INTERNATIONAL STANDARD ISO 3449

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Earth-moving machinery — Falling-object protective structures — Laboratory tests and performance requirements

Engins de terrassement — Structures de protection contre les chutes d'objets — Essais de laboratoire et critères de performance

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3449 was drawn up by Technical Committee ISO/TC 127, *Earth-moving machinery,* and circulated to the Member Bodies in February 1974.

It has been approved by the Member Bodies of the following countries :

Australia	Germany	Sweden
Brazil	Israel	Thailand
Bulgaria	Japan	Turkey
Canada	Netherlands	United Kingdom
Chile	New Zealand	U.S.A.
Czechoslovakia	Poland	U.S.S.R.
Finland	Romania	Yugoslavia
France	South Africa, Rep. of	

No Member Body expressed disapproval of the document.

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Earth-moving machinery — Falling-object protective structures — Laboratory tests and performance requirements

1 SCOPE

1.1 This International Standard sets out

a) the laboratory tests for measurement of structural characteristics and

b) the requirements for performance

of a falling-object protective structure (FOPS), and intimately relates to the deflection-limiting volume (DLV) (see ISO 3164).

1.2 The laboratory tests are a means of testing the characteristics of the structures used to protect the operator from localized impact penetration and indirectly of the load-carrying capacity of the supporting structure to resisting impact loading.

1.3 This International Standard is intended to establish a consistent, repeatable means of evaluating characteristics of falling-object protective structures (FOPS) under loading and to prescribe performance requirements for these structures under such loading.

2 FIELD OF APPLICATION

2.1 This International Standard applies to the following types of operator-controlled machine :

- rubber-tyred front-end loaders and dozers;
- rubber-tyred motor graders;
- rubber-tyred prime movers;
- crawler-tractor loaders and dozers.

2.2 Excluded from this International Standard are :

- self-propelled compactors;
- drills;
- paving machines;
- rubber-tyred skid-steer machines;
- machines having a power rating less than 15 kW (20 hp);
- belt loaders;
- excavators;
- cranes;
- drag lines.

3 REFERENCES

ISO 3164, *Earth-moving machinery — Laboratory evaluations of roll-over and falling-object protective structures — Specification for the deflection-limiting volume.*

ISO 3471, *Earth-moving machinery — Roll-over protective structures — Laboratory tests and performance requirements.*

4 DEFINITIONS

For the purposes of this International Standard, the following definitions apply :

4.1 front-end loader (rubber tyred) : A machine composed of a wheeled tractor with an integral linkage system on the front of which is mounted a bucket that loads material through forward motion of a machine capable of transporting and discharging material. See figure 1.

4.2 motor grader (rubber tyred) : A self-propelled rubber-tyred machine having an adjustable blade positioned between the front and rear wheels. See figure 2.

4.3 prime mover (rubber tyred) : A mobile machine equipped with a power unit for movement and control of various attachments. See figure 3.

4.4 crawler-tractor loader: A machine composed of an engine and power-train chassis riding on an endless track mechanism and designed to take such equipment as front-end loaders, bulldozer blades and rippers, or to pull a drawbar load. See figure 4.

4.5 dozer (rubber tyred) : A machine composed of a wheeled tractor with a bulldozer blade mounted at the front of the machine. See figure 5.

NOTE — The definitions in 4.1 to 4.5 and figures 1 to 5 are presented for information and will be co-ordinated by ISO/TC 127/SC 4.

4.6 roll-over protective structure : A system of structural members arranged on a machine in such a way as to reduce

the possibility of the machine crushing the operator in the event of an accidental turn-over.

4.7 deflection-limiting volume : That volume, related to the operator, which serves to set limits and deflections permissible when performing laboratory evaluations of ROPS and FOPS. The volume is based on the seat dimensions for 95 % of operators, that is height 192 cm (75.5 in) and mass 98 kg (215 lb). See ISO 3164.

4.8 falling-object protective structure : A system of structural members arranged in such a way as to provide operators with reasonable protection from falling objects (for example trees, rocks).

5 SYMBOLS

The following symbols are used in this International Standard :

5.1 FOPS : Falling-object protective structure.

5.2 DLV : Deflection-limiting volume.

5.3 ROPS : Roll-over protective structure.

6 GENERAL

The following points are stated to aid in understanding the underlying principles, intention, and application of this International Standard.

6.1 This evaluation procedure will not necessarily duplicate structural deformations due to a given actual impact of falling trees, rocks or other objects.

6.2 This evaluation procedure is generally destructive of the FOPS assembly, as permanent deformation is apt to be induced.

6.3 Although FOPS meeting these criteria may not give crush protection under all conceivable circumstances in which the machine could be struck from above, it is expected that crush protection will be ensured under at least the following condition : a blunt object (see figure 6) dropped from a height sufficient to develop an energy of 11 600 J (8 500 lbf.ft).

6.4 The temperature-material requirement of 8.3 is intended to be a base-line of measurement for testing to ensure that the FOPS will have meaningful resistance to brittle fracture and does not necessarily relate to operating conditions.

6.5 Because, in an actual situation involving a falling object, loading will be dynamic (possibly impact), the use of conventional "safety factors" based on static force loading should be used with caution. The "safety factor" of a FOPS is related more to energy absorption capability and details of weld design and welding procedure than it is to static force resistance.

7 LABORATORY TESTS

7.1 Facilities

The following items shall be provided :

7.1.1 A standard laboratory drop test object, made of steel, as shown in figure 6.

7.1.2 A means of raising the standard object to the required height.

7.1.3 A means of releasing the standard object so that it drops without restraint.

7.1.4 A surface of such firmness that it is not penetrated by the vehicle or test bed under the loading of the drop test.

7.1.5 A means of determining whether the FOPS enters the deflection-limiting volume during the drop test. This may be either of the following :

a) a deflection-limiting volume, in the upright attitude, made of a material which will indicate any penetration by the FOPS; grease may be put on the lower surface of the FOPS cover to indicate such penetration;

b) a dynamic instrumentation system of sufficient frequency response to indicate the pertinent deflection with respect to the deflection-limiting volume.

7.2 Test conditions

7.2.1 *Measuring accuracy*

The following measuring accuracy shall be adhered to when conducting the test :

Means for measuring	Accuracy
Deflection of FOPS	± 5 % of maximum deflection measured

7.2.2 *Machine or test bed condition*

7.2.2.1 The FOPS to be evaluated shall be attached to the machine structure as it would be in actual machine use. A complete machine is not required; however, the portion to which the FOPS is mounted shall be identical to the actual structure, and the vertical stiffness of a test bed shall be not less than that of an actual machine as described in 7.2.2.2.

7.2.2.2 If the FOPS is mounted on a machine, the following stipulations apply :

– there are no limitations on customary attachments and/or payload;

– all ground-engaging tools shall be in the normal carry position;

– all suspension systems, including pneumatic tyres, shall be set at operating levels. Variable suspensions shall be in the "maximum stiffness" range;

– all cab elements, such as windows, normally removable panels or non-structural fittings, shall be removed so that they do not contribute to the strength of the FOPS.

7.3 Procedure

The test procedure shall consist of the following operations, in the order listed.

7.3.1 Place the standard laboratory drop test object (7.1.1), on top of the FOPS (small end of the object down) at the location designated in 7.3.2.

NOTE – An optional drop test object is a sphere or ball with a maximum diameter of 400 mm (15,75 in) and with the capability of developing an energy of 11 600 J (8 500 lbf.ft).

7.3.2 The small end of the object shall be entirely within the vertical projection of the deflection-limiting volume, in that volume's upright position, on the FOPS top.

Case 1

When major, upper, horizontal members of FOPS do not enter the projection of the zone on the top.

The centre of the drop test object shall be at that point which has the greatest possible sum of perpendicular distances ($X + Y$ in figure 7) from the major, upper, horizontal structural members.

Case 2

When major, upper, horizontal members do enter the projection of the zone on the top.

The centre of the drop test object shall be in the segment of greatest area. This area is the projected area of the zone without major, upper, horizontal members. The centre of the drop test object shall be at that point, within the segment of greatest area, which has the greatest possible sum of perpendicular distances ($X + Y$ in figure 7) from the major, upper horizontal structural members.

7.3.3 Raise the drop test object vertically to a height above the position indicated in 7.3.1 and 7.3.2 to develop an energy of 11 600 J (8 500 lbf.ft), based on the mass of an object shaped as shown in figure 6. The drop test object shall be aimed to impact at a location on the FOPS to produce the maximum deflection.

NOTE – To develop an energy of 11 600 J (8 500 lbf.ft), the drop test object shall be raised to between 3,6 and 5,1 m (12 to 17 ft). The height to be selected will vary according to the mass of the drop test object.

7.3.4 Release the drop test object so that it falls without effective restraint onto the FOPS.

7.3.5 As it is unlikely that the free fall will result in the drop test object hitting at the location and/or in the attitude of 7.3.1 and 7.3.2, the following limits are placed on deviations.

7.3.5.1 The initial impact of the small end of the drop test object shall be entirely within a circle of 200 mm (8 in) radius (the centre of this circle is to coincide with the vertical centre line of the drop test object as positioned according to 7.3.1 and 7.3.2) but not on any major, upper, horizontal member.

7.3.5.2 The first contact between the drop test object and the FOPS shall only be along the small end of the drop test object and/or the radius contiguous to that end (see figure 6).

7.3.5.3 There is no limitation on location or attitude of subsequent impacts due to rebound.

8 PERFORMANCE REQUIREMENTS

8.1 The protective properties of the FOPS system shall be estimated by the ability of the cabin or protective structure to retain its safety zone intact after the impact. The deflection-limiting volume as stated in ISO 3164 shall not be entered by any part of the protective structure under the first or subsequent impact of the drop test object. Should the drop test object penetrate the FOPS, it shall be assumed that the FOPS has failed.

8.2 Where the structure provides for both ROPS and FOPS, the FOPS shall also meet the performance requirements for the appropriate roll-over protective structure set forth in ISO 3471. Where ROPS is not involved, a different structure may be used to support the FOPS as long as the deflection-limiting volume is not violated in the test.

NOTE – Should the same structure be used for both evaluations, the drop test procedure shall precede the ROPS loading with removal of impact dents or replacement of the FOPS cover permissible.

8.3 Temperature-material requirements

8.3.1 The laboratory evaluations shall be performed with FOPS and machine frame members soaked to $-17{,}8\ ^{\circ}C$ ($0\ ^{\circ}F$) or below.

8.3.2 If the evaluations are not performed at this temperature, the following minimum material requirements shall be met.

8.3.2.1 Bolts and nuts used to attach the FOPS (or FOPS cover and its supporting structure) to the machine frame and to connect structural parts to the FOPS cover shall be property class 8.8 or 10.9 bolts (ISO/R 898/I) and 8 or 10 property class nuts (ISO/R 898/II).

8.3.2.2 Structural members of the FOPS and ROPS (or FOPS cover) and the mounts which attach them to the machine frame shall be made from steels that have one of the following Charpy V-notch impact strengths :

10 mm × 10 mm specimen :	10,8 J at − 30 °C (8 lbf·ft at − 20 °F)
10 mm × 5 mm specimen :	7,5 J at − 30 °C (5.5 lbf·ft at − 20 °F)
10 mm × 2,5 mm specimen :	5,5 J at − 30 °C (4 lbf·ft at − 20 °F)

NOTES

1 Specimens are to be "longitudinal" and taken from flat stock, tubular, or structural sections before forming or welding for use in FOPS. Specimens from tubular or structural sections are to be taken from the middle of the side of greatest dimension and shall not include welds.

2 In those countries using the inch system, the grade of the bolts or nuts used shall be of an equivalent grade as set out in their national standards (i.e. equal to the cab material).

3 The requirements of 8.3.2.2 are set forth as information until such time as ISO develops an International Standard.

8.3.3 Materials used shall be processed in such a manner as to eliminate sharp corners and edges that are adjacent to the operator or service personnel work areas.

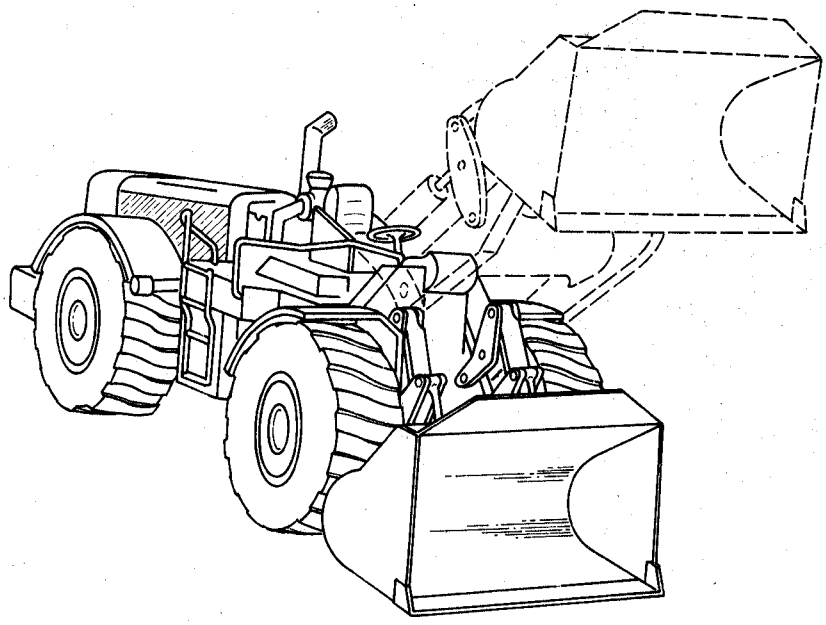


FIGURE 1 – **Front-end loader (rubber tyred)**

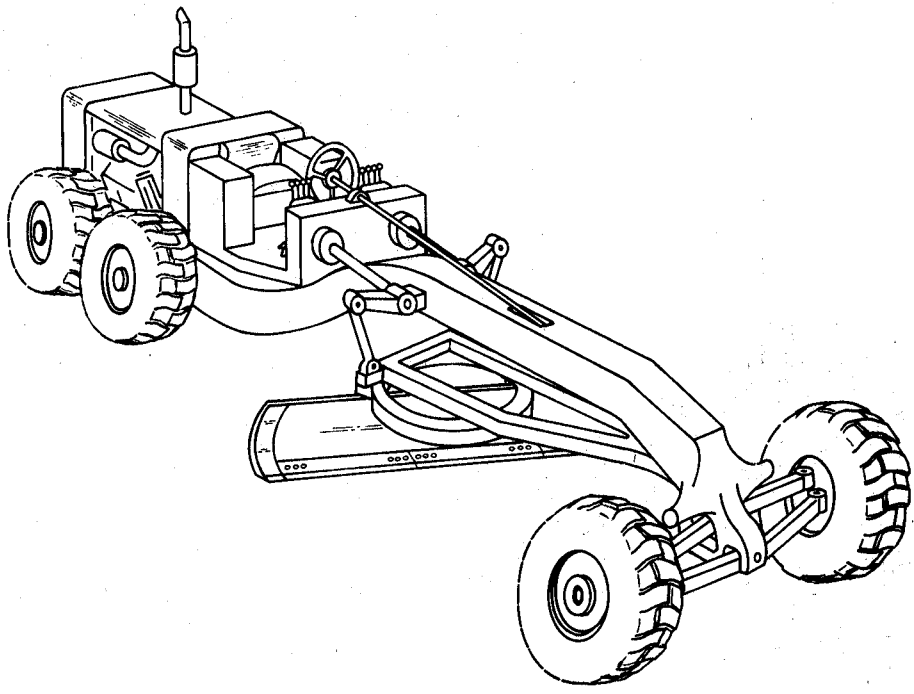


FIGURE 2 – **Motor grader (rubber tyred)**

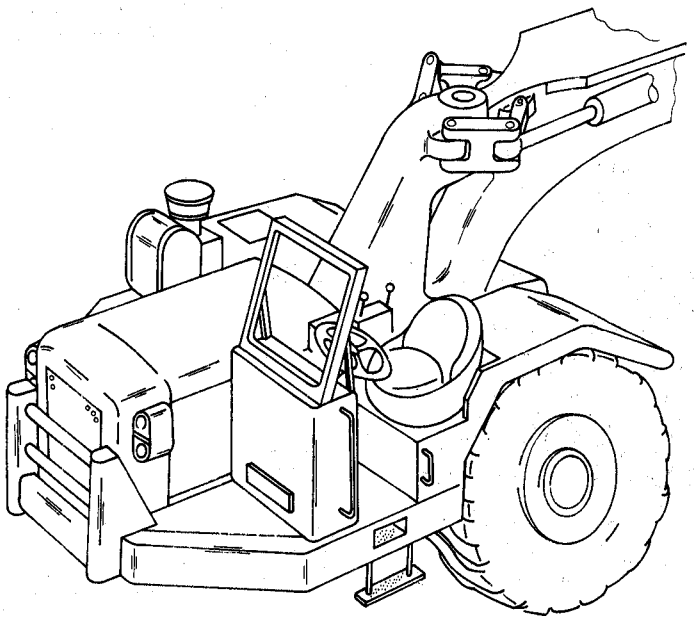


FIGURE 3 – **Prime mover (rubber tyred)**

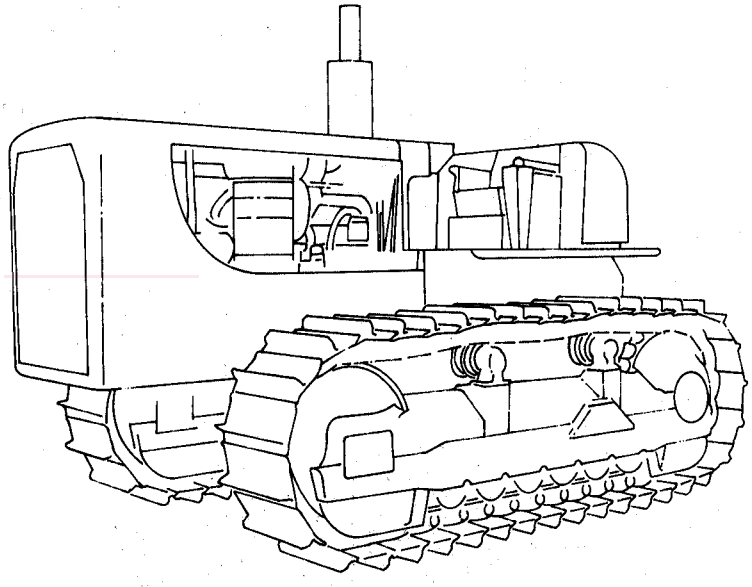


FIGURE 4 – **Crawler-tractor**

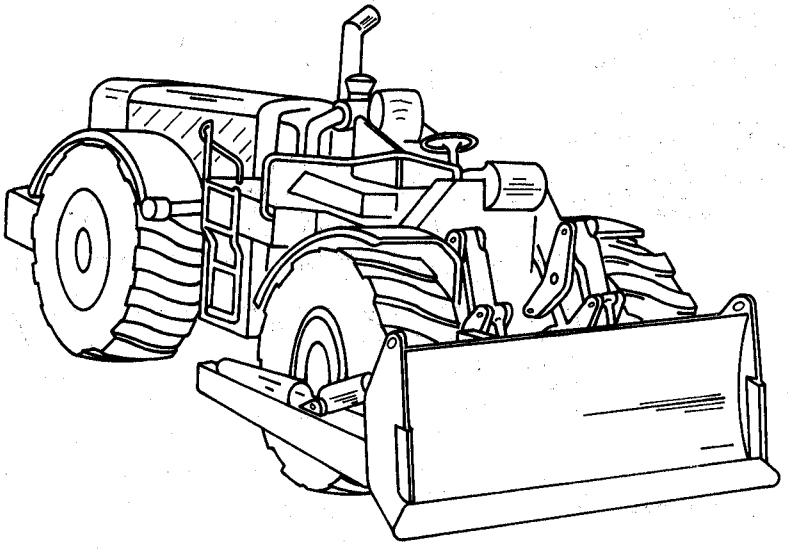
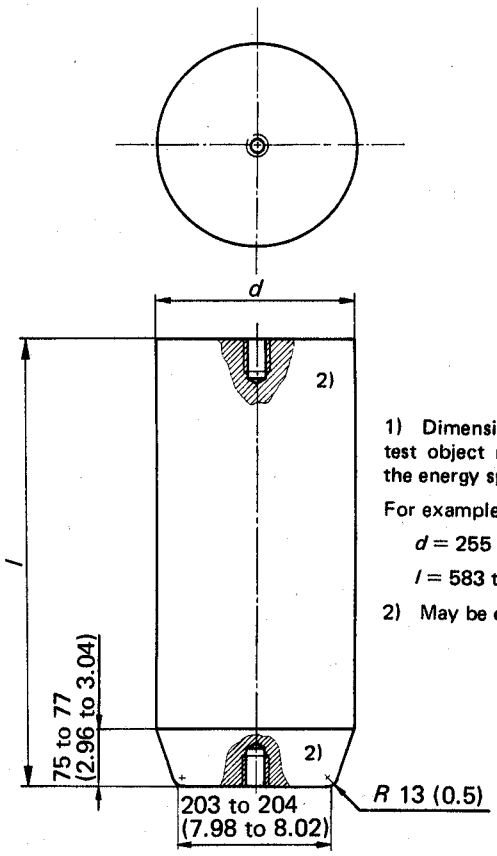


FIGURE 5 – **Dozer (rubber tyred)**

Dimensions in millimetres
(Inch values in parentheses)



1) Dimensions *d* and *l* are optional, depending on the mass of the test object required to match the height of drop that will provide the energy specified in 7.3.3.

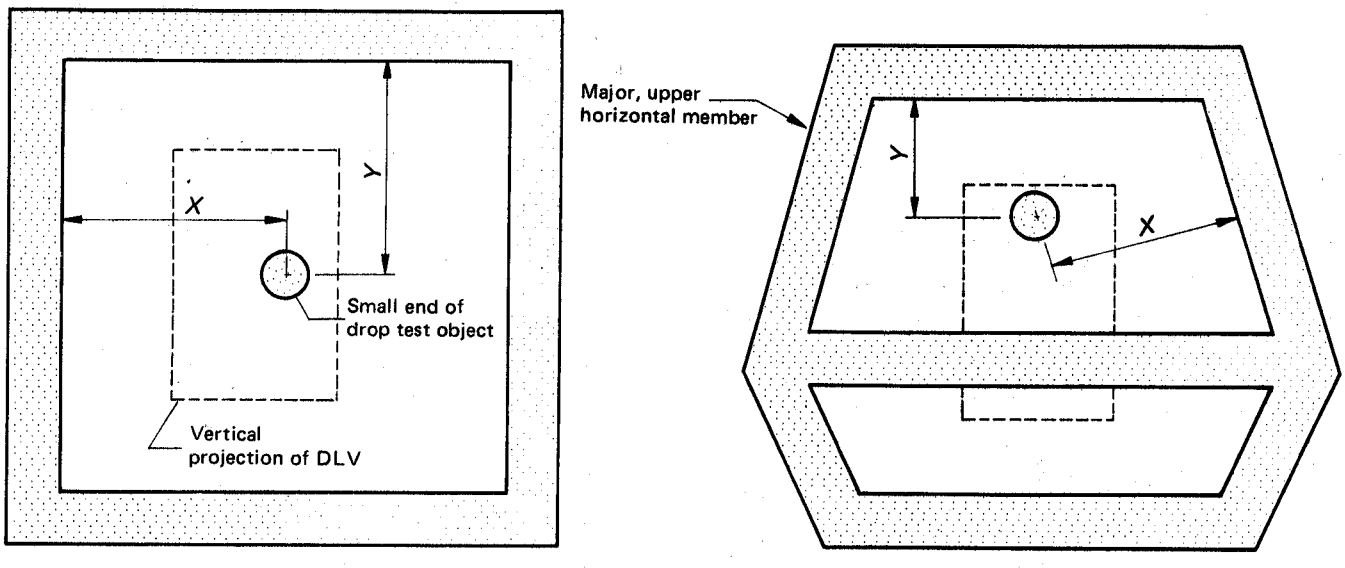
For example, for a drop test object mass of 227 kg (500 lb)

d = 255 to 260 (10.00 to 10.20)

l = 583 to 585 (22.96 to 23.04)

2) May be drilled and tapped for a lifting eye.

FIGURE 6 — **Standard laboratory drop test object**



Case 1 **Case 2**

FIGURE 7 — **Drop test impact points**