

Design and Performance Specifications for a Generic Buck Representing a Small Family Car Used in the Assessment of Pedestrian Dummy Whole Body Impact Response

RATIONALE

Performance evaluations of pedestrian dummies require standardized test methodologies and equipment. A full-scale vehicle to pedestrian impact test is an essential performance evaluation for a pedestrian dummy. While production vehicles obviously provide a realistic platform for vehicle to pedestrian impacts, the limited long-term availability of production vehicles combined with the geometric and stiffness constraints imposed by a particular vehicle model reduce their desirability for performance specifications. This Information Report provides the design and performance specifications required to develop a generic test buck, representing a small family car, for use in evaluating the biofidelity of pedestrian dummies in full-scale tests.

FOREWORD

Physical dummies and computational models are designed to be biofidelic in the pedestrian impact environment, meaning that they are intended to mimic the biomechanical response of a human when subjected to the same pedestrian impact scenario. Assessing biofidelity requires performing both component tests and full-scale tests. The component tests provide detailed evaluations of isolated body region responses with a corresponding vehicle component (e.g., pelvis impact response with the hood edge), while the full-scale pedestrian to vehicle test involves the interaction of the whole body of the pedestrian with the impacting areas of a car (e.g., front-end of the car). Although assessments of body region biofidelity of a dummy can be achieved using component tests, the complex kinematics of the pedestrian occurring during impact with a vehicle can only be replicated using full-scale tests involving a dummy and vehicle. Such full-scale tests are an essential performance evaluation for a pedestrian surrogate (i.e., dummy or computational model) and are critical for understanding the motions and sequence of body component impacts which lead to pedestrian trauma. Additionally, full scale tests are also necessary for the design and evaluation of safety technologies for pedestrian protection.

While production vehicles provide a realistic platform for vehicle-to-pedestrian impacts, production vehicles are undesirable for this purpose since they possess geometric and stiffness constraints based on the design of a particular model and have limited long-term availability. As time passes, the unavailability of a specific vehicle can lead to significant difficulties in replicating a previous test condition in future tests. Thus, for the purpose of standardized performance evaluations, it is desirable to utilize a generic vehicle test buck that is representative of a range of vehicles within a desired vehicle class (e.g., small family car). In comparison to a production vehicle, a generic buck can be designed to provide a repeatable and reproducible impact response while still accurately representing the response of either a specific vehicle or a range of specific vehicles within the passenger vehicle fleet. Additionally, a buck designed using standard and readily available engineering materials can ensure ease of accurate reproducibility and long-term availability for future tests. Uses for such a generic buck include the:

- Development of a standardized full-scale vehicle-to-pedestrian impact test procedure
- Study of whole-body pedestrian kinematics and impact response
- Evaluation of pedestrian dummy performance and biofidelity
- Validation of computer simulations of a pedestrian dummy
- Design and evaluation of safety technologies

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1. SCOPE

This Information Report addresses the design and performance specifications for a generic buck to be used in full-scale vehicle to pedestrian tests conducted to evaluate pedestrian dummy performance. Specifically, the buck is designed to mimic the impact response of the front end of a sedan within the small family car class during a collision with a pedestrian. The goal is to develop a generic buck with simplified geometry and a limited number of components made of clearly defined and readily available engineering materials to facilitate fabrication and reproducibility. To ensure performance of the buck, it is specified that the buck mimics the maximum crush distance, absorbed energy, and maximum force corresponding to a sedan within the small family car class during a pedestrian impact. The design and performance specifications provided in this document focus on: (1) the design specifications describing the materials and geometry of the generic buck and (2) the specific certification tests that are required to ensure that any fabricated buck meets the necessary design specifications.

1.1 Purpose

This document provides the design and performance specifications required to develop and certify a generic buck, representing the small family car class, for use in evaluating the biofidelity of pedestrian dummies in full scale tests.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2782 Performance Specifications for a Midsize Male Pedestrian Research Dummy

SAE J2868 Pedestrian Dummy Full Scale Test Results and Resource Materials

2.1.2 IRCOBI Publications

Available from IRCOBI Secretariat, c/o AGU Zurich, Winkelriedstrasse 27 - CH-8006 Zurich, Switzerland www.ircobi.org.

Pipkorn, B., Forsberg, C., Takahashi, Y., Ikeda, M., Fredriksson, R., Svensson, C., Thesleff, A., Development and Component Validation of a Generic Vehicle Front Buck for Pedestrian Impact Evaluation, Proceedings of the 2014 IRCOBI Conference, pp. 718-729.

Takahashi, Y., Ikeda, M., Asanuma, H., Svensson, C., Pipkorn, B., Forsberg, C., Fredriksson, R., Full-Scale Validation of a Generic Buck for Pedestrian Impact Simulation. Proceedings of the 2014 IRCOBI Conference, pp. 730-745.

Forman, J., Joodaki, H., Forghani A., Riley, P., Bollapragada, V., Lessley D., Overby, B., Heltzel, S., Crandall, J., Biofidelity Corridors for Whole-Body Pedestrian Impact with a Generic Buck. Proceedings of the 2015 IRCOBI Conference, pp. 356-372.

2.1.3 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 3784:1976 Road vehicles -- Measurement of impact velocity in collision tests

ISO 6487:2002 Road vehicles -- Measurement techniques in impact tests -- Instrumentation

2.1.4 Other Publications

"Global technical regulation No. 9 (GTR 9): PEDESTRIAN SAFETY (Established in the Global Registry on 12 November 2008)", ECE/TRANS/180/Add.9 (2009).

APROSYS, The Generalised Geometry Corridors, Generic Shapes and Sizes of the Vehicle Fleet Covering Cars, MPVs and SUVs, Report AP-SP31-007R (2006).

APROSYS. Stiffness Corridors for the Current European Fleet. Report AP-SP31-0009R (2006).

EuroNCAP 2001, "EuroNCAP pedestrian testing protocols" Version 3, April 2001

EuroNCAP 2004, "EuroNCAP pedestrian testing protocols" Version 4.1, March 2004

European Enhanced Vehicle-safety Committee. EEVC Working Group 17 Report – Improved test methods to evaluate pedestrian protection afforded by passenger cars. 1998.

Transport Research Laboratory (TRL), "User Documentation for the TRL Pedestrian Upper Legform Impactor", June 1997

3. DEFINITIONS

SHALL: Used to denote specifications, performances, or requirements which must be met in order to comply with this Information Report.

SHOULD: Used to denote specifications, performances, or requirements which are recommended, but failure to comply does not constitute a failure to comply with the Information Report.

VULNERABLE ROAD USERS: Terminology used in Global Technical Regulations, European Union regulations, and commonly used in the field of safety research (see ESV session guide) to describe pedestrians and the lightly protected road users.

4. ABBREVIATIONS AND SYMBOLS

4.1 Abbreviations

APROSYS	Advanced PROtective Systems
CAC	Channel Amplitude Class
CFC	Channel Frequency Class
CV	Coefficient of Variation
NCAP	New Car Assessment Program
EEVC	European Enhanced Vehicle-safety Committee
FE	Finite Element
GTR	Global Technical Regulation
IRCOBI	International Research Council on the Biomechanics of Impact
ISO	International Organization for Standardization
MCL	Medial Collateral Ligament
POLAR	Pedestrian dummy fOr Laboratory Research
SD	Standard Deviation
T1, T8, etc.	Thoracic vertebrae number 1, 2, etc.
TRL	Transport Research Laboratory
UNECE	United Nations Economic Commission for Europe

4.2 Symbols

4.2.1 Vehicle Reference System (fixed with respect to the moving vehicle)

- x Positive motions are forward with respect to the car
- z Positive motions are down
- V_r Resultant velocity in the vehicle reference system xz plane

5. BUCK DESIGN SPECIFICATION

5.1 General Requirement

The design specifications should provide requirements to develop a generic buck, representing the small family car class, for use in evaluating the biofidelity of pedestrian dummies in full scale tests.

5.2 Design Objectives

The generic test buck should be a non-production vehicle representation that is configured to accurately characterize a vehicle within the small family car class. Specifically, the buck should be designed to mimic the impact response, of a vehicle front end, resulting from a collision with a pedestrian in a full-scale test. As the primary intention is to evaluate kinematic response of a pedestrian dummy using the buck, head impact to the windshield may not be accurately represented because the head is the body region that contacts the car surface at the very end of the car-to-pedestrian interaction. The buck should be generic in that the design incorporates a simplified geometry using a limited number of components to represent the front end of a vehicle. Furthermore, the buck should consist of clearly defined and readily available engineering materials with a minimal number of curved surfaces to facilitate fabrication and reproducibility.

It is intended that the buck will be used in full-scale vehicle to pedestrian impact tests conducted to evaluate pedestrian dummy performance for an impact occurring at the center of the vehicle. The buck should represent both the geometric and stiffness characteristics of a vehicle within a given vehicle class and should provide a repeatable and reproducible impact response. Additionally, the buck should sustain no damage to non-replaceable components at a 50 km/h impact.

The results of the relevant studies demonstrating that the buck is representative of a “good” rated small family car by Euro NCAP pedestrian subsystem tests can be found in Appendix D.

5.3 Geometric Representation

The buck should represent the geometric characteristics of the small family car class. Specifically, the 2D centerline cross-sectional contour of the buck should be within the range of those exhibited by actual vehicles in the small family car class. An example comparison between the generic buck 2D geometry and the 2D centerline cross-sectional contour data provided by APROSYS for “good” rated sedans by the Euro NCAP pedestrian subsystem tests in the passenger vehicle fleet is illustrated in Figure D1 of Appendix D. Such comparison ensures that the geometry of the generic buck is consistent with the small family car class that it represents.

5.4 Major Vehicle Components

While the generic buck design incorporates a simplified geometry and a limited number of components, the buck should consist of the major parts (components) of a vehicle that are engaged in a pedestrian collision. Thus, the buck should possess the following six major components important for pedestrian impacts: lower bumper, bumper, grille, hood edge, hood, and windshield (Figure 1).

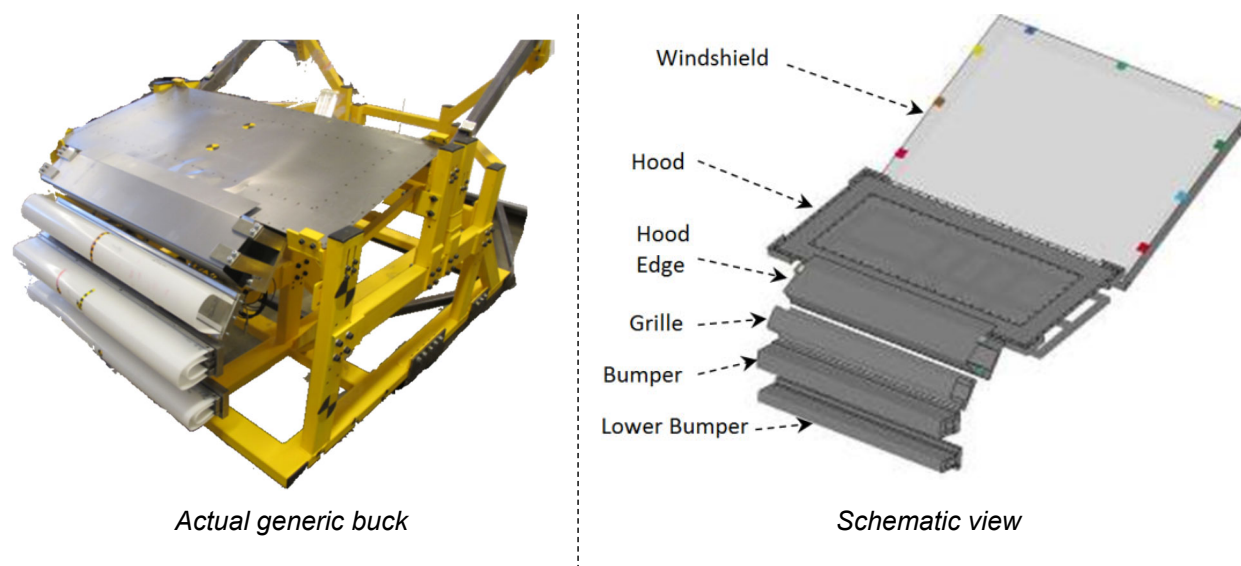


Figure 1 - Generic buck (left) and identification of the six major vehicle components incorporated in the generic buck design (right)

5.5 Design Details

5.5.1 Support Structure and Major Vehicle Component Assembly

The generic buck should incorporate a rigid support frame (Figure 2) to support the six major vehicle components discussed in 5.4 and illustrated in Figure 1. While it is intended that the vehicle components of 5.4 should be replaced after each test, the support structure will be designed such that no damage should be sustained during the pedestrian impacts. Appendix A provides detailed drawings for the buck support structure and major vehicle components.



Figure 2 - Multiple views of generic buck with the six major vehicle components installed and supported by a rigid tubular steel support frame

5.5.2 Lower Bumper

The lower bumper should be constructed from polyethylene (PE-300). The lower bumper should be closed sections in a two-layer design allowing for two-step force displacement behaviors when loaded. The construction of the lower bumper is illustrated in Figure 3. The lower bumper components should be rigidly attached to the support frame via rigid support beams.

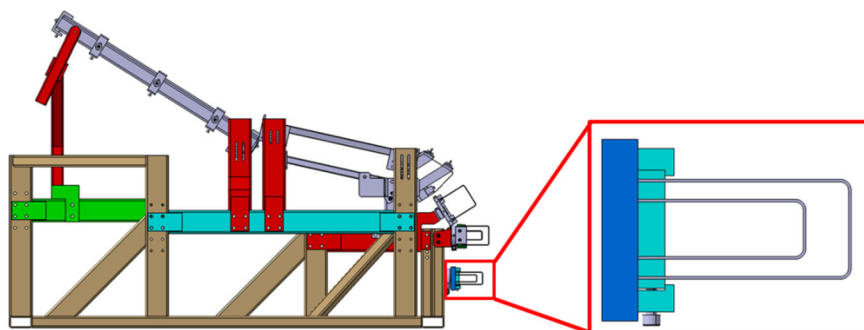


Figure 3 - Lower bumper construction

5.5.3 Bumper

The bumper should be constructed from polyethylene (PE-300). The bumper should be closed sections in a two-layer design allowing for two-step force displacement behaviors when loaded. The construction of the bumper is illustrated in Figure 4. The bumper components should be rigidly attached to the support frame via rigid support beams.

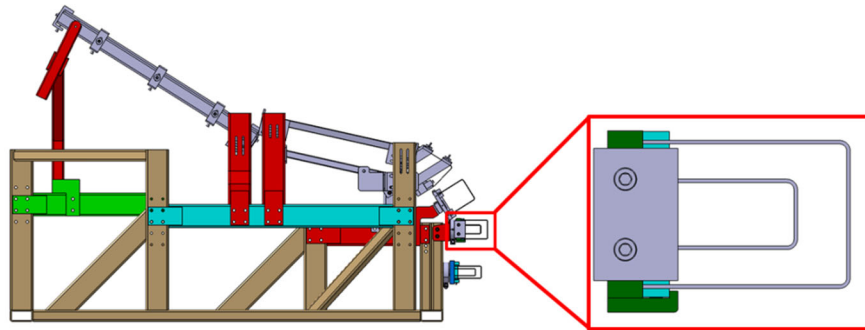


Figure 4 - Bumper construction

5.5.4 Grille

The grille should be constructed of polyethylene (PE-300). The grille should be a closed section. The construction of the grille is illustrated in Figure 5. The grille component should be rigidly attached to the support frame via rigid support beams.

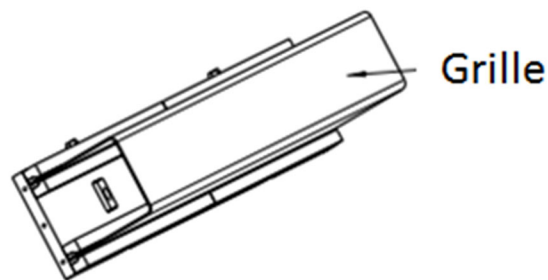


Figure 5 - Grille construction

5.5.5 Hood Edge

The hood edge should be constructed of steel (DC01). The hood edge should be an open section with a support in each end and the upper edge resting on the hood with an overlap. The construction of hood edge is illustrated in Figure 6. The hood edge component should be rigidly attached to the support frame via rigid support beams.

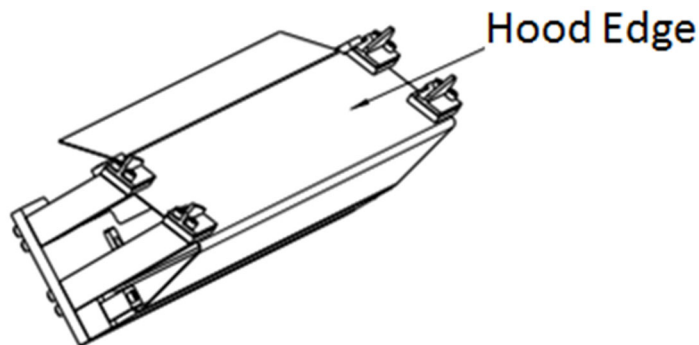


Figure 6 - Hood edge construction

5.5.6 Hood

The hood should be constructed of steel (DC01). The deformable hood should be a square steel sheet (0.75 mm) with a rectangular support (0.75 mm) welded around the edge. The hood should be held by gravity within four fixed connection supports that prevent the translation of the hood in the x-, y-, and negative z-directions (Figure 7). The engine block should be modeled as a rigid structure 130 mm below the hood.

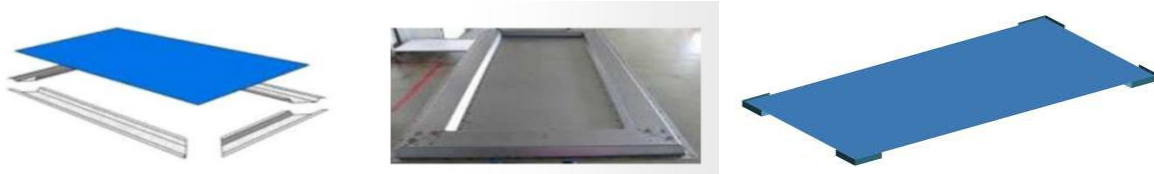


Figure 7 - Hood construction

5.5.7 Windshield

The windshield should be constructed of 8.0 mm polycarbonate (Lexan 9030) and secured with clamps as illustrated in Figure 8. The tightening torque for the clamps should be $22 \text{ Nm} \pm 2 \text{ Nm}$.

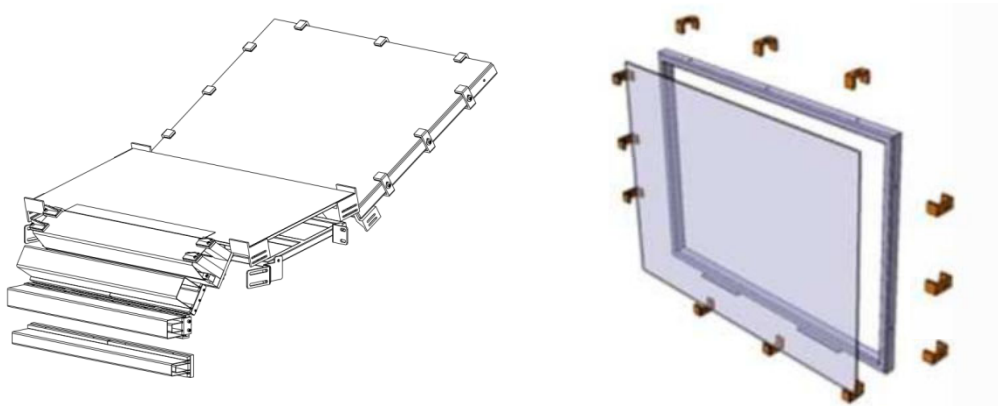


Figure 8 - Windshield construction

5.6 Buck Instrumentation

In order to quantify detailed reaction loads generated by the pedestrian-vehicle interaction, load cells may be installed between the buck supporting frame and the rigid backing supports for each of the compliant front-end components (Figure 9). In this example generic buck, for the hood edge and grille, a 3-axis load cell was used on the right and left sides of the buck. For the bumper and lower bumper, a single-axis load cell was used on the left and right sides of the buck. An example of local coordinate axes for the load cells is illustrated in Figure 9. Additionally, single string potentiometers were used to measure hood deformation at the upper and lower edges of the hood on the centerline of the vehicle. Table 1 provides the details regarding the described instrumentation used for the example generic buck. Although not implemented in this example generic buck, it is recommended to install accelerometers if inertial compensation of the load cells forces is necessary.

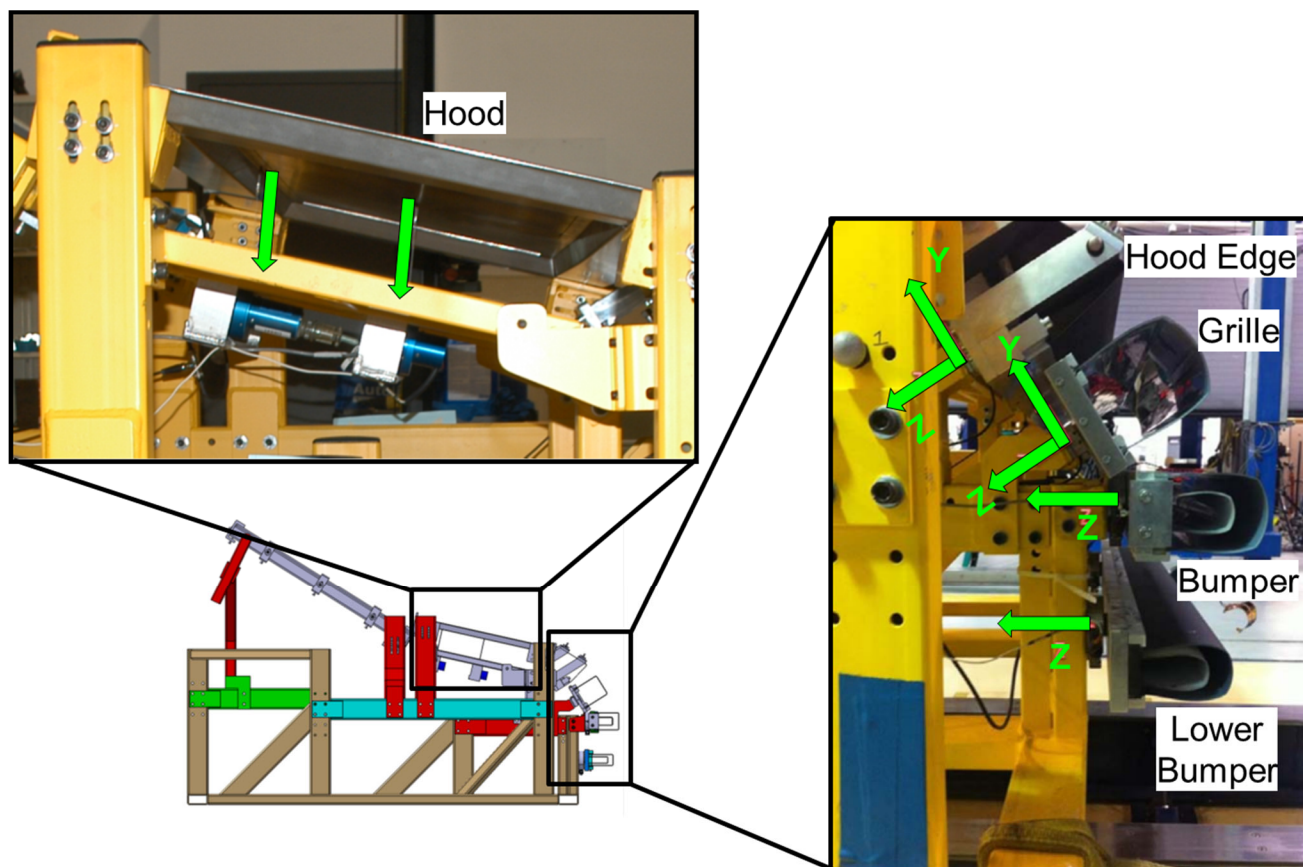


Figure 9 - Buck load cells and an example of local load cell coordinate systems

Table 1 - Example buck instrumentation details

Instrumentation Type	Manufacturer [†]	Model [†]	Buck Component	Driver Side/Passenger Side/Center	Measurement Parameter	Number of Axes
Load Cell	Humanetics	2358LN2	Hood Edge	Driver	Force	3
Load Cell	Humanetics	2358LN2	Hood Edge	Passenger	Force	3
Load Cell	Humanetics	2358LN2	Grille	Driver	Force	3
Load Cell	Humanetics	2358LN2	Grille	Passenger	Force	3
Load Cell	Humanetics	41/572-05	Bumper	Driver	Force	1
Load Cell	Humanetics	41/572-05	Bumper	Passenger	Force	1
Load Cell	Humanetics	41/572-05	Lower Bumper	Driver	Force	1
Load Cell	Humanetics	41/572-05	Lower Bumper	Passenger	Force	1
String Pot	Firstmark	62-60-8142	Hood-Upper	Center	Displacement	1
String Pot	SpaceAge Control	162-3205H	Hood-Lower	Center	Displacement	1

[†] Or equivalent.

5.7 Materials

Materials used for the buck should not be production vehicle components given their limited period of availability, should be easy to obtain and to replace when damaged, and should provide repeatable and reproducible results. However, these components should have geometry, material characteristics, and impact responses that are comparable to those of the specific represented vehicle or vehicle category. Thus, the buck designed using standard and readily available engineering materials can ensure reproducibility for future tests, while avoiding the long-term availability issues affecting production vehicles.

As summarized in Table 2, the following materials should be used for the various major vehicle components of the buck. The bumper and the lower bumper should be constructed from polyethylene (PE-300) with the thicknesses of 2.0 mm and 1.5 mm for the inner and outer layers, respectively. The grille should be constructed of 2.0 mm polyethylene (PE-300). The hood edge should be constructed of 1.0 mm steel (DC01). The hood should be constructed of 0.75 mm steel (DC01). The windshield should be constructed of 8.0 mm polycarbonate (Lexan 9030). When the combinations of the exact material and the thickness of components specified in Table 2 are not available, different combinations may be used to conform to both the geometric requirements specified in 5.9 and the structural response requirements specified in 6.4.

Table 2 - Buck component materials and nominal material thicknesses

Component	General Material Description	Specific Material Description ^{††}	Nominal Material Thickness (mm)
Hood*	Steel	DC01 Steel ^{**}	0.75
Hood edge	Steel	DC01 Steel ^{**}	1.0
Grille	Polyethylene	PE-300	2.0
Bumper (inner and outer)	Polyethylene	PE-300	2.0
Lower Bumper (inner and outer)	Polyethylene	PE-300	1.5
Windshield	Polycarbonate	Lexan 9030	8.0

* The hood component also included a formed structural backing around its perimeter (refer to hood drawing in Appendix A).

** Young's modulus 210 GPa and yield stress of 147 MPa.

†† Can use the material corresponding to the specified trade name or an equivalent material.

5.8 Material Response

In order to characterize the material response of the specific materials used in the the buck construction, tensile coupon tests are provided for the utilized materials. The dimensions of the coupon are illustrated in Figure C1 of Appendix C. The material responses of utilized materials are provided in Figure C2 of Appendix C for the polyethylene and polycarbonate described in Table 2.

5.9 Geometry

This section covers geometry of the generic buck. Specifically, the aspects of buck assembly, component cross-sections, and associated geometric tolerances are covered.

5.9.1 Technical Drawings

The detailed geometry of the buck is provided in Appendix A. Specifically, Appendix A provides dimensioned technical drawings for all buck parts as well as all necessary assembly drawings. All buck parts should be fabricated as closely as possible to the drawing specifications and tolerances provided in Appendix A.

5.9.2 Buck Assembly

Figure 10 provides a right-side cross-sectional view of the assembled buck along its centerline. In order to provide buck-pedestrian interactions as intended, it is necessary to ensure that the external contour of the constructed buck is consistent with its intended design. Thus, all rigid supports for the buck front-end components (i.e., rigid supports for the lower bumper, bumper, grille, and hood edge) shall conform to the dimensions provided in Figure 10 within ± 3 mm for applicable linear dimensions, and within ± 1 degree for all applicable angle specifications.

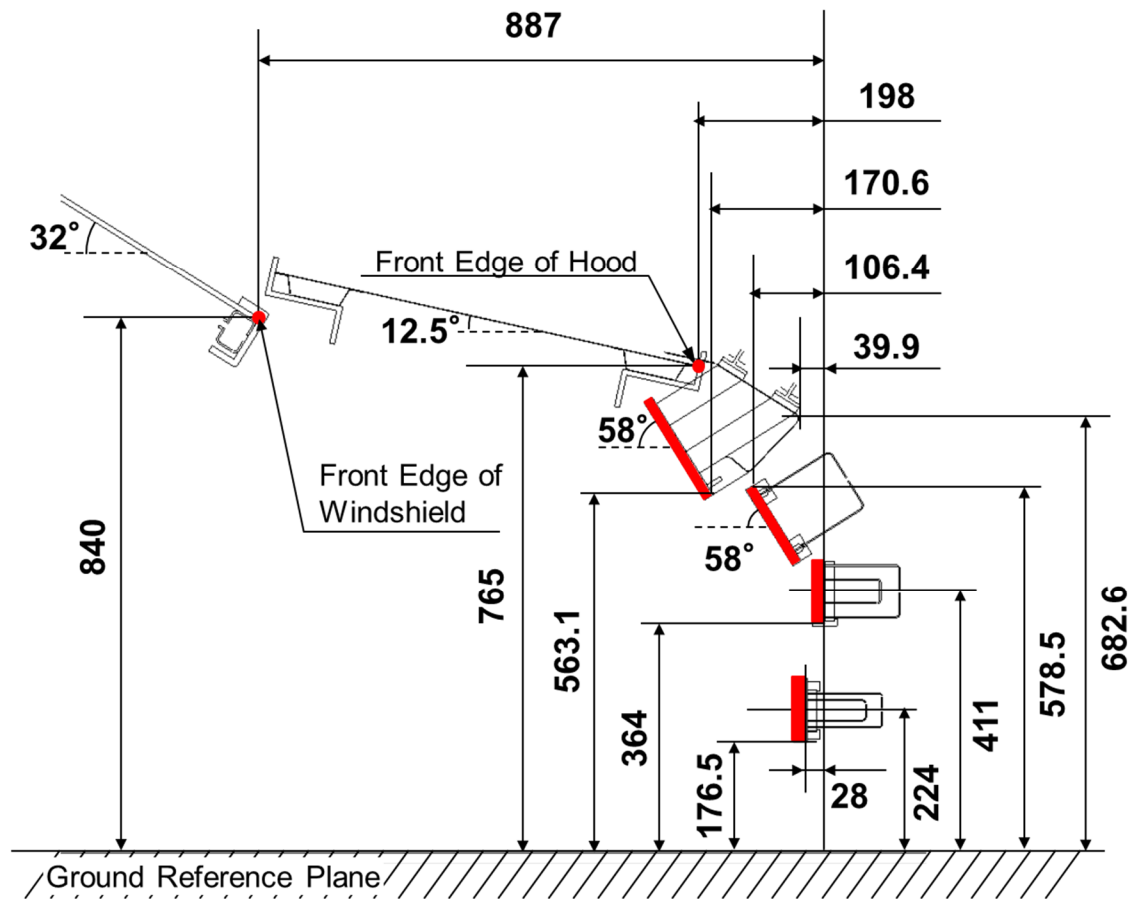
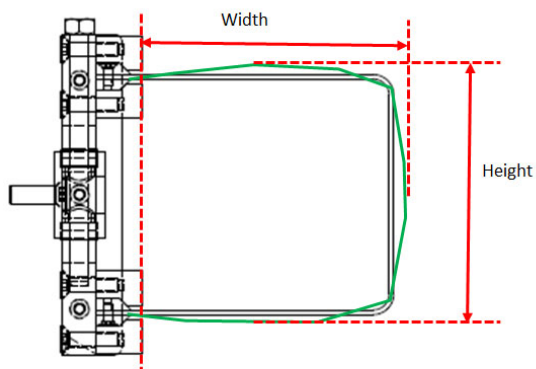


Figure 10 - Buck assembly and front-end profile geometric design details
(all dimensions are mm unless marked otherwise)

5.9.3 Buck Component Cross-Section

The compliant front-end components (grille, bumper, and lower bumper) are constructed with polyethylene as described previously in 5.7. The specific procedure to fabricate the components is provided in 5.10. The fabricated polyethylene components are secured to their respective rigid supporting structures (Figures 11 through 13). As covered in the previous section, the positioning of these rigid supporting bases for the buck components shall conform to the dimensions provided in Figure 10 within ± 3 mm for applicable linear dimensions, and within ± 1 degree for all applicable angle specifications. The grille component is comprised of a single layer of polyethylene, while the bumper and lower bumper are both comprised of an outer layer and also an inner layer. The cross-sectional shape for each polyethylene layer is quantified using a height and width dimension that is specific to each component and also to each layer. All buck component cross-sectional heights and widths illustrated in Figures 11 through 13 shall conform to measures provided in Table 3.

Schematic



Photo

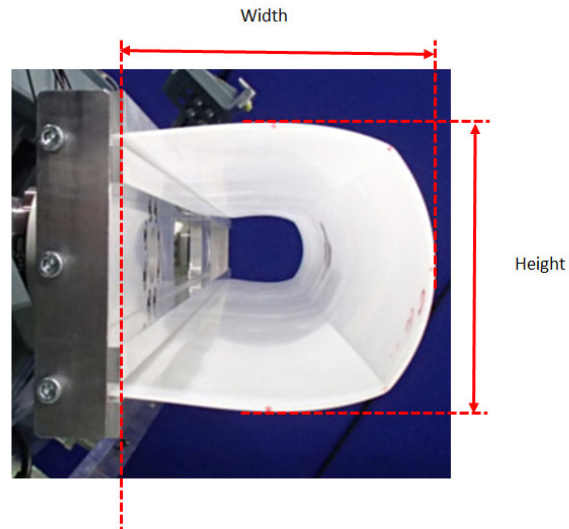
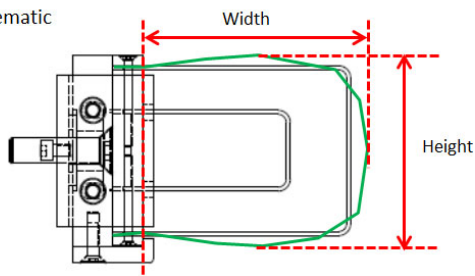


Figure 11 - Grille component cross-sectional width and height measures.
Schematic illustration (left) and photo of actual component (right).

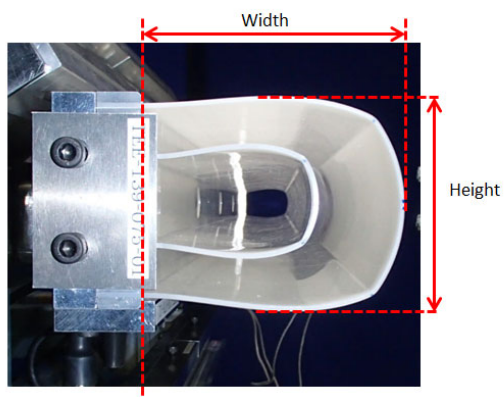
Outer parts

----- Baseline for measurement

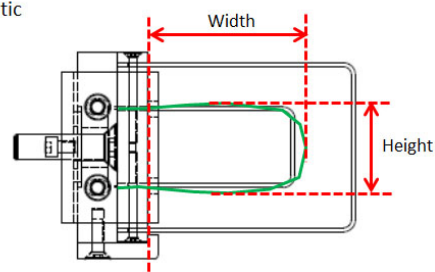
Schematic



Photo

Inner parts

Schematic



Photo

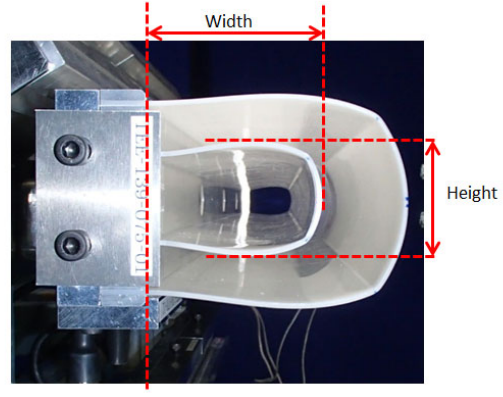
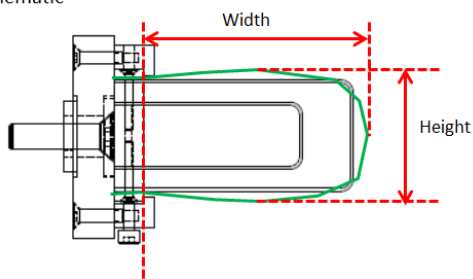


Figure 12 - Bumper component cross-sectional width and height measures for outer and inner layers.
Schematic illustration (top) and photos of actual components (bottom).

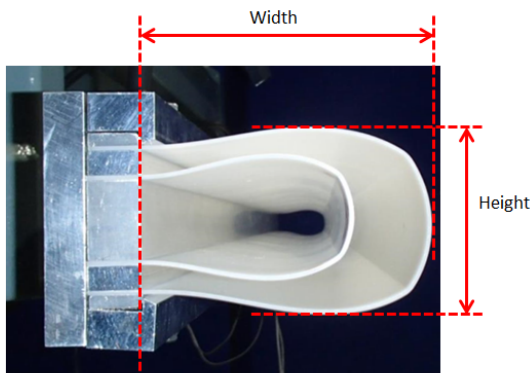
Outer parts

----- Baseline for measurement

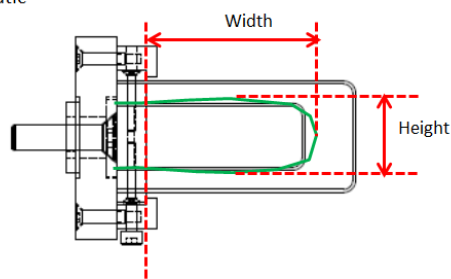
Schematic



Photo

Inner parts

Schematic



Photo

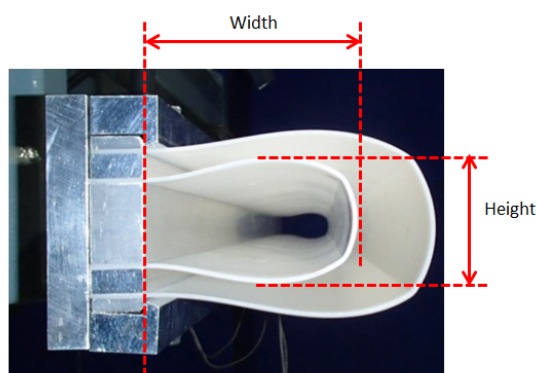


Figure 13 - Lower bumper component cross-sectional width and height measures for outer and inner layers. Schematic illustration (top) and photos of actual components (bottom).

Table 3 - Target height and width measurements for component cross-sections

Component	Outer Layer		Inner Layer	
	Height [†] (mm)	Width [†] (mm)	Height [†] (mm)	Width [†] (mm)
Grille	117	123	N/A	N/A
upper limit	120	131	N/A	N/A
lower limit	114	115	N/A	N/A
Bumper	92	115	49	76
upper limit	96	122	52	81
lower limit	88	108	46	74
Lower bumper	69	109	46	80
upper limit	75	112	52	81
lower limit	63	104	40	79

[†] Dimensions measured after these parts are fabricated in accordance with 5.10 and fixed to the rigid support base.

5.10 Buck Plastic Component Fabrication/Construction Method

A press brake with punch radius of 1 mm was used to shape the grille component. The same press brake with a punch radius of 1 mm was also used for the lower bumper and bumper, using a 60 degree die with a width of 24 mm. The polyethylene is required to be manually held together as the polyethylene buck components are assembled and secured to their corresponding rigid supports on the buck (Figures 11 through 13).

5.11 Storage of Buck Components

If the polyethylene components are required to be stored during a time period between fabrication and attachment to the buck, then storage considerations are required in order to prevent the polyethylene components from losing their originally fabricated shapes. Specifically, all components should be stored at room temperature ($20\text{ }^{\circ}\text{C} \pm 4\text{ }^{\circ}\text{C}$), and the fabrication bend angle for each component should be maintained using external support. For example, adhesive tape has been successfully employed to secure the component edges such that the intended bend angle is maintained during storage periods.

5.12 Impact Speed Range

It is intended that the buck should be used at an impact speed range of 30 to 50 km/h.

5.13 Pedestrian Impact Condition and Duration

It is intended that the buck should be used in full-scale pedestrian tests in which the pedestrian impact window of interest includes the initiation of car-pedestrian impact until the time of pedestrian head contact with the car. It is intended that no braking or other deceleration will be applied during the impact.

6. BUCK CERTIFICATION

The goal of this section is to provide a methodology for certifying a buck using dynamic tests. Specifically, for a buck built in accordance with this document, dynamic tests will be performed on individual buck components (lower bumper, bumper, grille, hood edge, hood, and windshield). The dynamic test for each component utilizes an impact energy that is representative of the absorbed energy for that component during a 40 km/h impact with a pedestrian dummy. A newly fabricated buck should be tested, and all the response requirements should be met prior to full-scale testing with a pedestrian dummy. The same procedure should be used whenever replacement parts of the generic buck are fabricated from a different batch of materials.

6.1 Impactors

6.1.1 Lower Bumper, Bumper, Grille, and Hood Edge Tests

The drawings of the rigid impactor to be used to test the lower bumper, bumper, grille and hood edge is provided in Figure E1 of Appendix E. In order to measure the force applied to the impactor and to calculate the displacement of the impactor, an accelerometer should be attached to the rigid impactor at the location specified in Figure E2 of Appendix E via the plate installed in front of the support plate of the cylindrical loading surface.

6.1.2 Hood Tests

Detailed drawings of the rigid impactor to be used to test the hood are provided in Figures E3 through E5 of Appendix E. In order to measure the force applied to the impactor and to calculate the displacement of the impactor, an accelerometer should be attached to the rigid impactor at the location specified in Figure E6 of Appendix E.

6.1.3 Windshield Tests

The impactor used for the windshield certification test is the standard Euro NCAP adult headform (Euro NCAP 2004).

6.2 Test Specifications

This buck was developed to be used for the research related to the pedestrian accidents. Therefore, the test specification was defined in accordance with the test specifications used in the global technical regulation (GTR) on pedestrian safety (UNECE 2009).

6.2.1 General Test Conditions and Data Processing

6.2.1.1 Mounting of Buck Component

At the time of testing, the buck component should be securely mounted.

6.2.1.2 Humidity and Temperature

The test facility and storage area should have a relative humidity of $40\% \pm 30\%$ and stabilized temperature of $20\text{ }^{\circ}\text{C} \pm 4\text{ }^{\circ}\text{C}$.

6.2.1.3 Time Restriction for Certification Test

Each test should be completed within 2 hours of when the buck component to be used is removed from the controlled storage area.

6.2.1.4 Accuracy of Velocity Measurement

The velocity of the impactor should be measured at some point during the free flight before impact, in accordance with the method specified in ISO 3784:1976. The accuracy of velocity measurement shall be $\pm 0.01\text{ m/s}$.

6.2.1.5 Calculation of Force and Deflection

The force should be calculated by multiplying the acceleration in the impact direction measured by the accelerometer attached to the impactor by the mass of the impactor filtered by the channel class CFC 180. The deflection should be calculated by double integrating the acceleration filtered by the channel class CFC 180.

6.2.2 Preparation of the Buck Component

The buck component should be stored during a period of at least 4 hours in a controlled storage area with the condition defined in 6.2.1.2. After removal from the storage the buck component should not be subjected to conditions other than those pertaining to the test area.

6.2.3 Test Impactor Setup for Hood Edge, Grille, Bumper, and Lower Bumper

The impactor for the certification tests on the lower bumper, bumper, grille, and hood edge is comprised of the impactor defined in 6.1.1 and the guidance components (linear slider for the upper legform test). The total mass of the impactor including the guidance components which are effectively part of the impactor during the impact shall be $6.0\text{ kg} \pm 15\%$. The channel amplitude class (CAC) response value, as defined in ISO 6487:2002, shall be 500 g for the acceleration.

6.2.4 Test Impactor Setup for Hood

The impactor for the certification test on the hood is defined in 6.1.2. The impactor is to be mounted to a drop carriage for use in a drop tower that can provide the required 6.0 m/s impact velocity. The total mass of the impactor and drop carriage shall be $12.0\text{ kg} \pm 15\%$. The channel amplitude class (CAC) response value, as defined in ISO 6487:2002, shall be 500 g for the acceleration.

6.2.5 Test Impactor Setup for Windshield

The impactor for the certification test on the windshield is defined in 6.1.3. The impactor is to be used with the standard head cannon (or equivalent device) used in Euro NCAP pedestrian headform tests.

6.3 Test Procedures

6.3.1 Lower Bumper, Bumper, Grille, and Hood Edge

The certification test for the lower bumper, bumper grille and hood edge is conducted by using the rigid impactor defined in 6.2.3. Figure 14 shows an example for the test setup of the certification test for these components. The rigid impactor for testing the lower bumper, bumper, grille and hood edge was designed to be attached to the slider of the upper legform impactor as defined in Euro NCAP Pedestrian Test Protocol (EEVC WG17 1998, EuroNCAP 2001 and 2004) to allow the use of generic pedestrian subsystem test machine. The test procedures were defined in accordance with the test procedures used in the GTR on pedestrian safety (UNECE 2009).

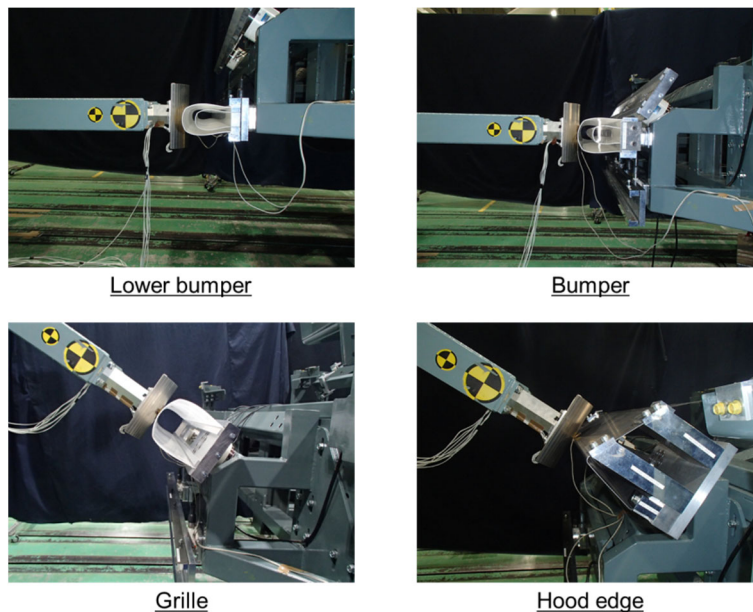


Figure 14 - Example for the test setup of the certification test for the lower bumper, bumper, grille, and hood edge

6.3.1.1 Impact Point

Table 4 and Figure 15 illustrate the impact points for the buck components. Target point is defined as the first contact point of the center of the impactor. The point of first contact of the impactor shall be within ± 10 mm tolerance to the selected impact point.

Table 4 - Target point of the impactor

	Impact section	Target point
Lower bumper	Vertical longitudinal median section	Vertical center of the component fixation
Bumper		
Grille		
Hood edge		Front edge of the hood edge

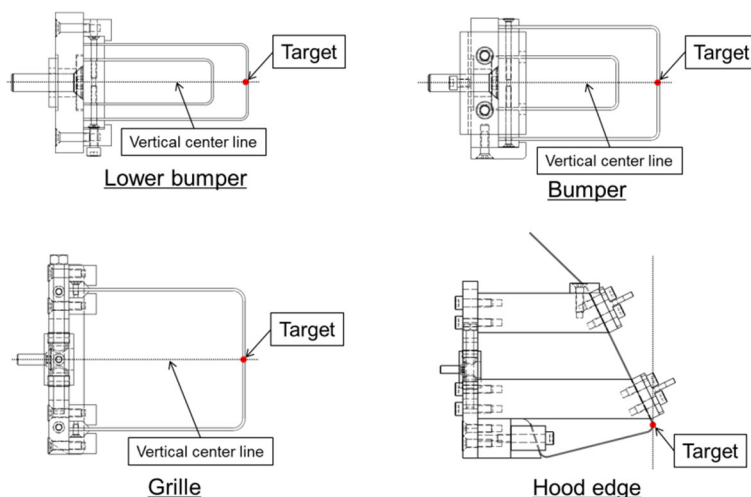


Figure 15 - Target point of the impactor in the vertical longitudinal median section

6.3.1.2 Impactor Motion

The guidance system should be fitted with low friction guides, insensitive to off-axis loading, that allow the impactor to move only in the specified direction of impact, when in contact with the buck component. The guides should prevent motion in other directions including rotation about any axis.

6.3.1.3 Impact Velocity

Table 5 shows the impactor velocity at the time of impact. The impact velocity shall be within $\pm 2\%$ tolerance.

Table 5 - Impact velocity

	Target velocity [m/s]	Tolerance
Bumper lower	4.5	$\pm 2\%$
Bumper	8.0	
Grille	3.1	
Hood edge	7.4	

6.3.1.4 Impact Angle

The direction of impact should be perpendicular to the rigid support of the buck component within ± 2 degree tolerance as shown in Figure 16. The direction of impact should be in the longitudinal vertical plane of the buck components to be tested.

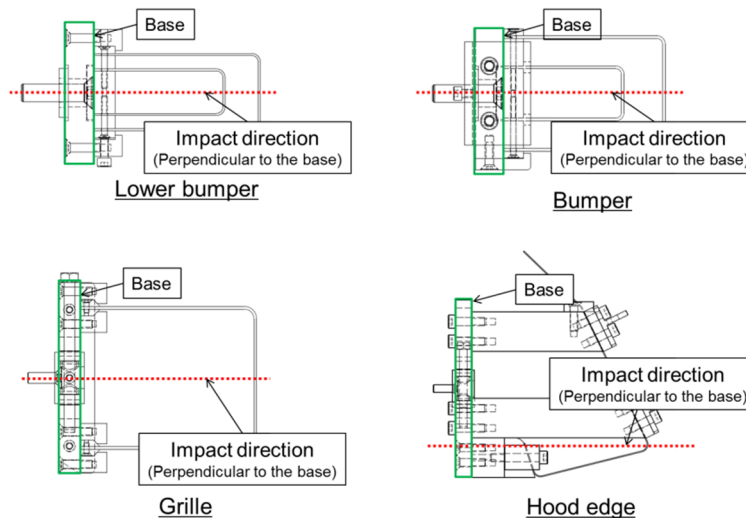


Figure 16 - Direction of impact for each component

6.3.2 Hood

The certification test for the hood is conducted using a drop tower to drop the rigid chestform impactor and the linear slider with a total mass of 12 kg downward vertically toward the hood at a velocity of 6 m/s (Figure 17). The hood is held in a horizontal position parallel to the laboratory floor and is supported at its four corners as illustrated in Figure 17. As described in D.2.2, the undeformed hood is held in a horizontal position parallel to the floor of the laboratory prior to the test.

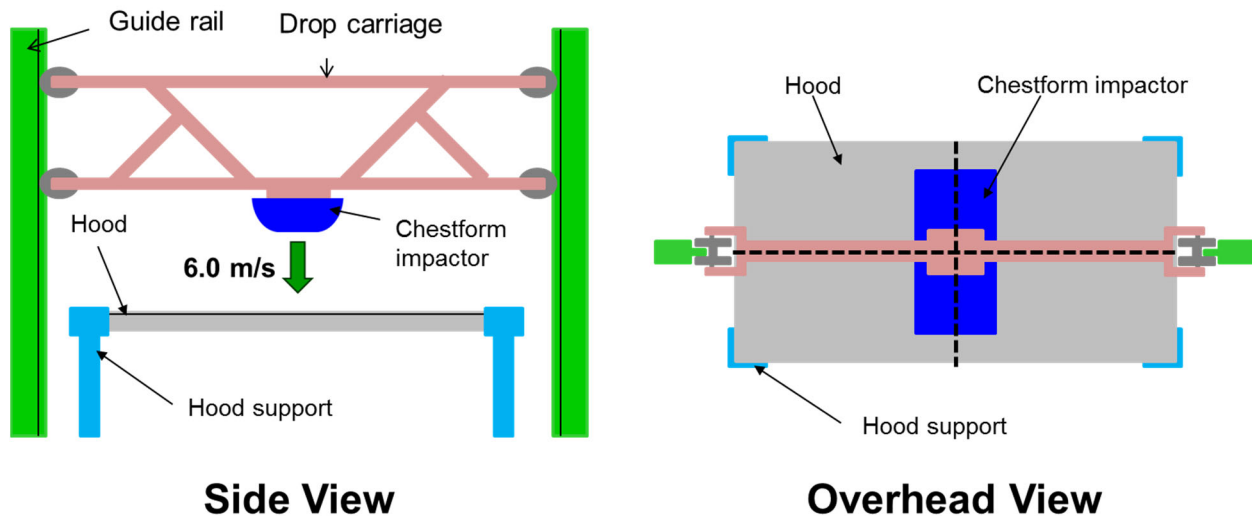


Figure 17 - Certification test setup for generic buck hood

6.3.2.1 Impact Point

The impact location for the hood certification test is the center of the hood within ± 10 mm of this specified location. The impactor is aligned such that the long axis of the impactor is oriented along the longitudinal centerline of the hood within ± 2 degrees of this specified orientation.

6.3.2.2 Impactor Motion

The guidance system should be fitted with low friction guides, insensitive to off-axis loading, that allow the impactor to move only in the specified direction of impact, when in contact with the hood. The guides should prevent motion in other directions including rotation about any axis.

6.3.2.3 Impact Velocity

The velocity of the impactor at the time of impact shall be $6.0 \text{ m/s} \pm 2\%$.

6.3.2.4 Impact Angle

The impactor should make contact with the hood such that the impacting surface of the impactor is aligned to be parallel to that of the hood within ± 2 degrees of the specified orientation.

6.3.3 Windshield

The certification test for the windshield is conducted using a head cannon, to launch a headform impactor (described in 6.1.3) into the center of the windshield at 11.1 m/s . The windshield should be comprised of 8 mm polycarbonate described in 5.7. The tightening torque for the clumps should be $22 \text{ Nm} \pm 2 \text{ Nm}$. During the test, the windshield is secured horizontally, parallel to the laboratory floor, and the headform is shot perpendicular to the windshield surface. Figure 18 provides a schematic illustration of the test setup for the windshield certification tests. Figure 19 illustrates the details of how the windshield is secured to the base frame using a total of nine aluminum clamps. Specifically, the clamps and the clamping configuration are the same as those used to secure the windshield on the actual generic buck.

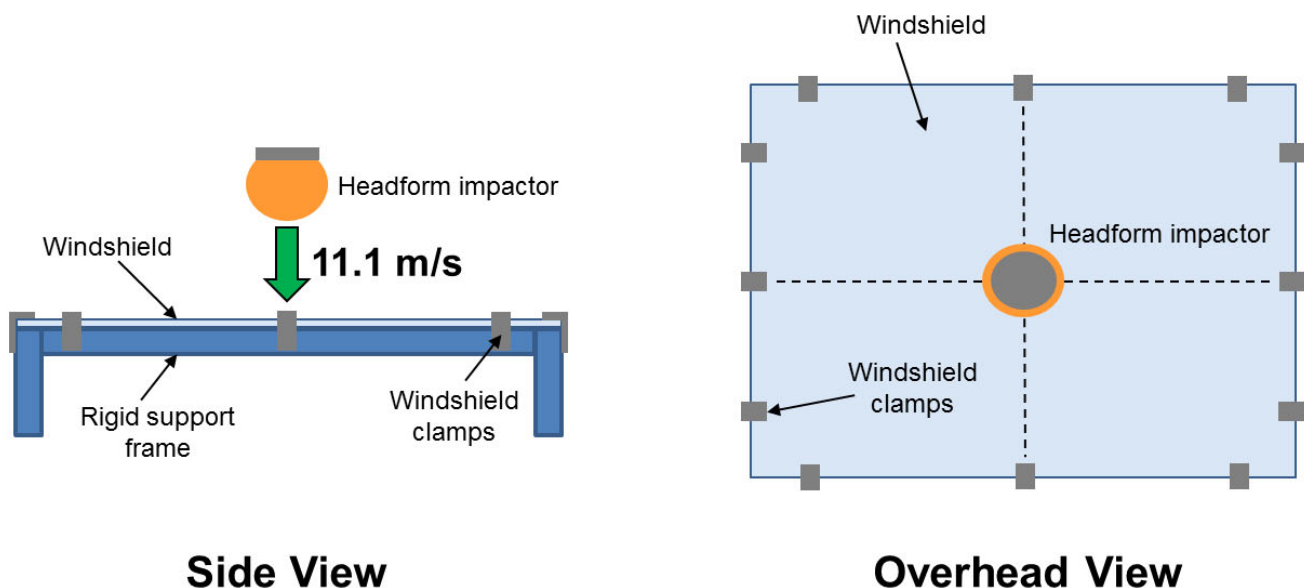


Figure 18 - Certification test setup for the buck windshield

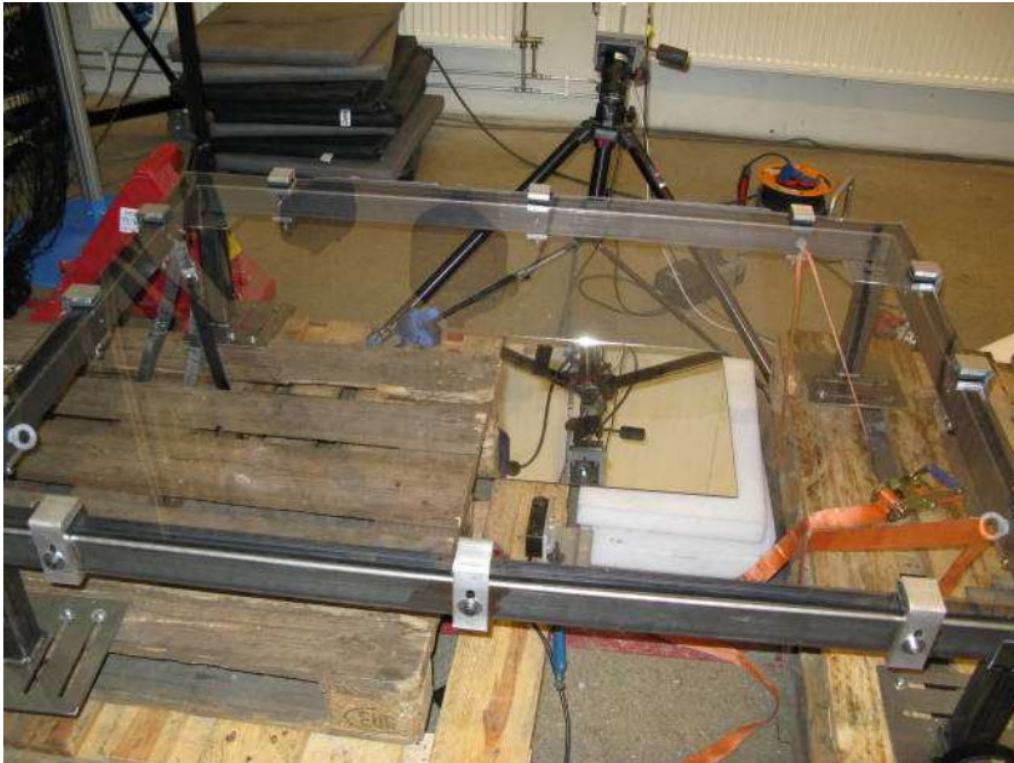


Figure 19 - Windshield secured to baseframe using aluminum clamps

6.3.3.1 Impact Point

The impact location for the windshield certification test is the center of the windshield, within ± 10 mm of this specified location.

6.3.3.2 Impactor Motion

The head cannon should be capable of launching the impactor at the specified velocity in a direction that is perpendicular to the surface of the windshield. The impactor should not move in other directions and should not rotate about any axis prior to contacting the surface of the windshield.

6.3.3.3 Impact Velocity

The velocity of the impactor at the time of impact shall be $11.1 \text{ m/s} \pm 2\%$.

6.3.3.4 Impact Angle

The impactor shall be launched perpendicular to the surface of the windshield, within ± 2 degrees of this specified impact angle.

6.4 Response Requirements

6.4.1 Lower Bumper

The force deflection response of the lower bumper should be calculated using the impactors, test specifications and test procedures defined in 6.1.1, 6.2.1 to 6.2.3 and 6.3.1, respectively. Figure 20 shows the force-deflection response corridor for the lower bumper. The force-deflection response of the lower bumper should fall within the corridor defined in Figure 20 and Table 6.

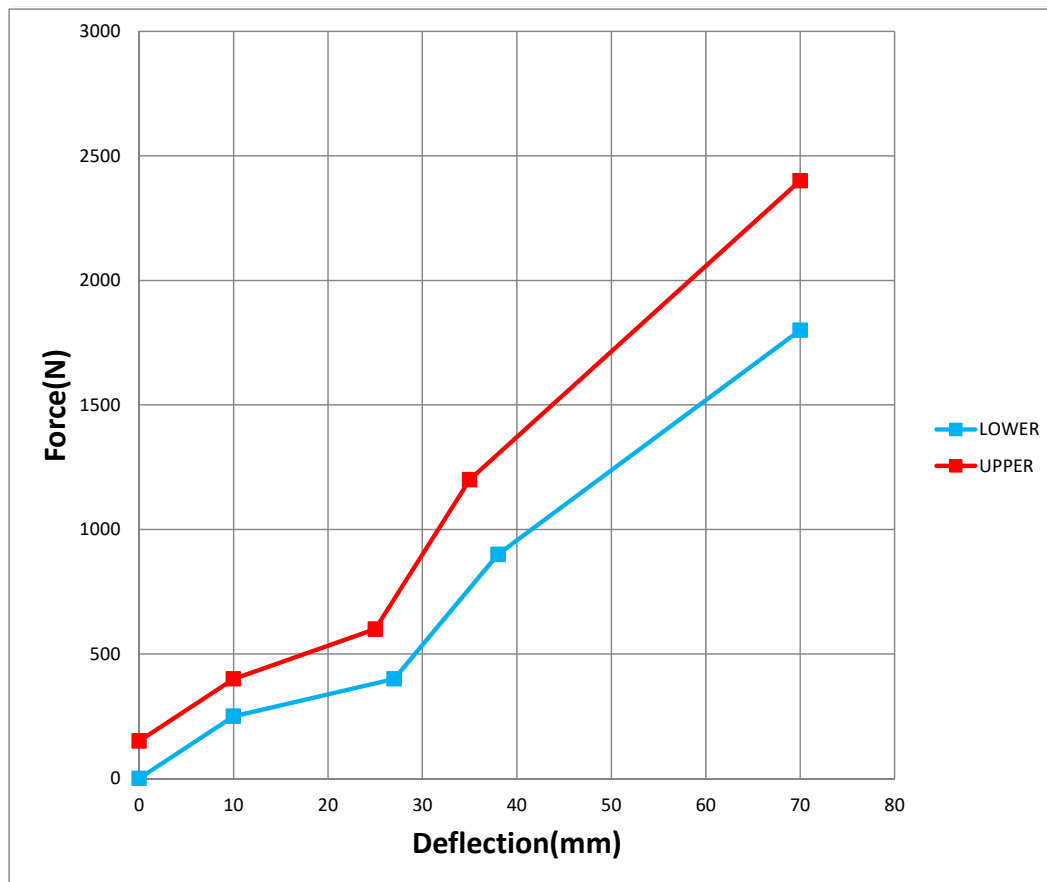


Figure 20 - Force-deflection response corridor for the lower bumper

Table 6 - Corridor for the lower bumper

Upper Bound	Deflection (mm)	Force (N)
	0	150
	10	400
	25	600
	35	1200
	70	2400
Lower Bound	Deflection (mm)	Force (N)
	0	0
	10	250
	27	400
	38	900
	70	1800

6.4.2 Bumper

The force deflection response of the bumper should be calculated using the impactors, test specifications and test procedures defined in 6.1.1, 6.2.1 to 6.2.3 and 6.3.1, respectively. Figure 21 shows the force-deflection response corridor for the bumper. The force deflection response of the bumper should fall within the corridor defined in Figure 21 and Table 7.

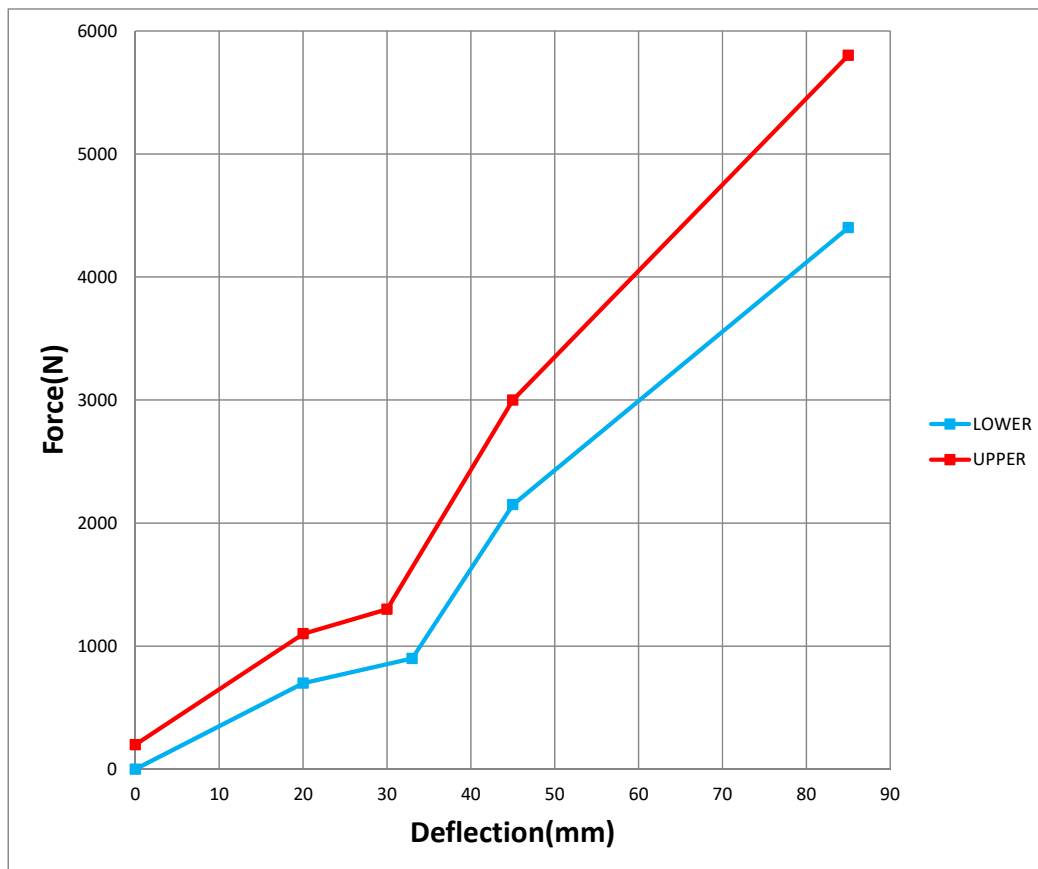


Figure 21 - Force-deflection response corridor for the bumper

Table 7 - Corridor for the bumper

Upper Bound	Deflection (mm)	Force (N)
	0	200
	10	1100
	30	1300
	45	3000
	85	5800
Lower Bound	Deflection (mm)	Force (N)
	0	0
	20	700
	33	900
	45	2150
	85	4400

6.4.3 Grille

The force deflection response of the grille should be calculated using the impactors, test specifications and test procedures defined in 6.1.1, 6.2.1 to 6.2.3 and 6.3.1, respectively. Figure 22 shows the force-deflection response corridor for the grille. The force deflection response of the grille should fall within the corridor defined in Figure 22 and Table 8.

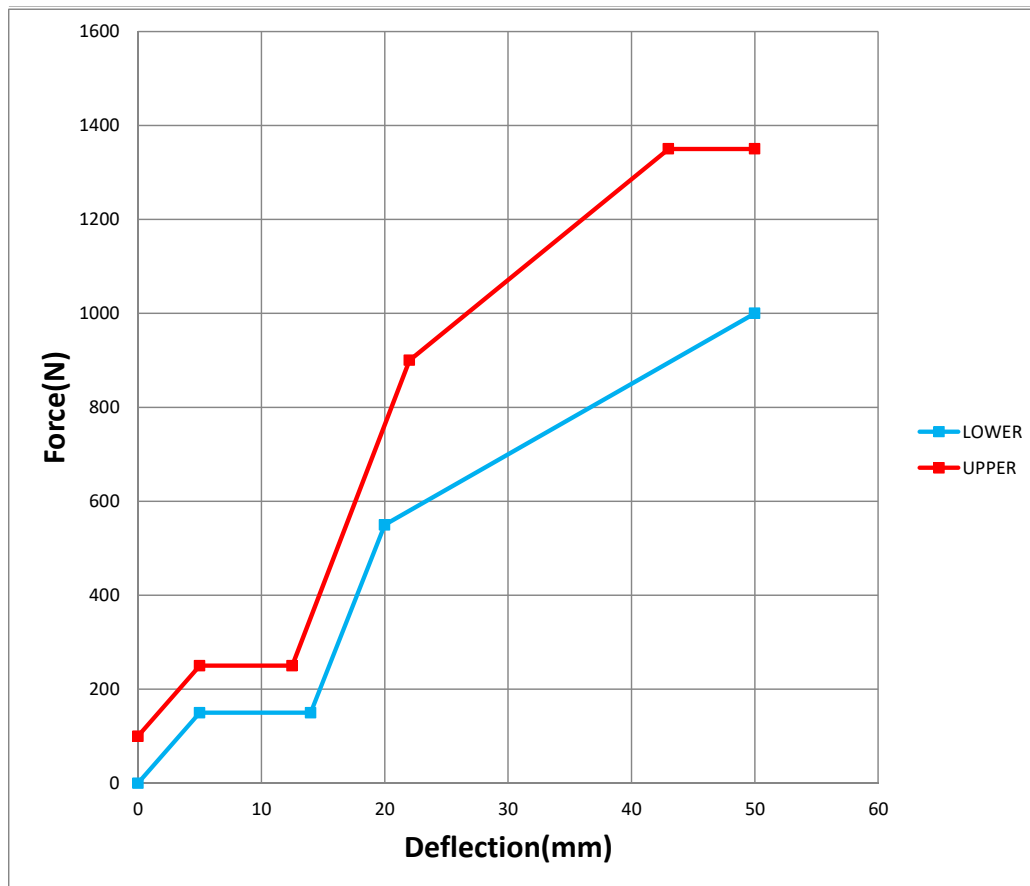


Figure 22 - Force-deflection response corridor for the grille

Table 8 - Corridor for the grille

Upper Bound	Deflection (mm)	Force (N)
	0	100
	5	250
	12.5	250
	22	900
	43	1350
	50	1350
Lower Bound	Deflection (mm)	Force (N)
	0	0
	5	150
	14	150
	20	550
	50	1000

6.4.4 Hood Edge

The force-deflection response of the hood edge should be calculated using the impactors, test specifications and test procedures defined in 6.1.1, 6.2.1 to 6.2.3 and 6.3.1, respectively. Figure 23 shows the force-deflection response corridor for the hood edge. The force-deflection response of the hood edge should fall within the corridor defined in Figure 23 and Table 9.

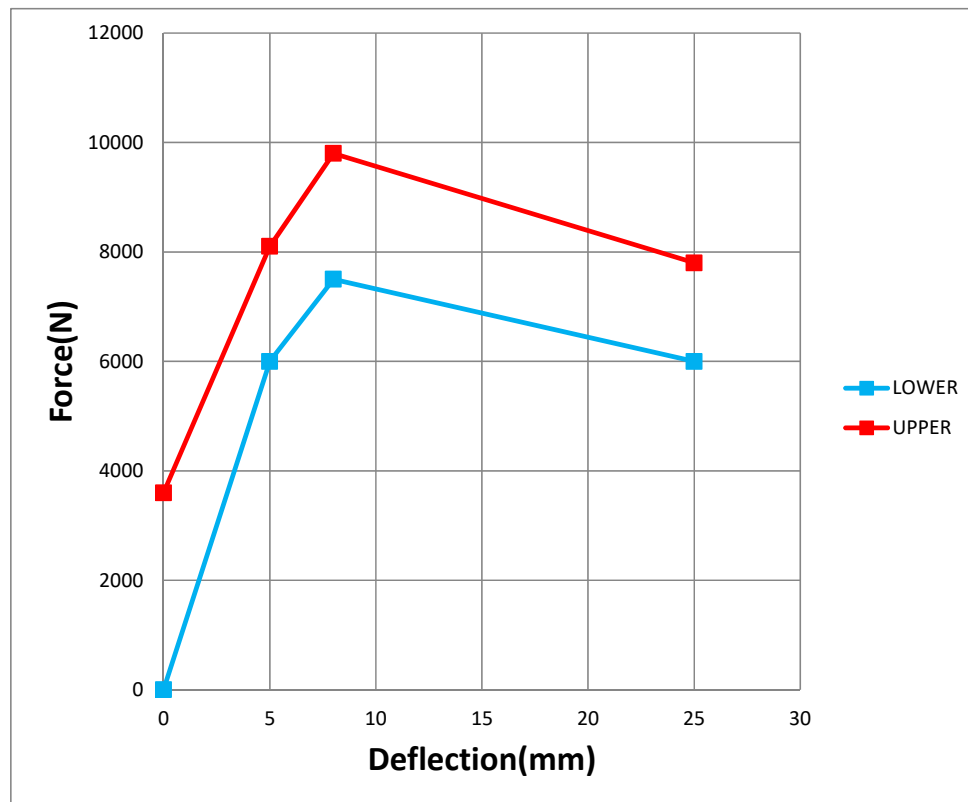


Figure 23 - Force-deflection response corridor for the hood edge

Table 9 - Corridor for the hood edge

Upper Bound	Deflection (mm)	Force (N)
	0	3600
	5	8100
	8	9800
	25	7800
Lower Bound	Deflection (mm)	Force (N)
	0	0
	5	6000
	8	7500
	25	6000

6.4.5 Hood

The force and deflection responses of the hood should be calculated using the impactor defined in 6.1.2, test specifications defined in 6.2.1 to 6.2.2 and 6.2.4 and test procedures defined in 6.3.2. Figure 24 shows the force-deflection response corridor for the hood. The force-deflection response of the hood should fall within the corridor defined in Figure 24 and Table 10. It should be noted that the corridor in Figure 24 does not include the initial inertial peak. As described in D.2.2 of Appendix D, the initial inertial peak is due to the stiffness of the rigid impactor and the simplified geometry of the buck hood, which leads to a flat initial engagement between the corresponding flat surfaces of the impactor and buck hood. Thus, the initial inertial peak is not included in the force-deflection corridor.

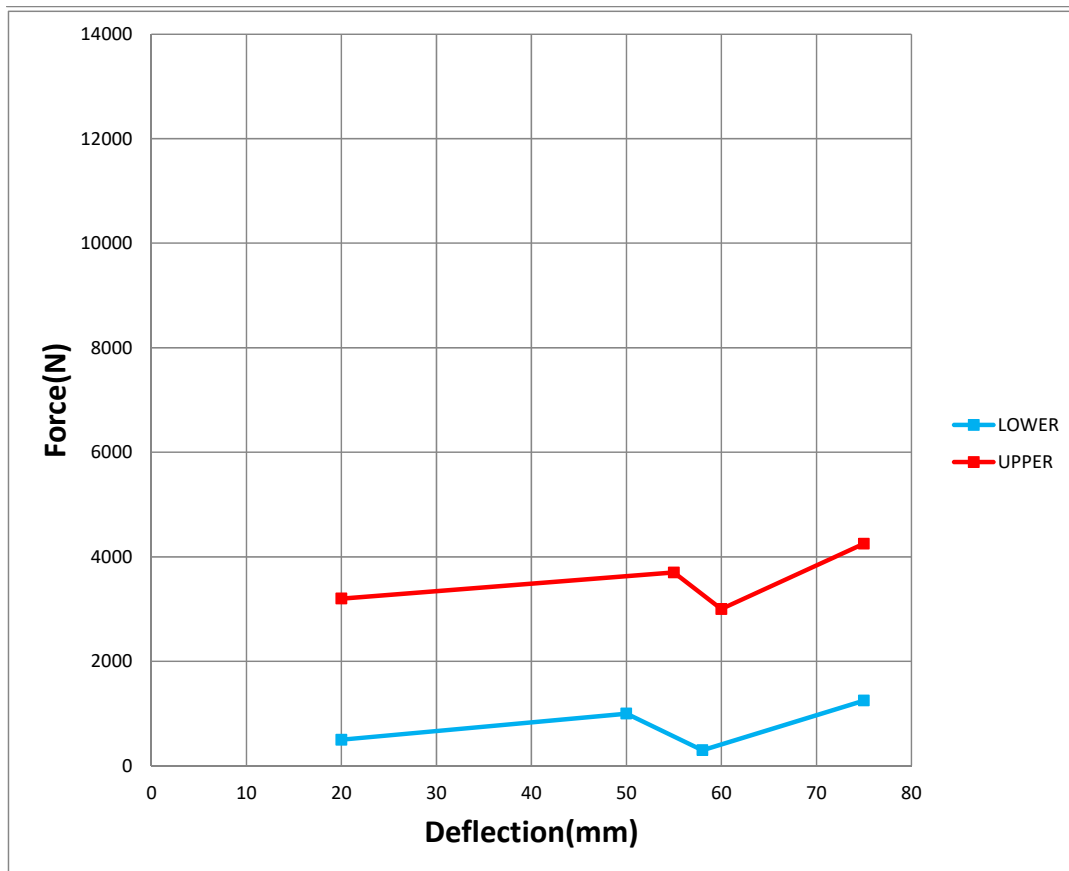


Figure 24 - Force-deflection response corridor for the hood

Table 10 - Corridor for the hood

Upper Bound	Deflection (mm)	Force (N)
	20	3200
	55	3700
	60	3000
	75	4250
Lower Bound	Deflection (mm)	Force (N)
	20	500
	50	1000
	58	300
	75	1250

6.4.6 Windshield

The force and deflection responses of the windshield should be calculated using the impactor defined in 6.1.3, test specifications defined in 6.2.1 to 6.2.2 and 6.2.5 and test procedures defined in 6.3.3, respectively. Figure 25 shows the force-deflection response corridor for the hood. The force-deflection response of the hood should fall within the corridor defined in Figure 25 and Table 11.

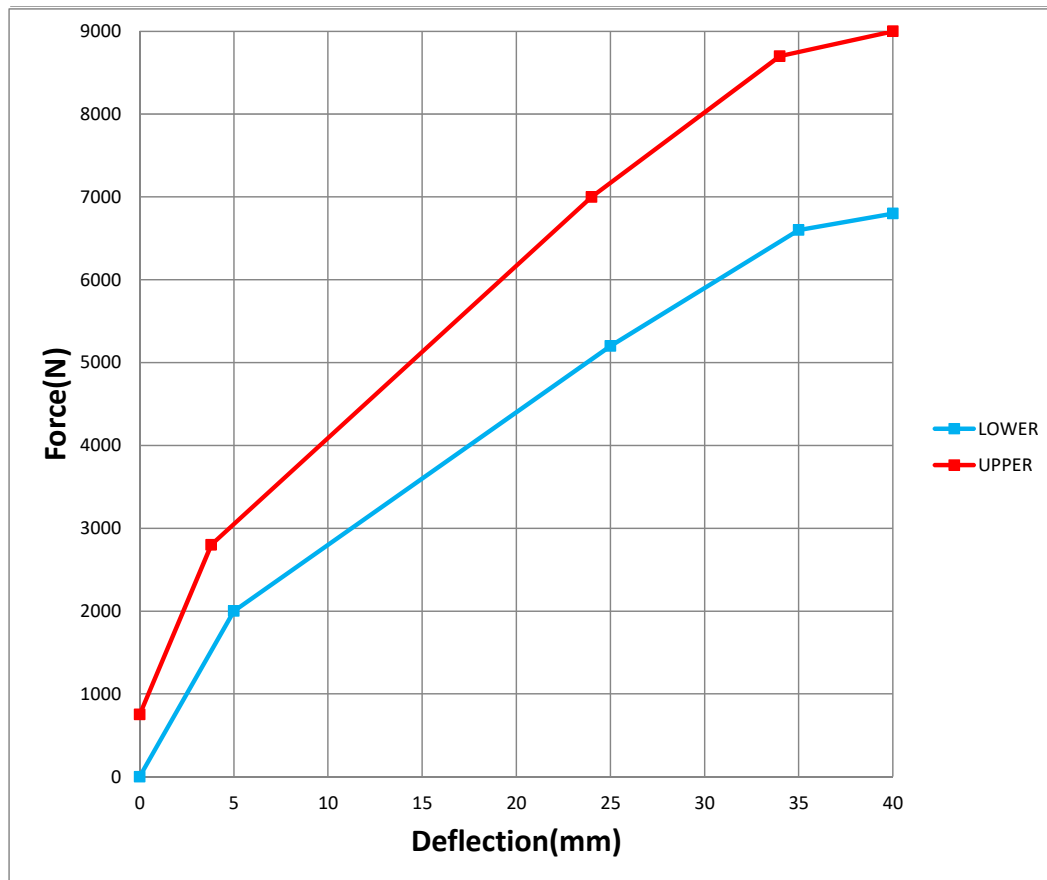


Figure 25 - Force-deflection response corridor for the windshield

Table 11 - Corridor for the windshield

Upper Bound	Deflection (mm)	Force (N)
	0	750
	3.8	2800
	24	7000
	34	8700
	40	9000
Lower Bound	Deflection (mm)	Force (N)
	0	0
	5	2000
	25	5200
	35	6600
	40	6800

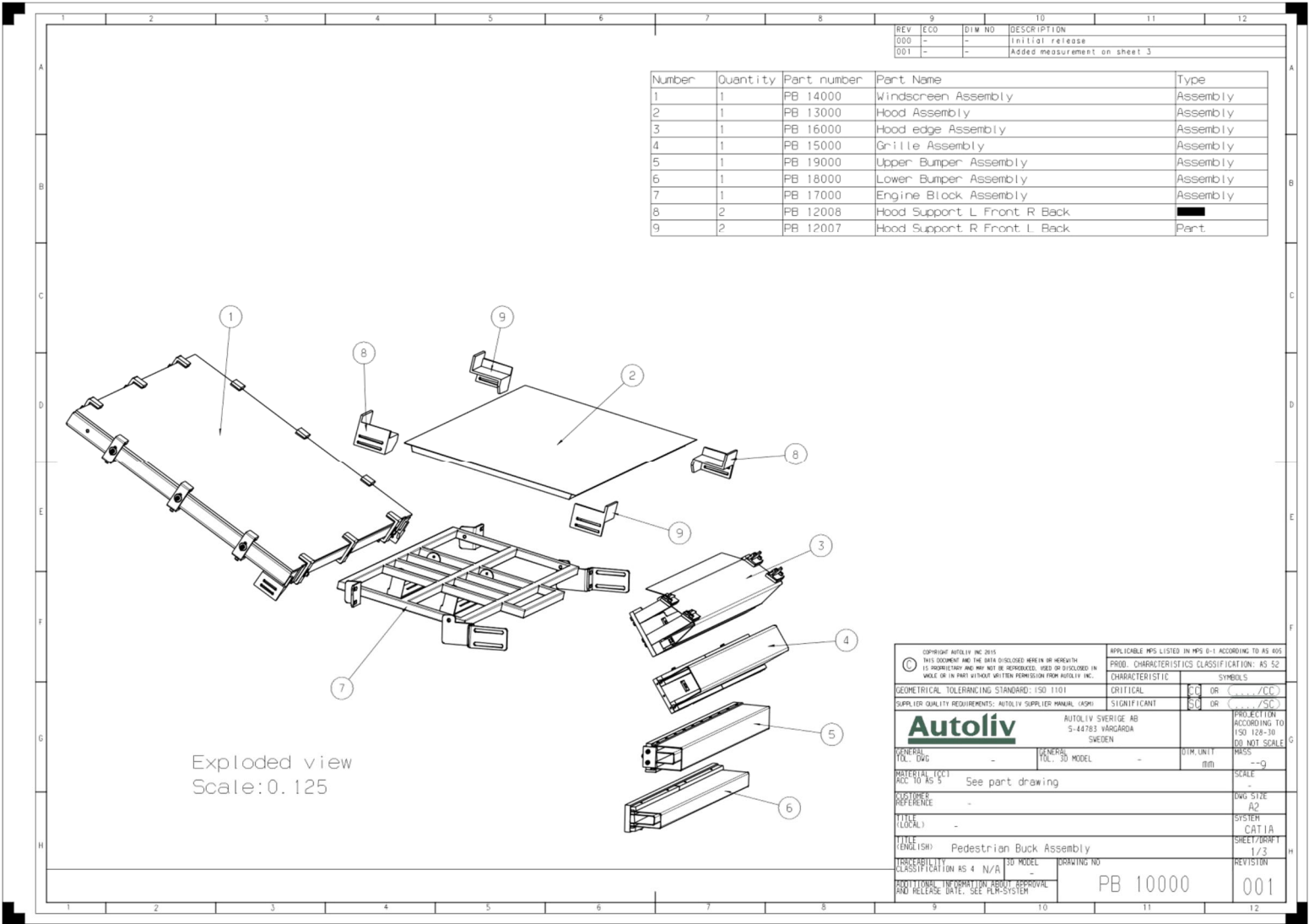
7. NOTES

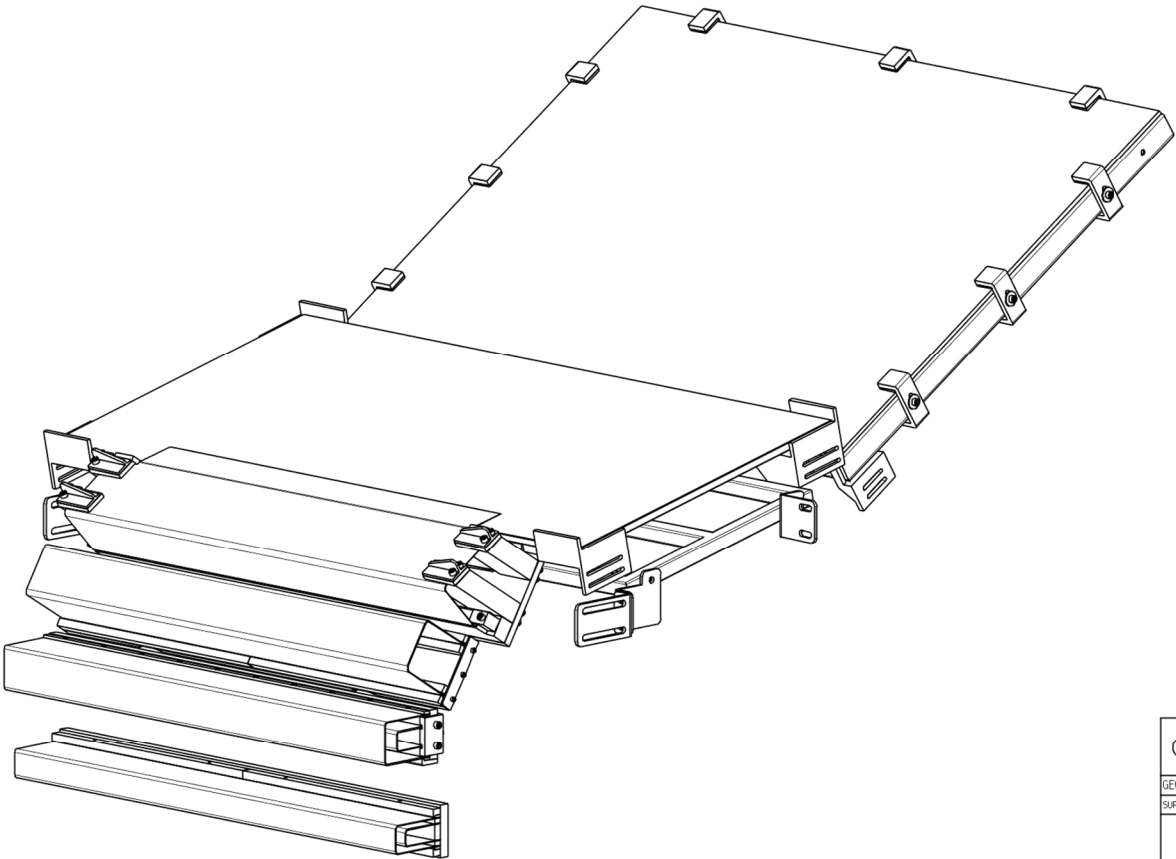
7.1 Revision Indicator

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE HUMAN BIOMECHANICS AND SIMULATIONS STANDARDS COMMITTEE OF
THE OCCUPANT PROTECTION AND BIOMECHANICS STEERING COMMITTEE

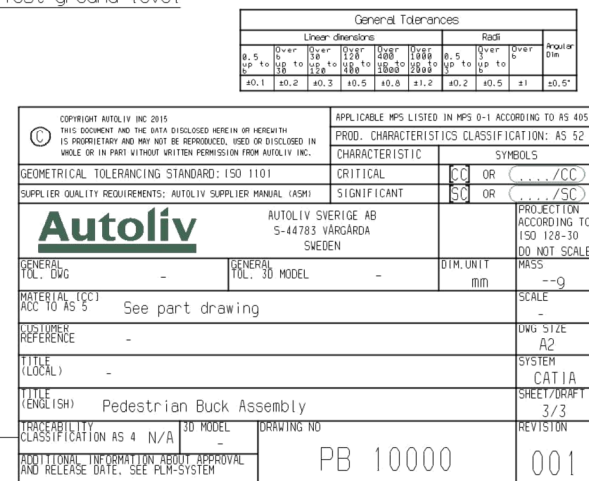
APPENDIX A - DETAILED DRAWINGS OF GENERIC BUCK

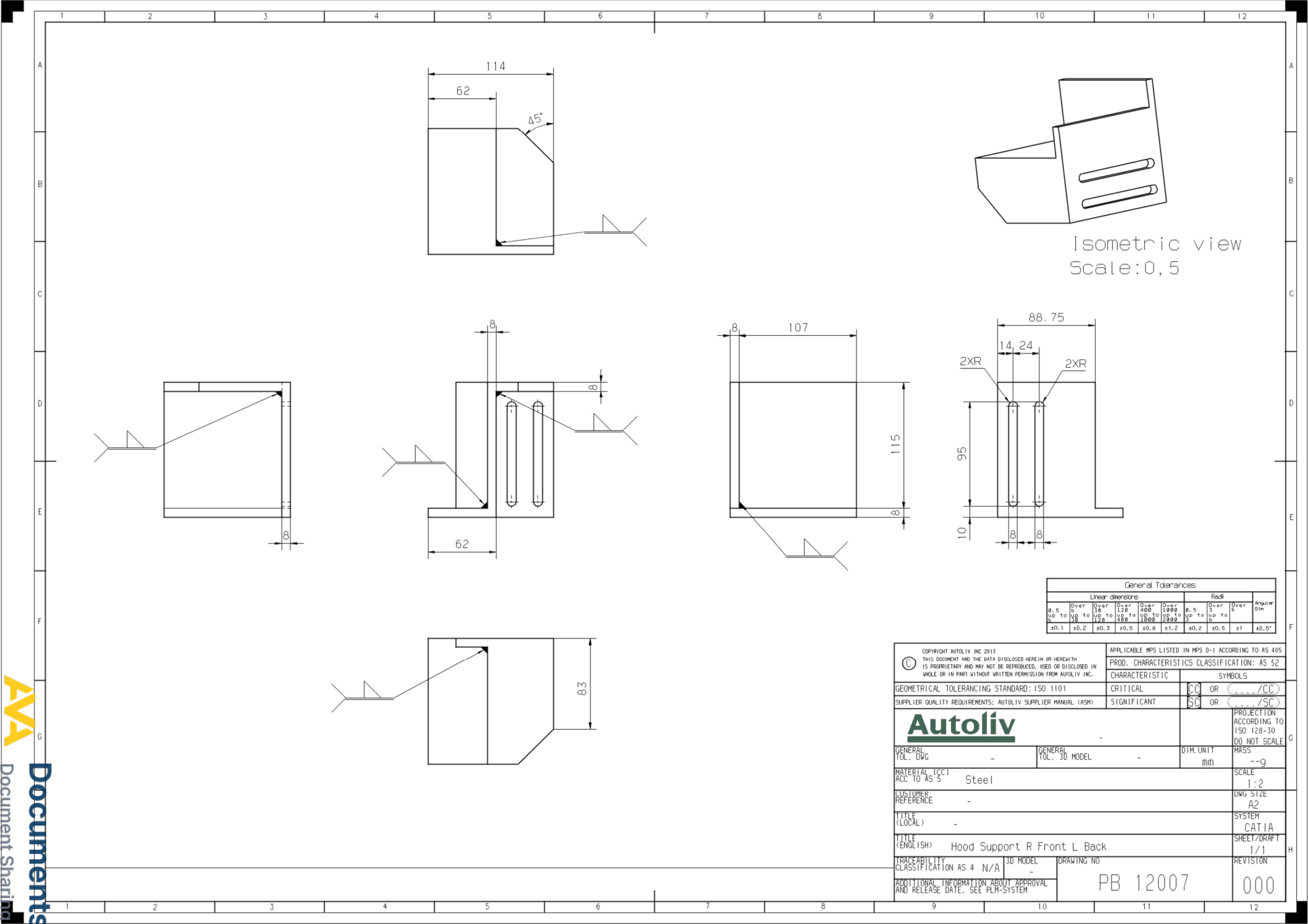


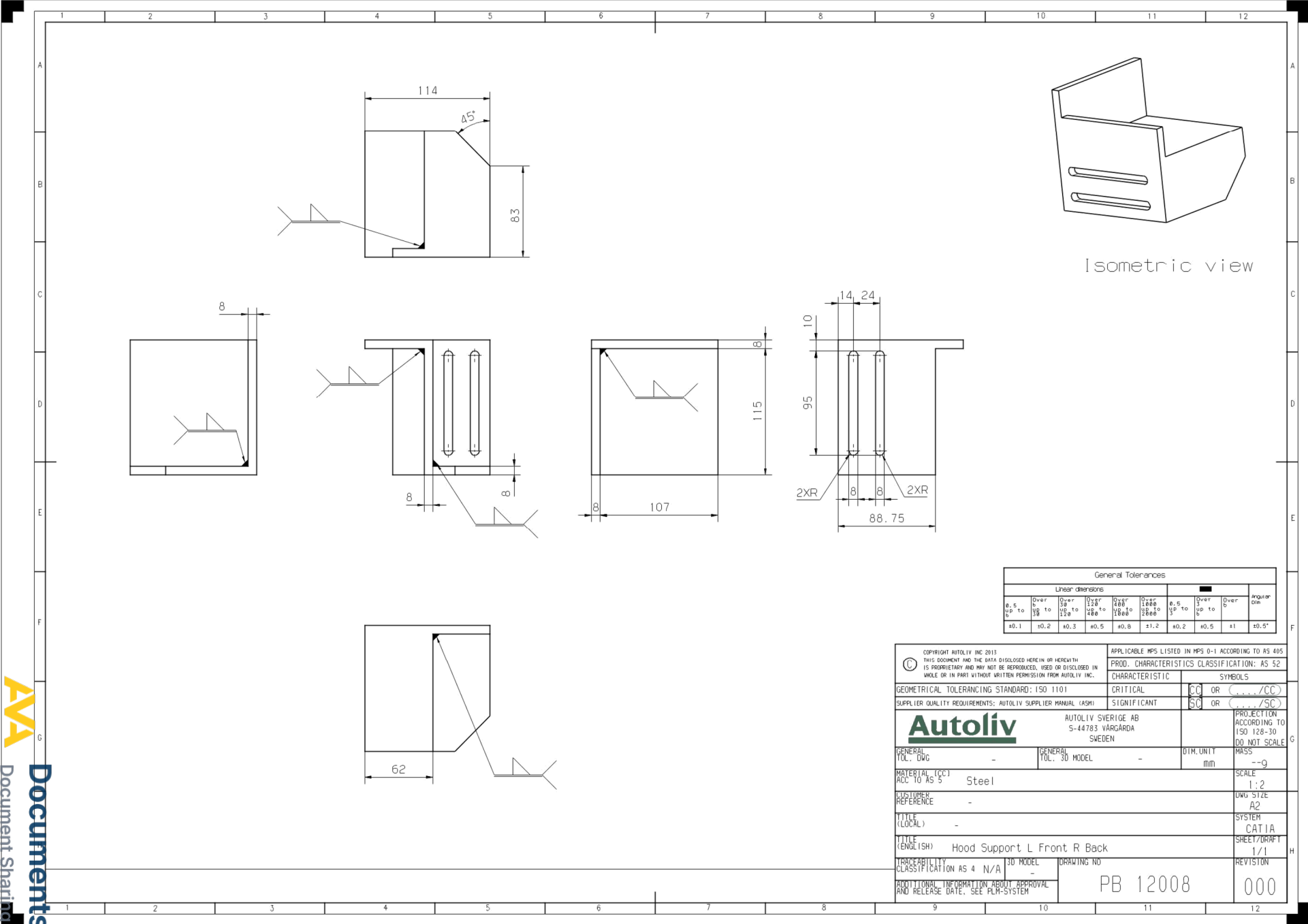


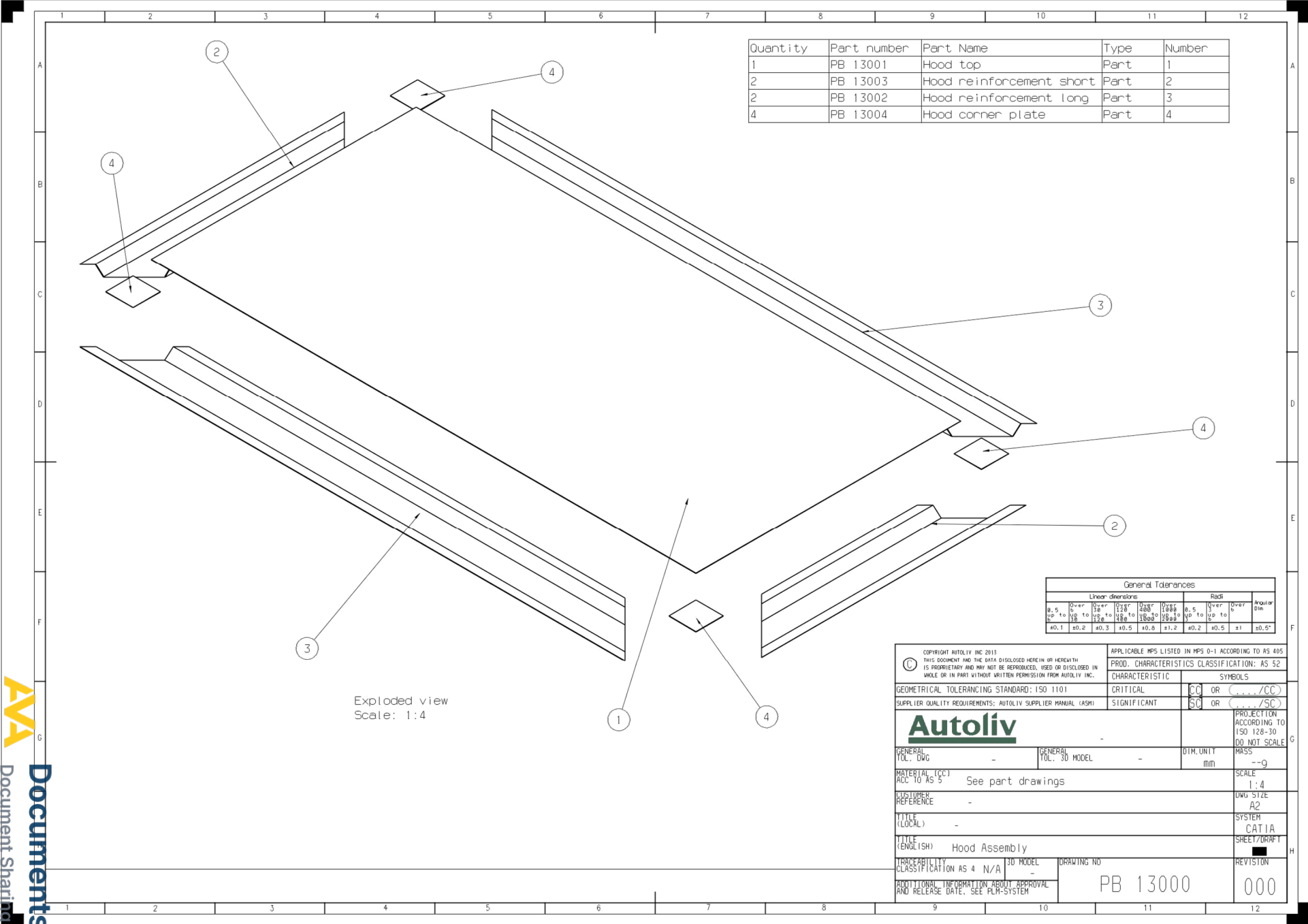
Isometric view
Scale: 1:6

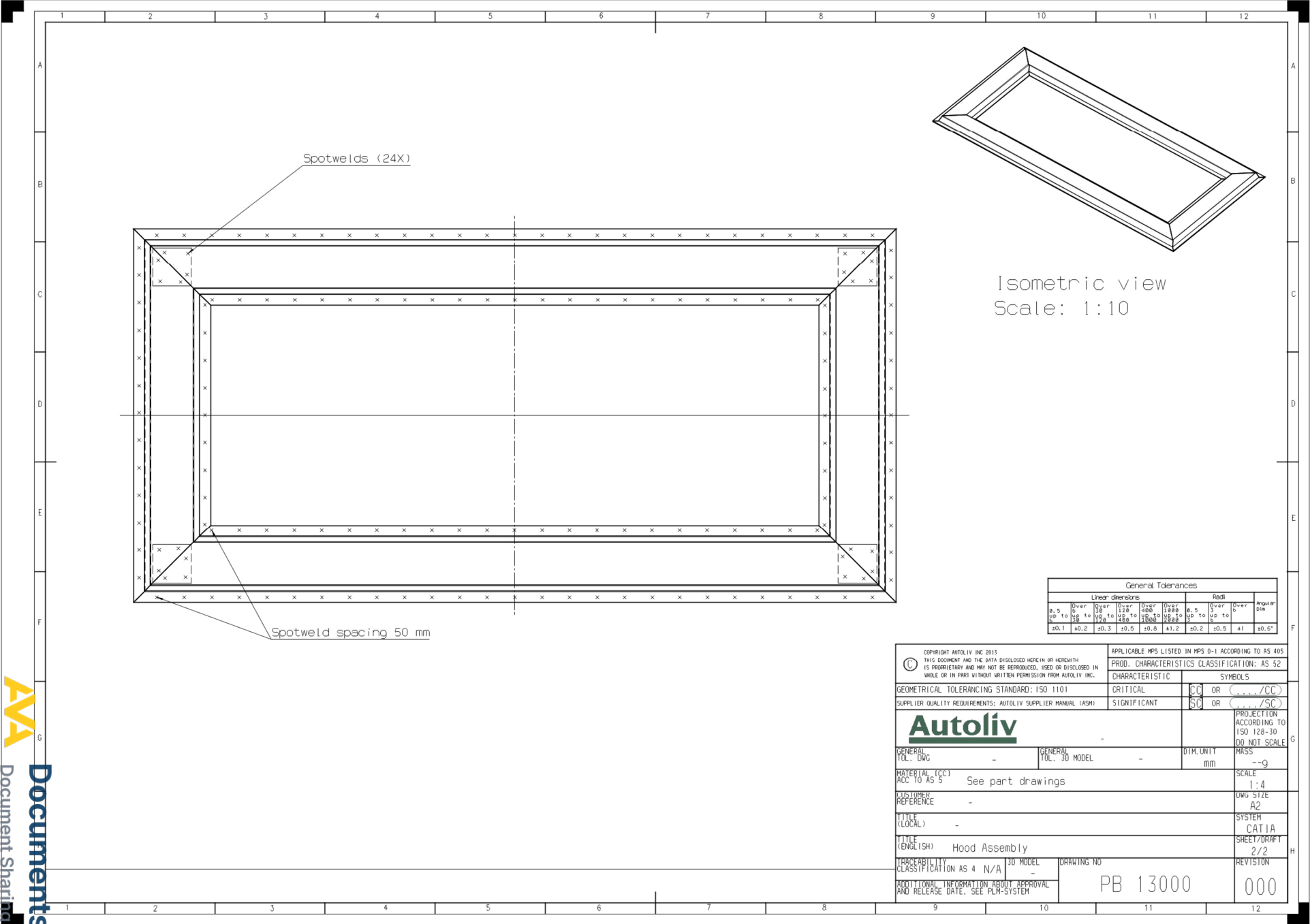
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		SIGNIFICANT	SC OR (---/SC)
Autoliv		AUTOLIV SVERIGE AB S-44783 VÄRGÅRDA SWEDEN	PROJECTION ACCORDING TO ISO 128-30 DO NOT SCALE
GENERAL TOL. DWG	-	GENERAL TOL. 3D MODEL	-
MATERIAL (CC)	See part drawing		SCALE
CLIPPER REFERENCE	-		DWG SIZE A2
TITLE (LOCAL)	-		SYSTEM CATIA
TITLE (ENGLISH)	Pedestrian Buck Assembly		SHEET/DRAFT 2/3
TRACEABILITY CLASSIFICATION AS 4	N/A	3D MODEL	-
ADDITIONAL INFORMATION ABOUT APPROVAL AND RELEASE DATE, SEE PLM-SYSTEM		DRAWING NO	PB 10000
			REVISION 001

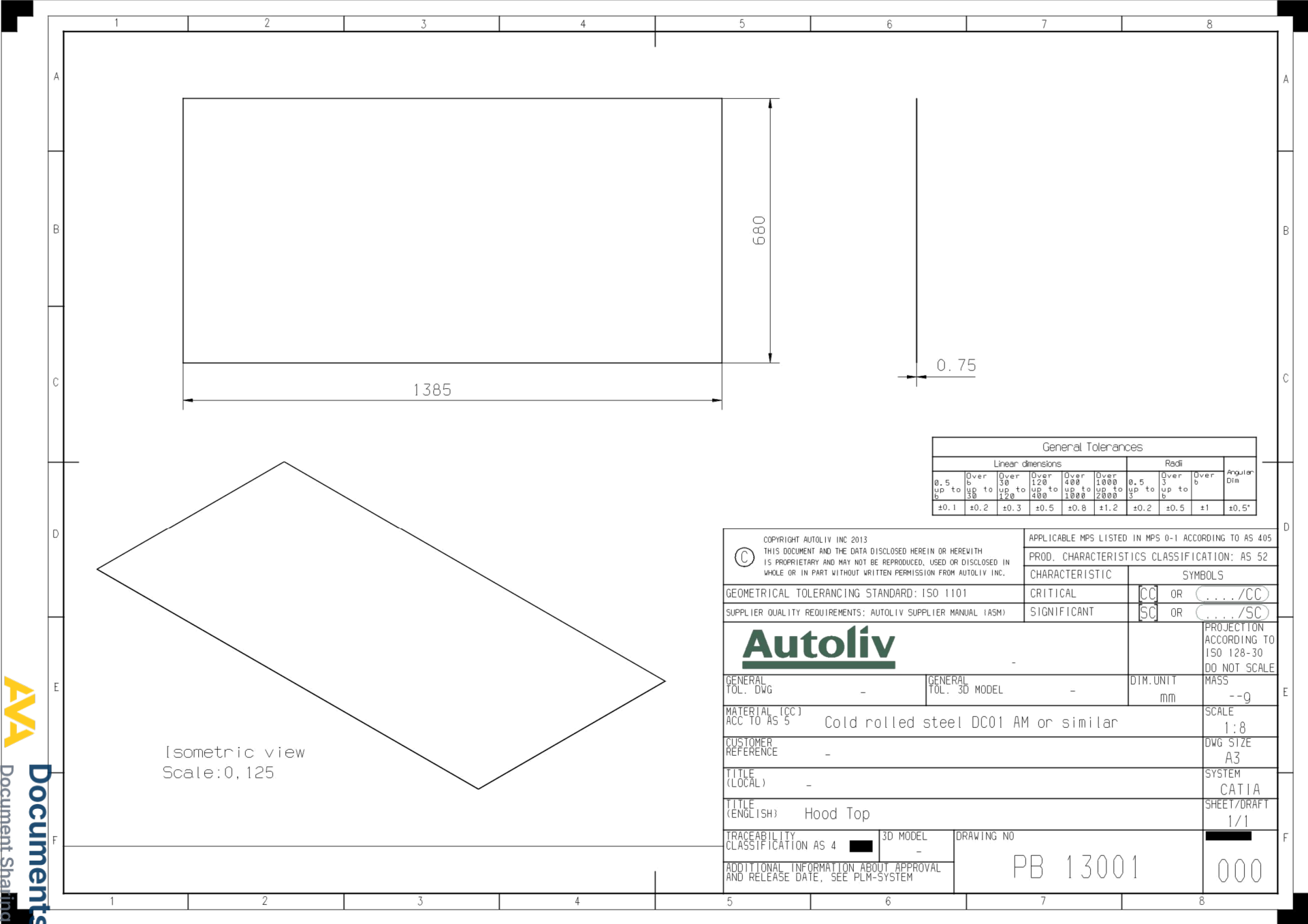


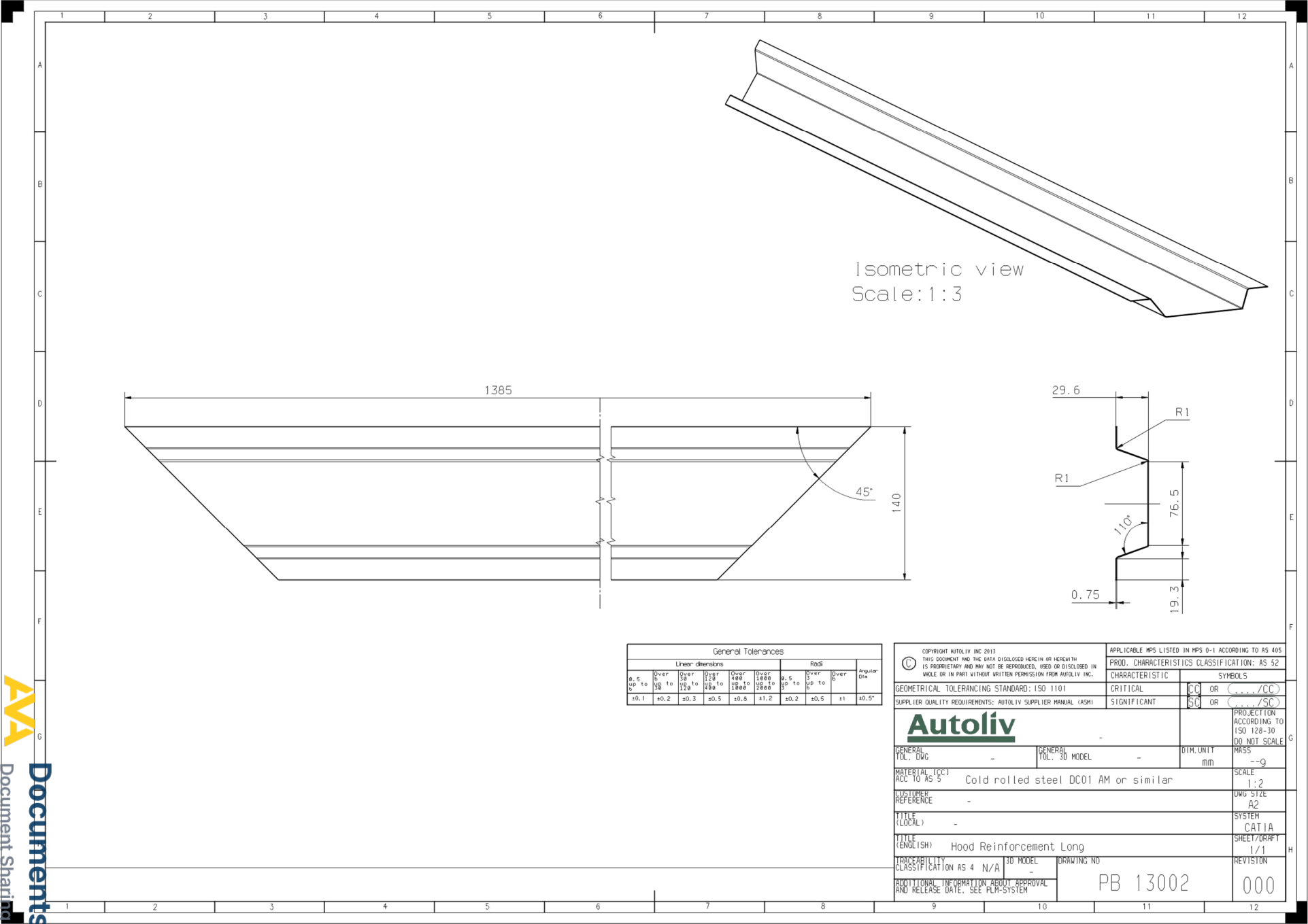


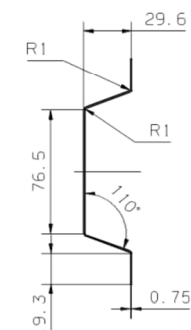
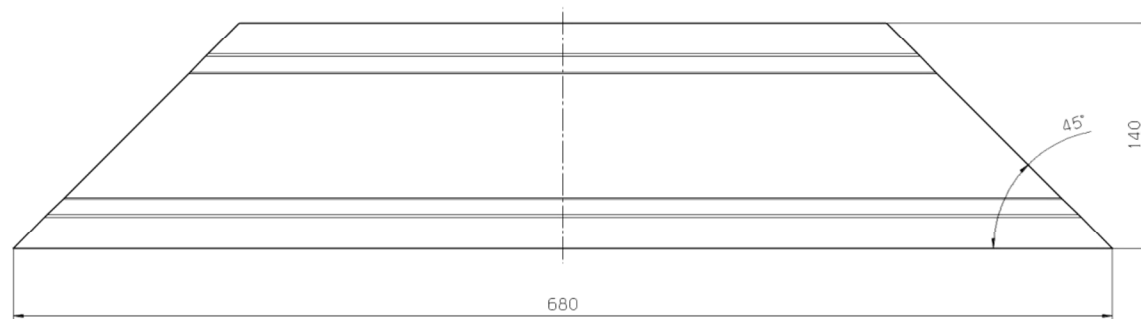






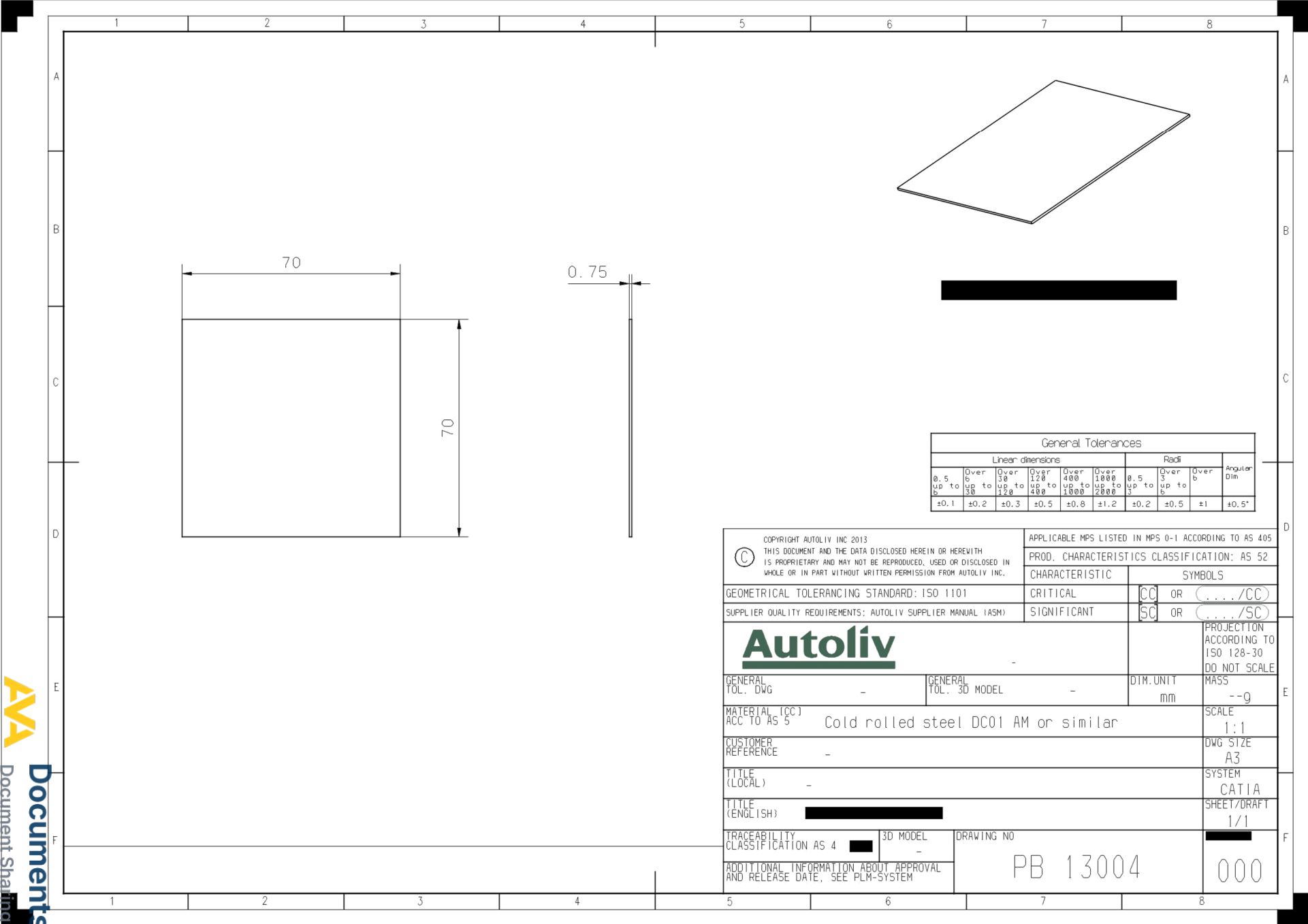






General Tolerances											
Linear dimensions							Radii			Ang. Dim.	
0.5 to 1.0	Over 1.0 to 3.0	Over 3.0 to 12.0	Over 12.0 to 25.0	Over 25.0 to 40.0	Over 40.0 to 100.0	Over 100.0 to 250.0	0.5 to 1.0	Over 1.0 to 3.0	Over 3.0 to 10.0		
±0.1	±0.2	±0.3	±0.5	±0.8	±1.2	±0.2	±0.5	±1	±0		

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		PROD. CHARACTERISTICS CLASSIFICATION: AS 52 CHARACTERISTIC SYMBOLS	
GEOMETRICAL TOLERANCING STANDARD: ISO 1101		CRITICAL	CC OR $\frac{CC}{\sqrt{CC}}$
SUPPLIER QUALITY REQUIREMENTS: AUTOLIV SUPPLIER MANUAL (ASM)		SIGNIFICANT	SC OR $\frac{SC}{\sqrt{SC}}$
Autoliv		PROTECTION ACCORDING TO ISO 128-30 DO NOT SCALE	
GENERAL TOL. DWG	-	GENERAL TOL. 3D MODEL	-
		DTM, UNIT	mm
MATERIAL (CC) ACC TO AS 5		Cold rolled steel DC01 AM or similar	
CUSTOMER REFERENCE		SCALE 1:2	
TITLE (LOCAL)		DWG. SIZE A2	
TITLE (ENG/ISH)		SYSTEM CATIA	
TRACEABILITY CLASSIFICATION AS 4 N/A		3D MODEL	-
		DRAWING NO	
ADDITIONAL INFORMATION ABOUT APPROVAL AND RELEASE DATE, SEE PLM-SYSTEM		SHEET/DRAFT 1/1	
		REVISION	



General Tolerances									
Linear dimensions						Radii		Angular Dim	
0.5 up to b	Over 6 up to 30	Over 30 up to 120	Over 120 up to 400	Over 400 up to 1000	Over 1000 up to 2000	0.5 up to 3	Over 3 up to b		
±0.1	±0.2	±0.3	±0.5	±0.8	±1.2	±0.2	±0.5	±1	±0.5°

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GEOMETRICAL TOLERANCING STANDARD: ISO 1101		PROD. CHARACTERISTICS CLASSIFICATION: AS 52	
SUPPLIER QUALITY REQUIREMENTS: AUTOLIV SUPPLIER MANUAL (ASM)		CHARACTERISTIC	
Autoliv		SYMBOLS	
GENERAL TOL. DWG -		CRITICAL CC OR (.... /CC)	
MATERIAL (CC) ACC TO AS 5 Cold rolled steel DC01 AM or similar		SIGNIFICANT SC OR (.... /SC)	
CUSTOMER REFERENCE -		PROJECTION ACCORDING TO ISO 128-30 DO NOT SCALE	
TITLE (LOCAL) -		DIM. UNIT mm	
TITLE (ENGLISH) [REDACTED]		MASS --g	
TRACEABILITY CLASSIFICATION AS 4 [REDACTED]		SCALE 1:1	
3D MODEL -		DWG SIZE A3	
DRAWING NO PB 13004		SYSTEM CATIA	
ADDITIONAL INFORMATION ABOUT APPROVAL AND RELEASE DATE, SEE PLM-SYSTEM		SHEET/DRAFT 1/1	
		000	

