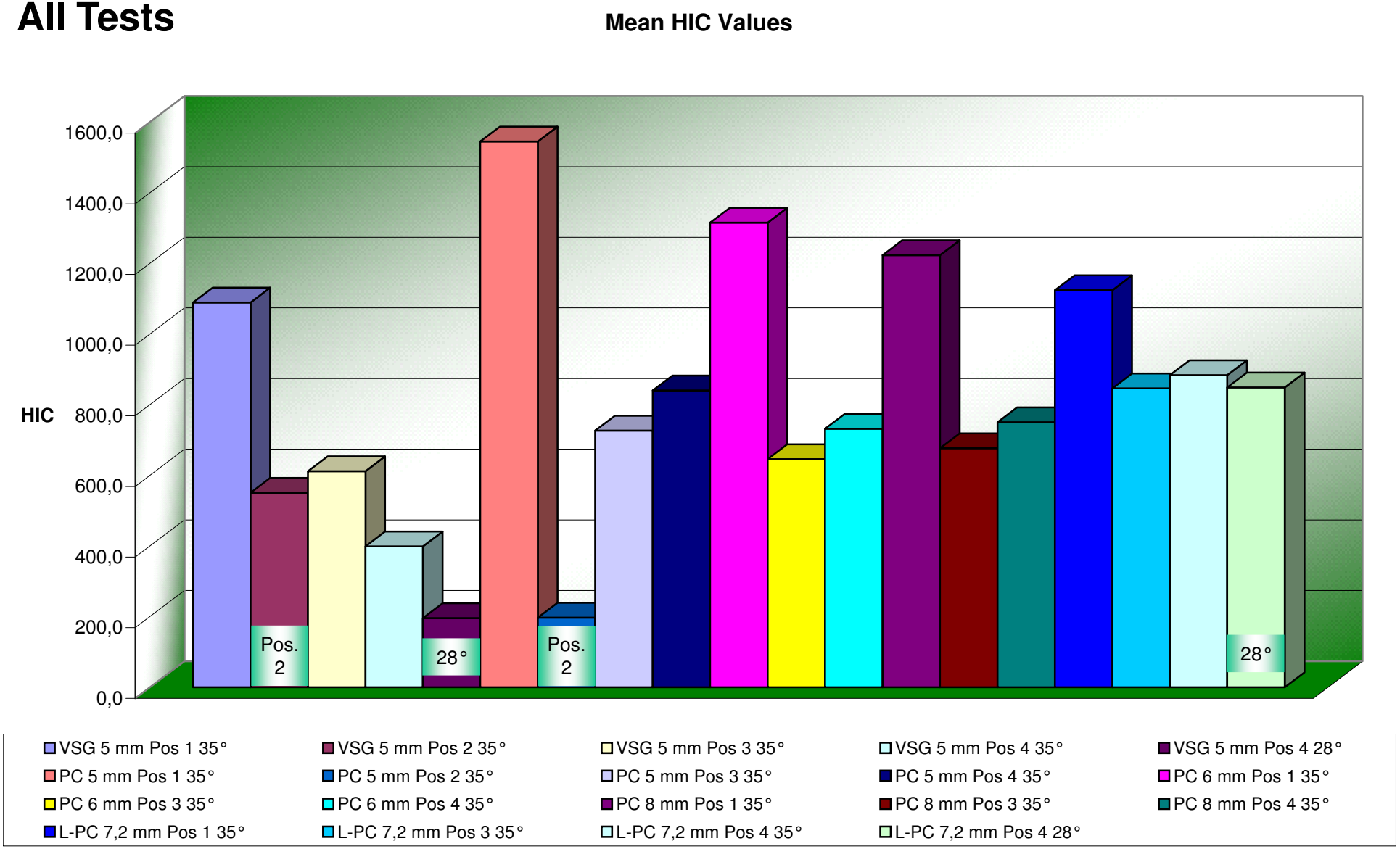
Vehicle Impact Tests

- Sample videos:

8 mm PC glazing

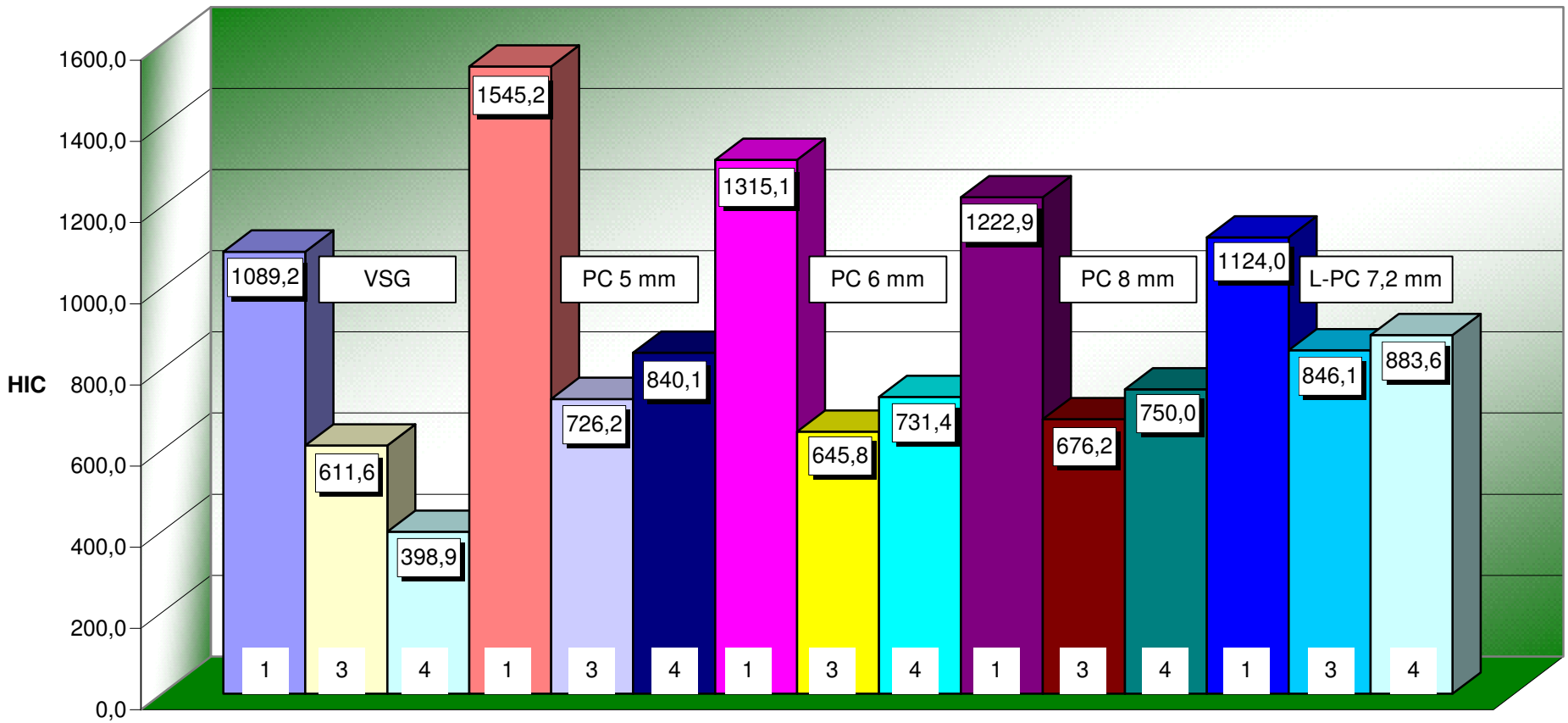
VSG glazing

All Tests


Mean HIC Values
HIC
1600,0
1400,0
1200,0
1000,0
800,0
600,0
400,0
200,0
0,0
Pos. 2
28°
Pos. 2
28°
VSG 5 mm Pos 1 35°
VSG 5 mm Pos 2 35°
VSG 5 mm Pos 3 35°
VSG 5 mm Pos 4 35°
VSG 5 mm Pos 4 28°
PC 5 mm Pos 1 35°
PC 5 mm Pos 2 35°
PC 5 mm Pos 3 35°
PC 5 mm Pos 4 35°
PC 6 mm Pos 1 35°
PC 6 mm Pos 3 35°
PC 6 mm Pos 4 35°
PC 8 mm Pos 1 35°
PC 8 mm Pos 3 35°
PC 8 mm Pos 4 35°
L-PC 7,2 mm Pos 1 35°
L-PC 7,2 mm Pos 3 35°
L-PC 7,2 mm Pos 4 35°
L-PC 7,2 mm Pos 4 28°

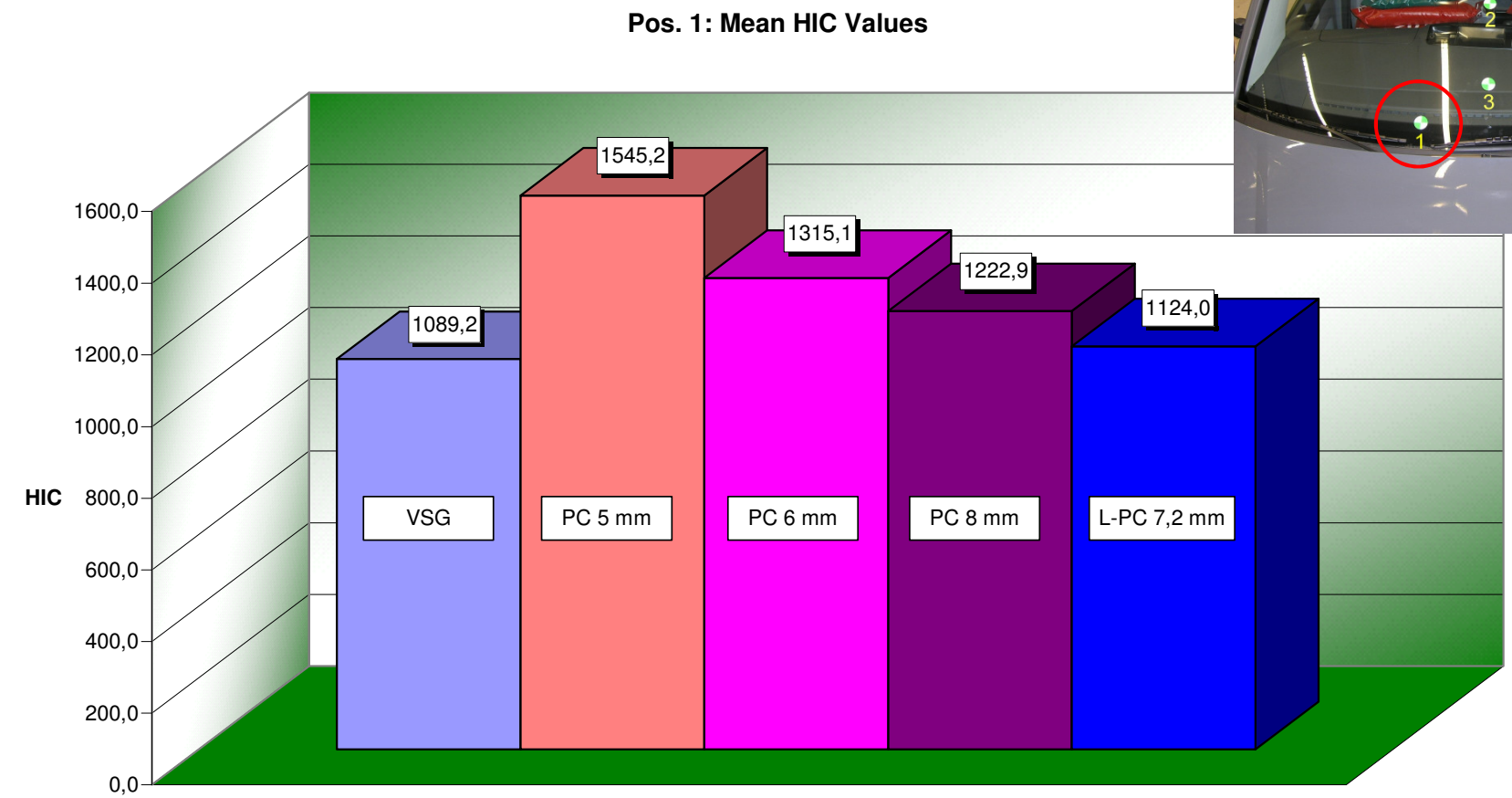
Comparable Tests

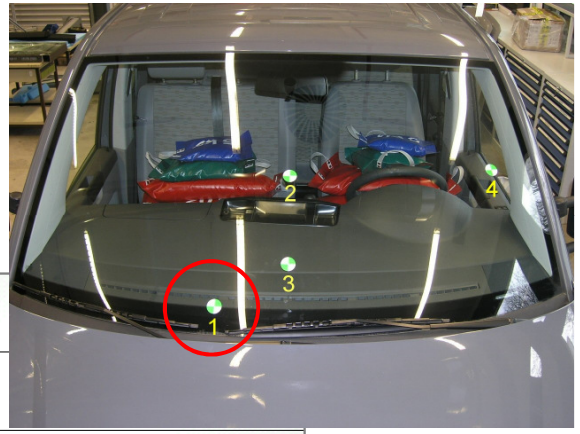
Mean HIC Values: 35°, Pos. 1, 3, 4



VSG 5 mm Pos 1 35°	VSG 5 mm Pos 3 35°	VSG 5 mm Pos 4 35°	PC 5 mm Pos 1 35°	PC 5 mm Pos 3 35°
PC 5 mm Pos 4 35°	PC 6 mm Pos 1 35°	PC 6 mm Pos 3 35°	PC 6 mm Pos 4 35°	PC 8 mm Pos 1 35°
PC 8 mm Pos 3 35°	PC 8 mm Pos 4 35°	L-PC 7,2 mm Pos 1 35°	L-PC 7,2 mm Pos 3 35°	L-PC 7,2 mm Pos 4 35°

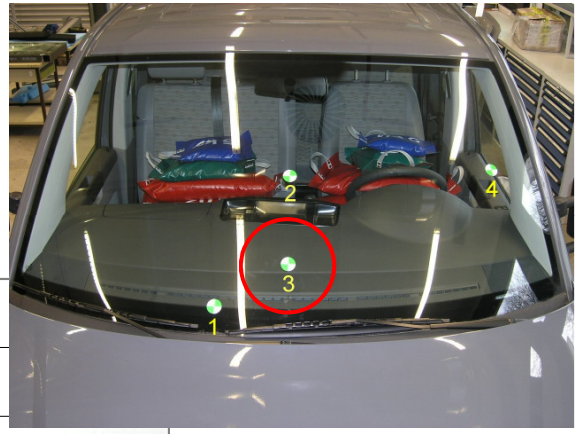
VSG vs. PC

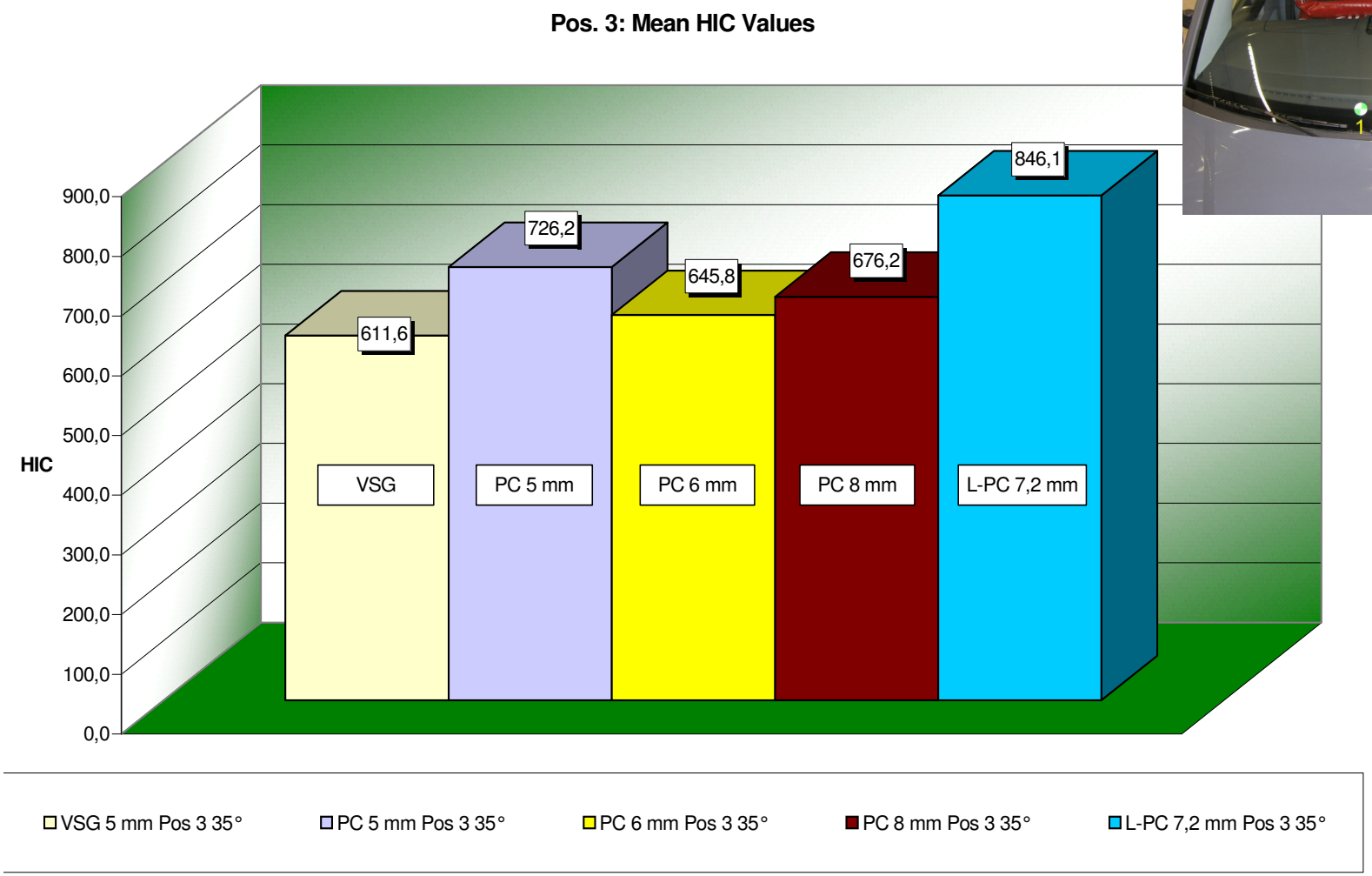




VSG 5 mm Pos 1 35° | PC 5 mm Pos 1 35° | PC 6 mm Pos 1 35° | PC 8 mm Pos 1 35° | L-PC 7,2 mm Pos 1 35°

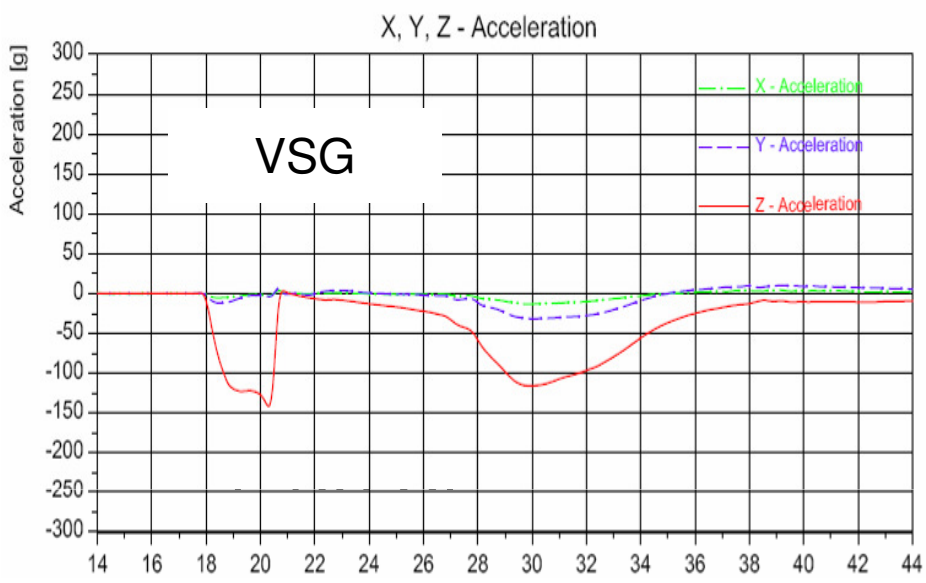
VSG vs. PC

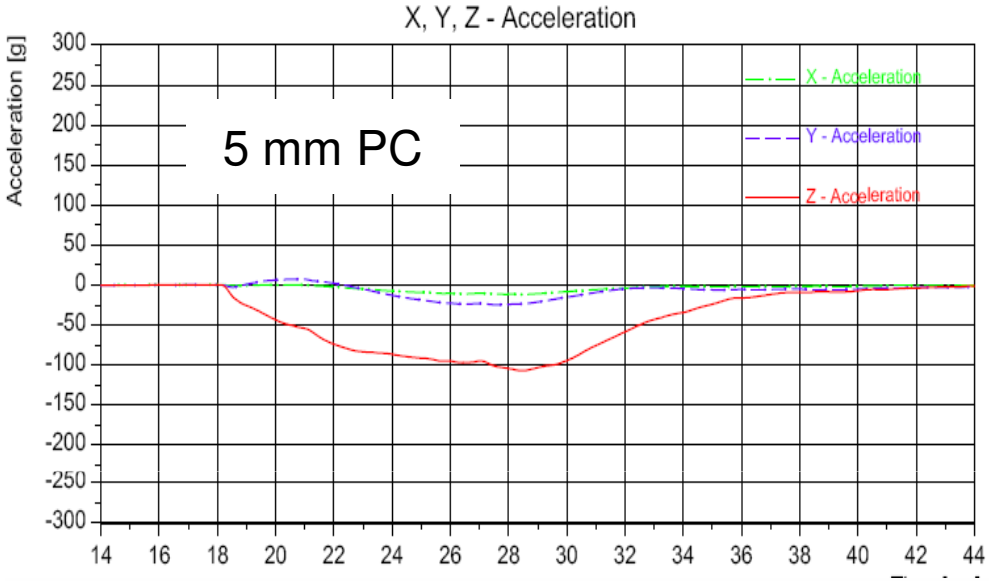

1
2
3
4

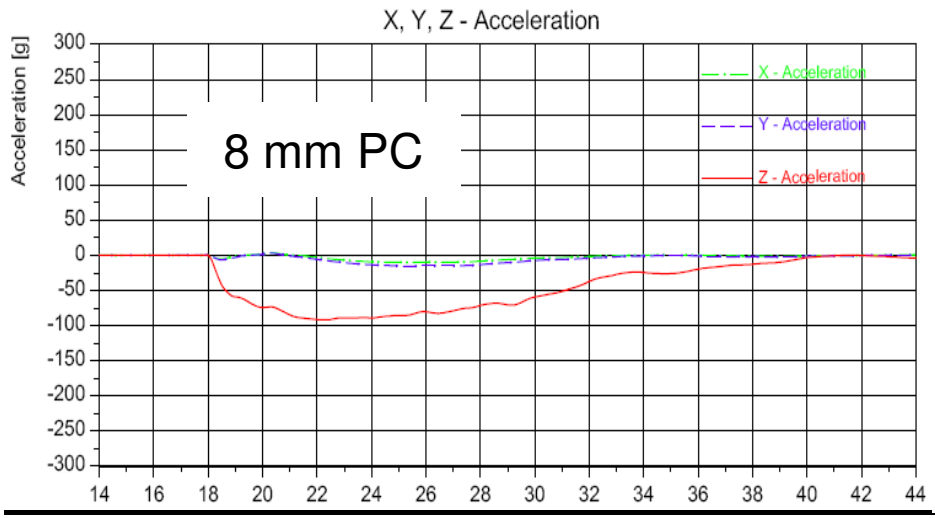

Pos. 3: Mean HIC Values
HIC
900,0
800,0
700,0
600,0
500,0
400,0
300,0
200,0
100,0
0,0
611,6
726,2
645,8
676,2
846,1
VSG
PC 5 mm
PC 6 mm
PC 8 mm
L-PC 7,2 mm
VSG 5 mm Pos 3 35°
PC 5 mm Pos 3 35°
PC 6 mm Pos 3 35°
PC 8 mm Pos 3 35°
L-PC 7,2 mm Pos 3 35°

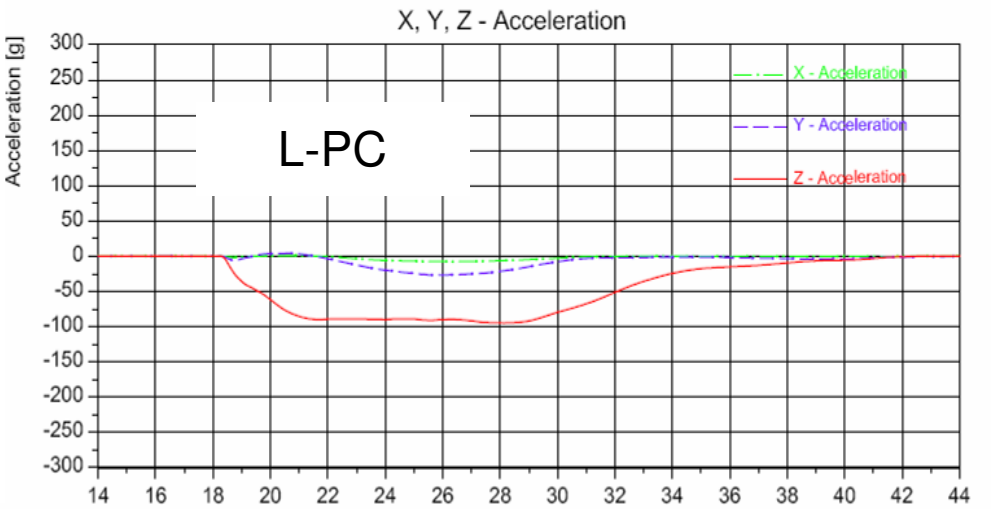
Vehicle Impact Tests

VSG vs. PC at Pos. 3





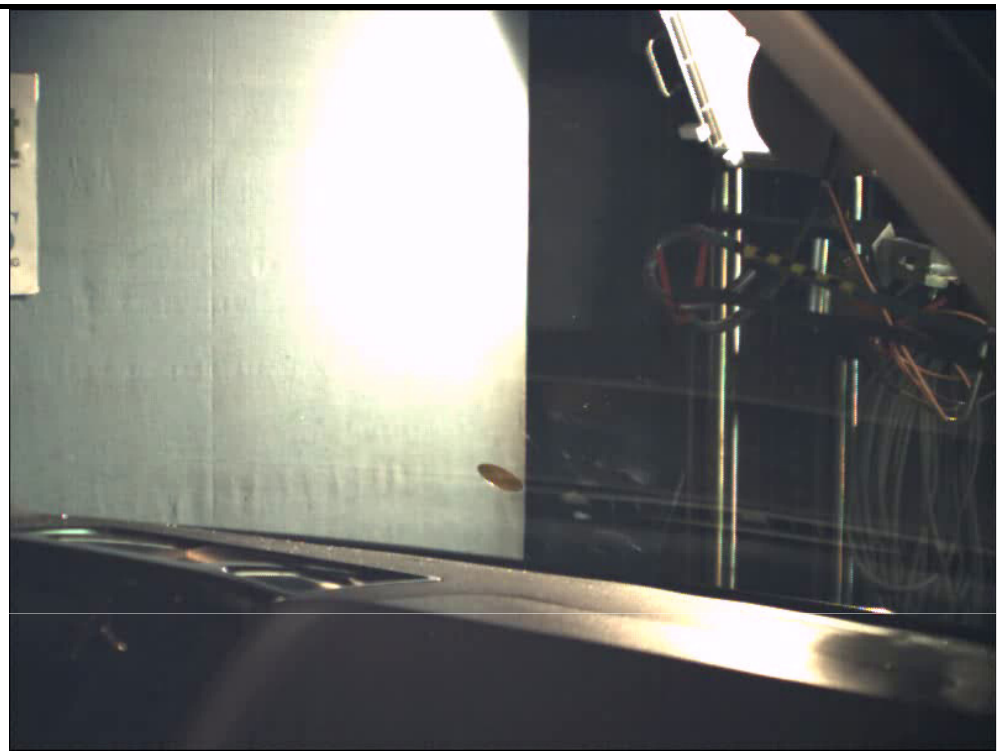




Vehicle Impact Tests

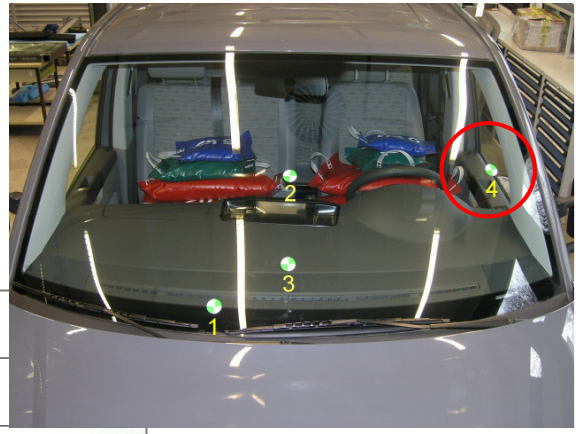
VSG vs. PC at Pos. 3

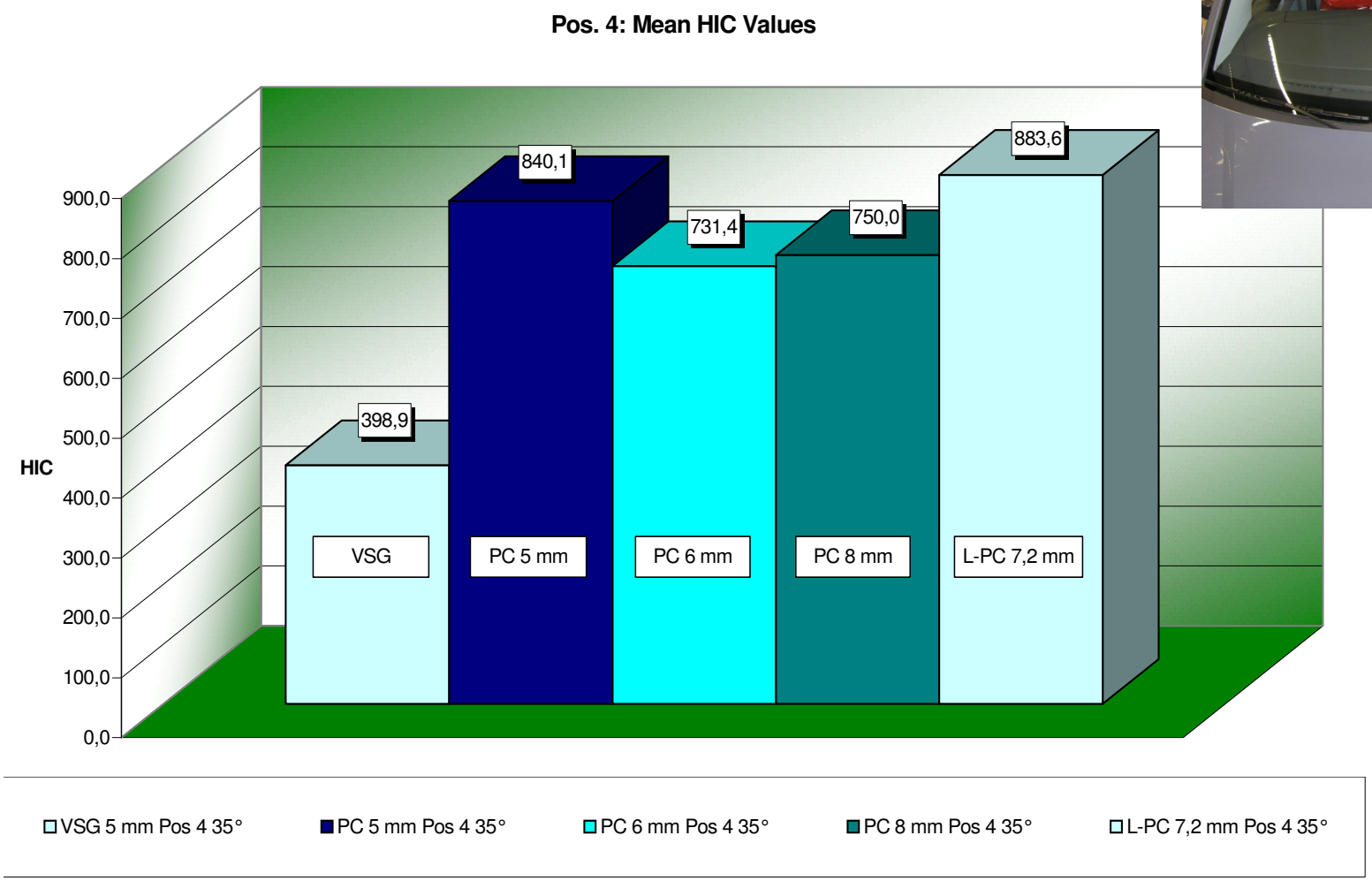
- VSG Glazing



- L-PC Glazing

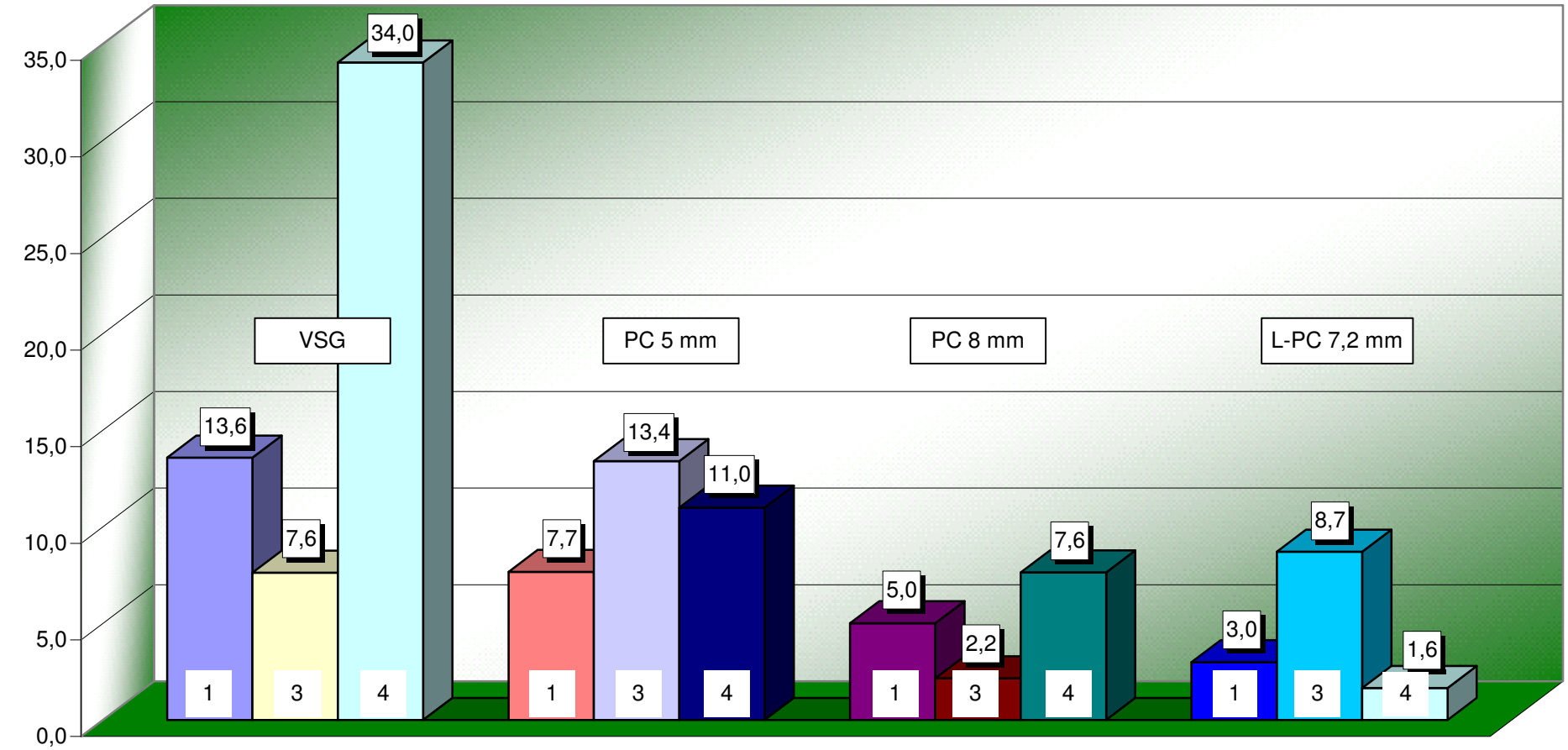
VSG vs. PC


1
2
3
4


Pos. 4: Mean HIC Values
HIC
900,0
800,0
700,0
600,0
500,0
400,0
300,0
200,0
100,0
0,0
398,9
840,1
731,4
750,0
883,6
VSG
PC 5 mm
PC 6 mm
PC 8 mm
L-PC 7,2 mm
VSG 5 mm Pos 4 35°
PC 5 mm Pos 4 35°
PC 6 mm Pos 4 35°
PC 8 mm Pos 4 35°
L-PC 7,2 mm Pos 4 35°

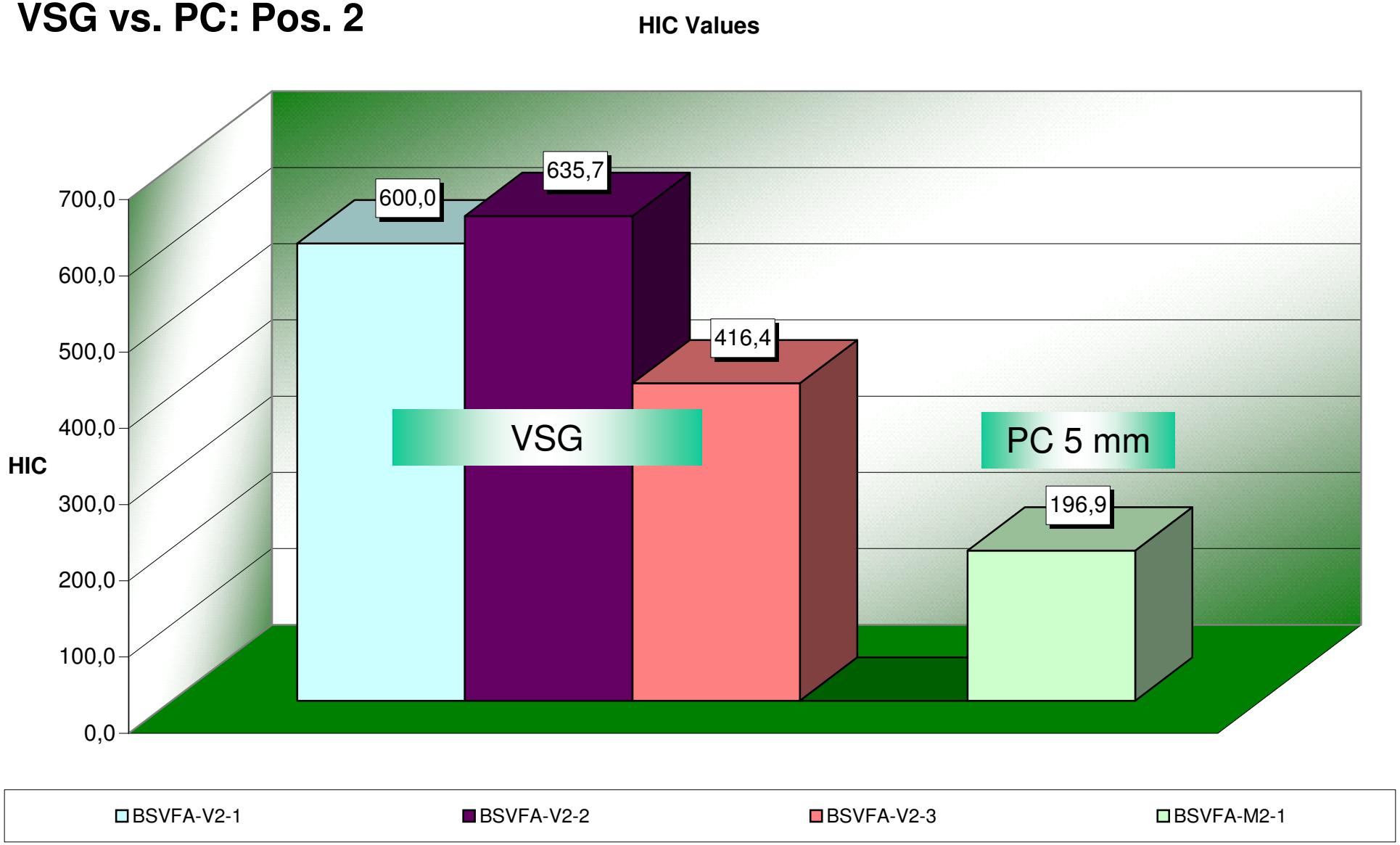
VSG vs. PC

Coefficient of Variation [%]: 35°, Pos. 1, 3, 4

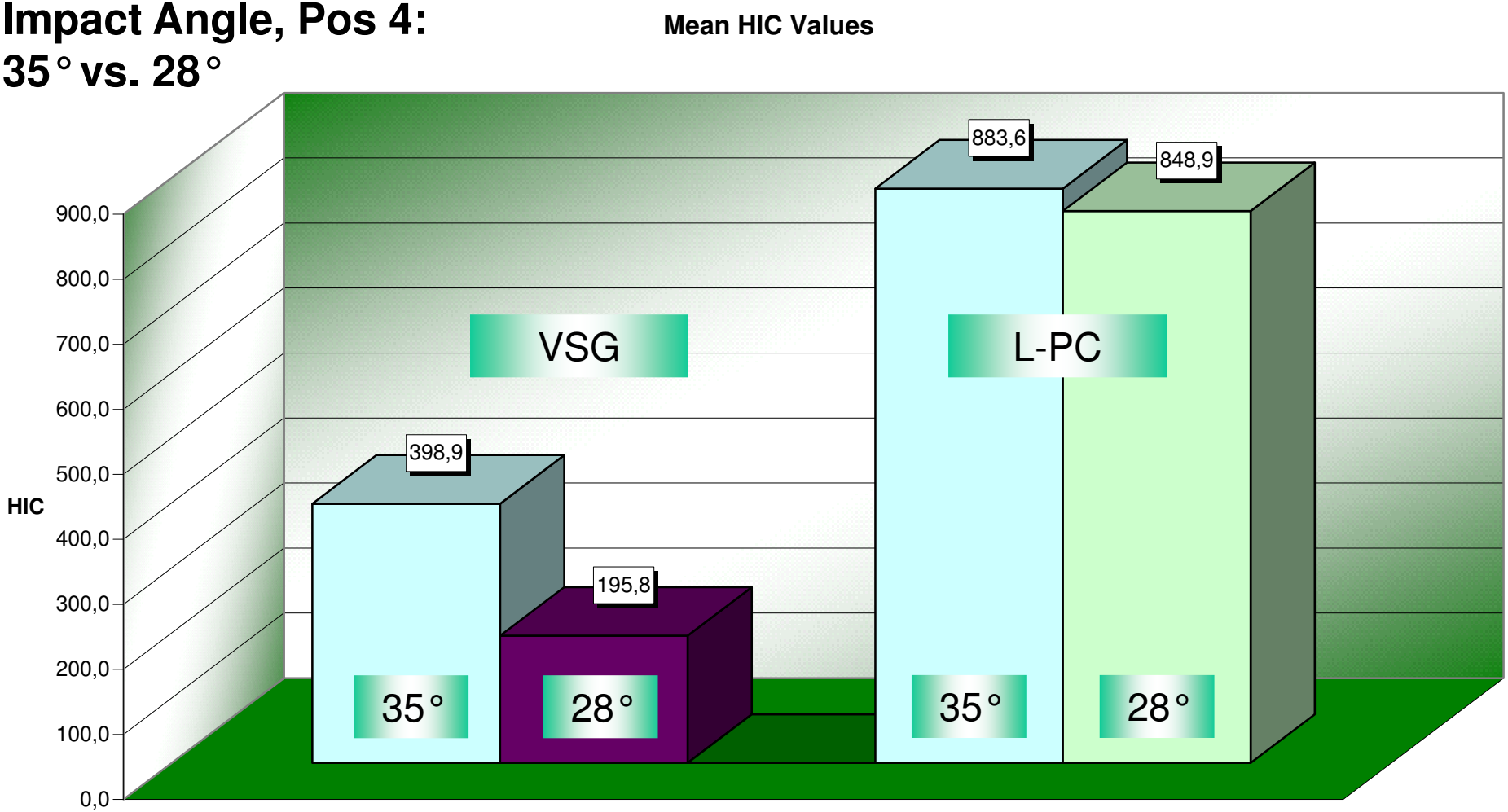


VSG 5 mm Pos 1 35°	VSG 5 mm Pos 3 35°	VSG 5 mm Pos 4 35°	PC 5 mm Pos 1 35°	PC 5 mm Pos 3 35°	PC 5 mm Pos 4 35°
PC 8 mm Pos 1 35°	PC 8 mm Pos 3 35°	PC 8 mm Pos 4 35°	L-PC 7,2 mm Pos 1 35°	L-PC 7,2 mm Pos 3 35°	L-PC 7,2 mm Pos 4 35°

VSG vs. PC: Pos. 2



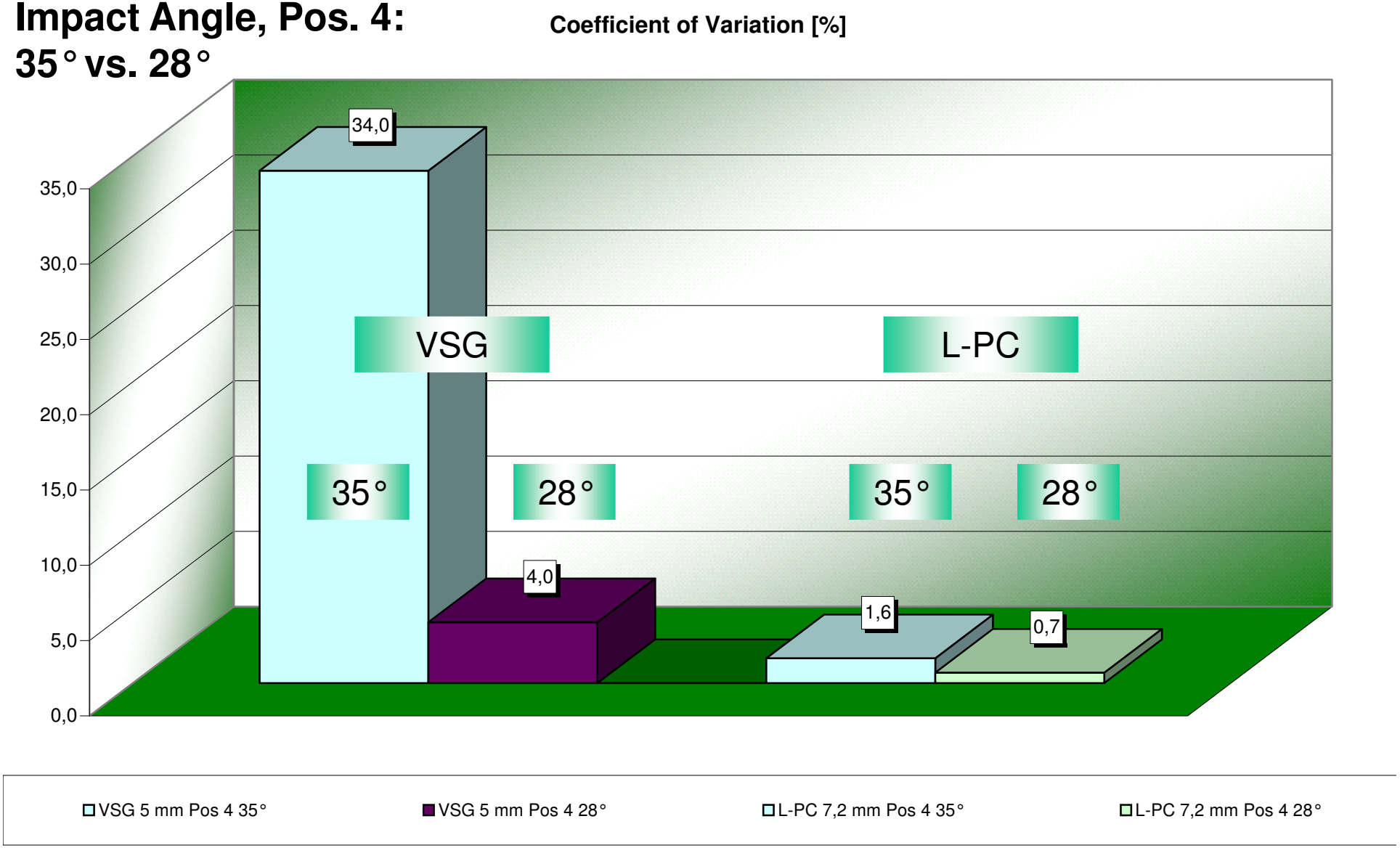
Impact Angle, Pos 4: 35° vs. 28°



VSG 5 mm Pos 4 35° | VSG 5 mm Pos 4 28° | L-PC 7,2 mm Pos 4 35° | L-PC 7,2 mm Pos 4 28°

Vehicle Impact Tests

Impact Angle, Pos. 4: 35° vs. 28°



Summary 3 (1):

Vehicle Tests

- No visible damage of the PC panes
- HIC values in tests with PC glazing at three (out of four) impact locations significantly higher than in tests with glass.
- However, at impact pos. 2, the single test performed on 5 mm PC glazing shows significantly lower results than all three tests with VSG
- At impact pos. 1 (windscreen base) the HIC results of the tests with PC panes decrease with increasing pane thickness.
- At impact pos. 3 and 4 the influence of the different pane thicknesses on the results is not significant

Summary 3 (2):

Vehicle Tests

- The scatter in tests with 8 mm PC and 7.2 mm L-PC glazing is significantly lower than in tests with VSG and 5 mm PC glazing
- The influence of the impact angle on VSG panes is significant: a lower impact angle results in lower HIC values and lower scatter
- The influence of the impact angle on PC glazing is marginal with respect to HIC results and scatter.

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Conclusions to Questions (1)

1. Does the use of plastic windscreens in vehicles lead to a higher injury risk for vulnerable road users, especially for pedestrians?

   Generally, higher HIC values were observed in tests with PC glazing. As the HIC is the current criterion for head injury severity assessment, PC glazing has to be seen as more injurious in terms of vulnerable road user protection.

   In addition, the significantly higher rebound of the head in tests with PC glazing is suspected to lead to higher neck injury risks and may also cause higher injury risks in secondary impacts.

   However, as in all tests with PC glazing no damage of the panes were observed, the risk of skin cut injuries might be significantly reduced.

Conclusions to Questions (2)

2. Can the current test procedure (Phantom head drop test) on the approval of glazing according to UN regulation Nr. 43 be used for plastic glazing? Which modifications or extensions might be necessary?

   As the test procedure prescribed in UN R 43 is generally accepted as a methodology to approve glass windscreen, this test series gives no indication that it is not feasible for PC glazing, especially because UN R 43 does not reflect any pedestrian protection aspects.

   The performance of the windscreen area according to the upcoming UN Regulation for pedestrian protection will initially not be relevant for vehicle type approval. However, pedestrian protection should be considered for plastic windscreens to ensure at least the same level of protection as glass windscreens.

Acknowledgements

We thank the following companies for their kind support to this project:

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