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Earth-moving machinery — Tip-over protection structure (TOPS) for compact excavators — Laboratory tests and performance requirements

Engins de terrassement — Structure de protection au basculement (TOPS) pour mini-pelles — Essais de laboratoire et critères de performance

Reference number
ISO 12117:1997(E)

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 12117 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

Annex A forms an integral part of this International Standard. Annex B is for information only.

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INTERNATIONAL STANDARD © ISO **ISO 12117:1997(E)**

Earth-moving machinery — Tip-over protection structure (TOPS) for compact excavators — Laboratory tests and performance requirements

1 Scope

This International Standard establishes a consistent and reproducible means of evaluating the load-carrying characteristics of tip-over protective structures (TOPS) under static loading, and prescribes performance requirements of a representative specimen under such loading.

It applies to TOPS of compact excavators (as defined in ISO 6165) with swing type boom, having an operating mass of 1 000 kg to 6 000 kg.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 148:1983, *Steel — Charpy impact test (V-notch).*

ISO 898-1:1988, *Mechanical properties of fasteners — Part 1: Bolts, screws, and studs.*

ISO 898-2:1992, *Mechanical properties of fasteners — Part 2: Nuts with specified proof load values — Coarse thread.*

ISO 3164:1995, *Earth-moving machinery — Laboratory evaluations of protective structures — Specifications for deflection-limiting volume.*

ISO 6165: —[1], *Earth-moving machinery — Basic types — Vocabulary.*

ISO 6683:1981, *Earth-moving machinery — Seat belts and seat belt anchorages.*

ISO 7135:1993, *Earth-moving machinery — Hydraulic excavators — Terminology and commercial specifications.*

ISO 9248:1992, *Earth-moving machinery — Units for dimensions, performance and capacities, and their measurement accuracies.*

ISO 10262: —[2], *Earth-moving machinery — Hydraulic excavators — Laboratory tests and performance requirements for falling-object guards.*

1) To be published. (Revision of ISO 6165:1987)

2) To be published.

3 Definitions

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

3.1 tip-over protective structure (TOPS): System of structural members whose primary purpose is to reduce the possibility of an operator, held by a seat belt system (3.5), being crushed should a machine tip-over.

NOTE — Structural members include any subframe, bracket, mounting, socket, bolt, pin, suspension, flexible shock absorber used to secure the system to the swing frame, but excludes mounting provisions that are integral with the swing frame.

3.1.1 cabin type TOPS: TOPS for machines with a cabin.

3.1.2 canopy type TOPS: TOPS for machines having an open canopy.

NOTE — Both of these types of TOPS are designed to be integrated with the main members of the TOPS for the evaluation test, whether they are separated from the load carrying members or not.

3.2 falling object guard (FOG): System of top guard and front guard for the protection of the excavator operator station. (See ISO 10262.)

3.3 swing frame: Main chassis or main load bearing structural member(s) of the revolving upper frame of the mini-excavator upon which the TOPS is directly mounted.

3.4 swing-type boom: Boom pivoted horizontally at the boom base. (See ISO 7135:1993, figure 18.)

3.5 seat belt system: Seat belt assembly with anchorages. [ISO 6683:1981, definition 4.3.]

3.6 bedplate: Substantially rigid part of the test fixtures to which the machine frame is attached for the purpose of the test.

3.7 deflection-limiting volume (DLV): Orthogonal approximation of a large, seated, male operator wearing normal clothing and a protective helmet. (See ISO 3164:1995, figure 1.) [ISO 3164:1995, definition 3.1]

3.8 representative specimen: TOPS, mounting hardware and machine frame (complete or partial) for test purposes that is within the manufacturer's specifications.

3.9 load distribution device: Device used to prevent localized penetration of the TOPS members at the load application point.

3.10 load application point: Point on the TOPS structure where the test load is applied to the TOPS structure.

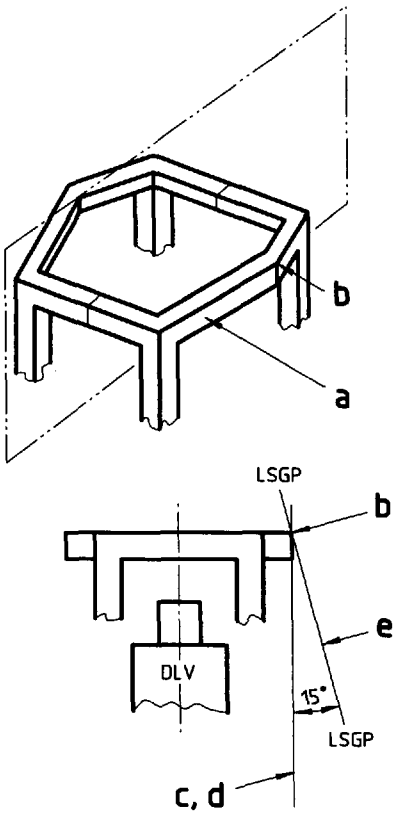
3.11 deflection of TOPS: Movement of the TOPS structure caused by the application of the load and measured at the load application point.

3.12 simulated ground plane (SGP): Flat surface on which a machine, after tipping over, is assumed to come to rest.

3.13 lateral simulated ground plane (LSGP): For a machine coming to rest on its side, the plane 15° away from the DLV about the horizontal axis within the plane established in the vertical plane passing through the outermost point (see figure 1). This establishes the LSGP. The LSGP is established on an unloaded TOPS and moves with the member to which load is applied while maintaining its 15° angle with respect to the vertical.

3.14 operating mass: Mass of the base machine, with equipment and attachments as specified by the manufacturer, operator (75 kg), full fuel tank, and all fluid systems at the levels specified by the manufacturer.

NOTE — Soil, mud, rocks, branches, debris, etc. that commonly adhere to or lie on machines in use are not considered as part of the mass of any machine. Material dug, carried or handled in any manner is not considered part of the machine mass in determining test requirements.



Key

a Upper TOPS member to which the lateral load is applied
b Outermost point from the end view of member a
c Vertical line through point b
d Vertical plane parallel to the machine longitudinal centreline through line c
e Lateral simulated ground plane

Figure 1 — Determination of lateral simulated ground plane (LSGP)

4 Symbols

The following symbols are used in this International Standard.

4.1 U: Energy, expressed in joules, absorbed by the structure, related to the machine mass.

4.2 F: Force, expressed in newtons.

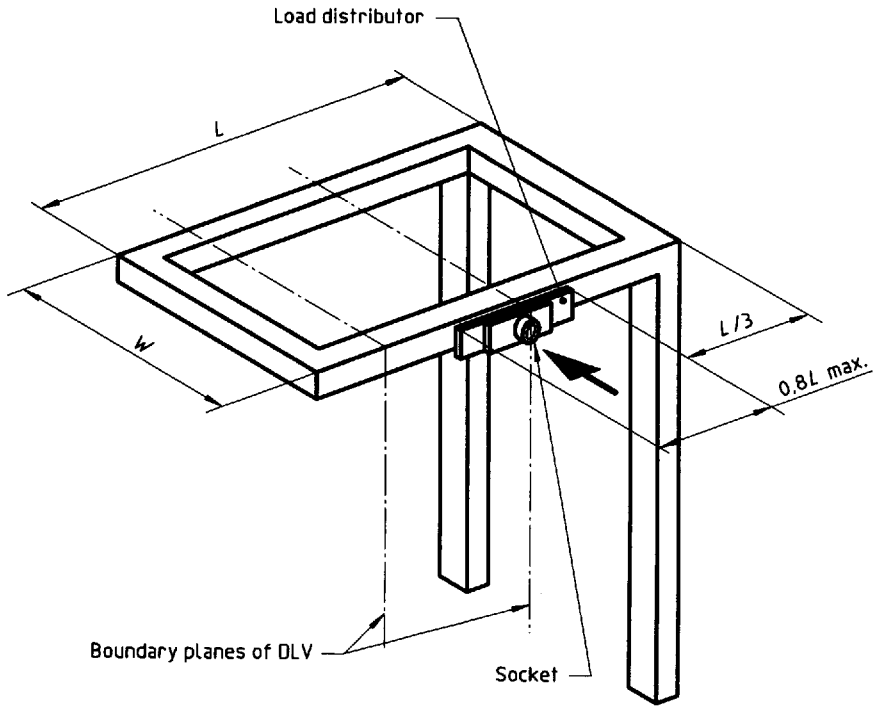
4.3 m: Manufacturer's maximum recommended mass, expressed in kilograms.

The manufacturer's maximum recommended mass includes attachments in operating condition with all reservoirs full to capacity, tools and TOPS.

4.4 L: Length of the TOPS, expressed in millimetres, defined as below.

a) For a one- or two-post TOPS with a FOG and/or cantilevered load-carrying structural members, the length, L, is that portion of the cantilevered load-carrying members which covers the vertical projection of the length of the DLV of the operator. It is measured at the top of the TOPS, from the extreme face of the TOPS post(s) to the far end of the cantilevered load-carrying members (see figure 2).

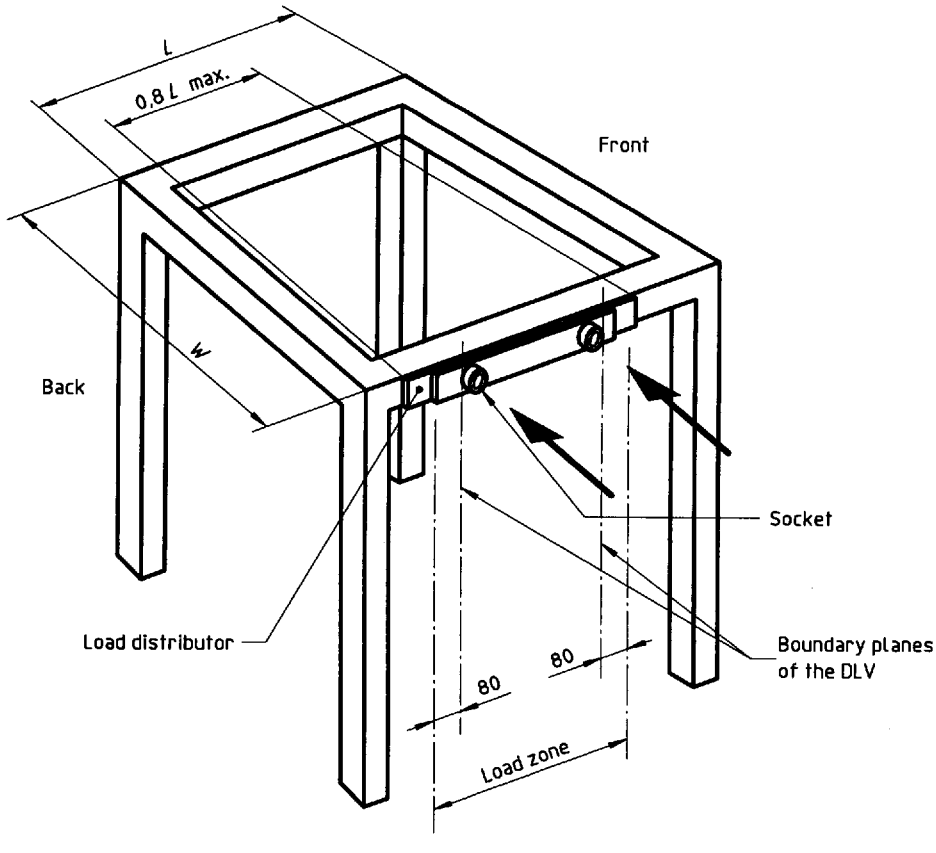
b) For all other TOPS, the length, L, is the greatest total longitudinal distance between the outsides of the front and rear posts (see figure 3).



NOTE — Load distributor and socket are used to prevent local penetration and to hold the end of the load-generating device.

Figure 2 — Two-post TOPS lateral load application point

Dimensions in millimetres



NOTE — Load distributor and socket are used to prevent local penetration and to hold the end of the load-generating device.

Figure 3 — Four-post TOPS lateral load application point

4.5 W: Width of the TOPS, expressed in millimetres, defined as below.

a) For a one- or two-post TOPS with a FOG and/or cantilevered load-carrying structural members, the width, W, is that portion of the cantilevered load-carrying members which covers the vertical projection of the width of the DLV. It is measured at the top of the TOPS, from the extreme face of the TOPS post to the far end of the cantilevered load-carrying members (see figure 2).

b) For all other TOPS, the width, W, is the greatest total width between the outsides of the left and right TOPS posts (see figure 3).

4.6 Δ: Deformation of the TOPS, expressed in millimetres.

5 Test method and facilities

5.1 General

The requirement for TOPS is energy absorption in the lateral direction. There are limitations on deflections under the lateral loading. The energy requirements and limitations on deflection (DLV) under lateral loading are intended to assure that the TOPS will not significantly deform while retaining significant capability to withstand impact in the tip.

The evaluation procedure will not necessarily duplicate structural deformations due to a given actual tip-over. However, it is expected that crush protection for a seat-belted operator will be assured under at least the following conditions:

— a flat hard soil surface;

— 90° of tip-over about the swing frame longitudinal axis without losing contact with the surface.

5.2 Instrumentation

Systems used to measure mass, force and deflection shall be capable of meeting the requirements of ISO 9248.

5.3 Test facilities

Fixtures shall be adequate to secure the TOPS/swing frame assembly to a bedplate and to apply the required lateral load as determined by the formulae given in table 1.

5.4 TOPS/swing frame assembly and attachment to bedplate

5.4.1 The TOPS shall be attached to the swing frame as it would be on an operating machine (see figure 4). A complete swing frame is not required for the evaluation. However, the swing frame and mounted TOPS test specimen shall represent the structural configuration of an operating installation. All normally detachable windows, panels, doors, and other non-structural elements shall be removed so that they do not contribute to, nor detract from, the structural evaluation.

5.4.2 The TOPS/swing frame assembly shall be secured to the bedplate so that the members connecting the assembly and bedplate experience minimal deflection during testing. The TOPS/swing frame assembly shall not receive any support from the bedplate, other than that due to the initial attachment.

5.4.3 The test shall be conducted with any machine/ground suspension elements blocked externally so that they do not contribute to the load-deflection behaviour of the test specimen. Suspension elements used to attach the TOPS to the machine frame and acting as a load path shall be in place and functioning at the start of the test.

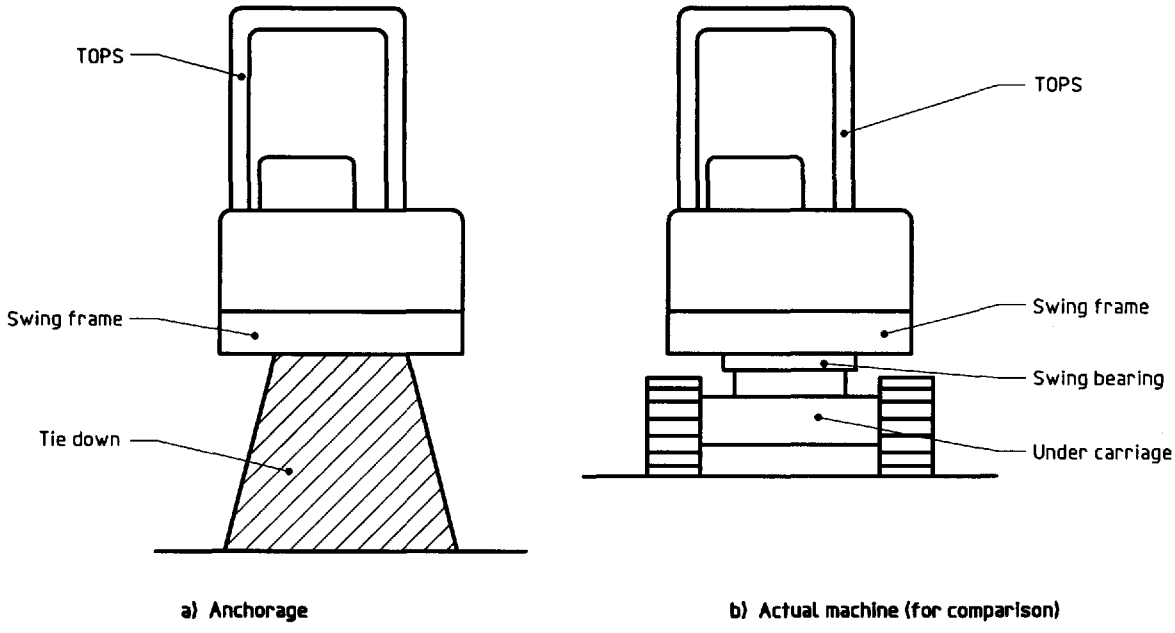


Figure 4 — Anchorage of swing frame

6 Test loading procedures

6.1 General

6.1.1 All load application points shall be identified and marked on the structure before any loading is applied.

6.1.2 No straightening or repair is permitted during loading phases.

6.1.3 A load-distribution device may be used to prevent localized penetration. It shall not impede rotation of the TOPS.

6.1.4 The TOPS structure shall have the energy absorption capability against longitudinal load energy as being specified in table 1. Through normal design techniques, a TOPS design may have adequate longitudinal resistance, therefore, a longitudinal loading test is not mandated in this International Standard. If, however, such a test is required, it should be carried out in accordance with annex B.

Table 1 — Formulae for the determination of energy required

Lateral load energy J	Longitudinal load energy J
$13\,000\left(\frac{m}{10\,000}\right)^{1,25}$	$4\,300\left(\frac{m}{10\,000}\right)^{1,25}$

6.2 Lateral loading

6.2.1 The load distribution device shall not distribute the load over a distance greater than 80 % of the length, L.

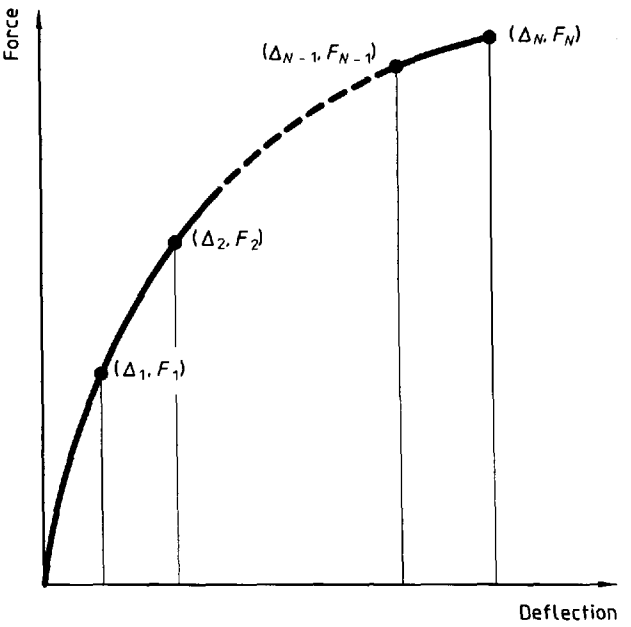
6.2.2 For one- or two-post TOPS, initial loading shall be dictated by the length, L, and the vertical projections of the front and rear planes of the DLV. The load application point may not be within $L/3$ from the one- or two-post TOPS structure. Should the $L/3$ point be between the vertical projection of DLV and the one- or two-post TOPS structure, the load application point shall be moved away from the structure until it enters the vertical projection of the DLV. (See figure 2.)

6.2.3 For a TOPS of more than two posts, the load application point shall be located between vertical projections of planes 80 mm outside of the front and rear boundary planes of the DLV. (See figure 3.)

6.2.4 Where the operator's seat is not located on the swing frame longitudinal centerline, the loading shall be applied against the outermost side nearest the seat. Where the operator's seat is on the swing frame longitudinal centerline, if the TOPS structure and mounting are such that different force-deflection results are likely by loading from left or right sides, the side load shall be that which will place the most severe loading requirements on the TOPS/swing frame assembly.

6.2.5 The initial direction of the loading shall be horizontal and perpendicular to a vertical plane through the swing frame longitudinal centerline. As loading continues, TOPS/swing frame deformations may cause the direction of loading to change; this is permissible.

6.2.6 The rate of deflection shall be such that the loading can be considered static. The rate of load application can be considered static if the rate of deflection at the load application point is not greater than 5 mm/s. At deflection increments no greater than 15 mm (at the point of application of the resultant load), the values of force and deflection are to be recorded. This loading is to continue until the TOPS has achieved the energy requirements. See figure 5 for the method of calculating the energy, U. The deflection used in calculating the energy is to be that of the TOPS along the line of action of the force. Any deflection of members used to support the load application device shall not be included in the total deflection.



Energy

$$U = \frac{\Delta_1 F_1}{2} + (\Delta_2 - \Delta_1)\frac{F_1 + F_2}{2} + ... + (\Delta_N - \Delta_{N-1})\frac{F_{N-1} + F_N}{2}$$

Figure 5 — Force-deflection curve for loading test

7 Material temperature criteria

7.1 In addition to the loading requirements, there is a material temperature requirement to ensure that the TOPS will have meaningful resistance to brittle fracture. This requirement may be met by applying the static loadings with all structural members at, or below, − 18 °C if material specifications and procurement ensure that materials in TOPS subsequently manufactured will have toughness characteristics similar to those in the tested representative specimen. Alternatively, the requirement may be met by applying the loadings at higher temperatures if all TOPS structural members are fabricated from materials that meet the mechanical requirements in 7.2 to 7.4.

7.2 Bolts used structurally shall be metric property class 8.8, 9.8 or 10.9 (see ISO 898-1). Nuts used structurally shall be metric property class 8 or 10 (see ISO 898-2).

NOTE — In those countries using the inch system, it is important that the bolts and nuts used be of an equivalent grade.

7.3 Structural members of the TOPS and the mounts which attach it to the machine frame shall be made of steels that meet or exceed one of the Charpy V-notch (CVN) impact strengths at – 30 °C shown in table 2. (The Charpy V-notch evaluation is primarily a quality control check and the indicated temperature does not directly relate to operating conditions.)

Specimens are to be "longitudinal" and taken from flat stock, tubular, or structural sections before forming or welding for use in the TOPS. Specimens from tubular or structural sections shall be taken from the middle of the side of greatest dimension and shall not include welds (see ISO 148).

7.4 Steel with a maximum carbon content of 0,20 % and less than 2,5 mm thick shall be considered to meet the requirements of the Charpy test.

8 Acceptance criteria

8.1 The specific lateral energy requirements shall be met or exceeded in the testing of a single representative specimen. The equations for determining the values to be met are given in table 1.

Table 2 — Minimum Charpy V-notch impact strengths

Specimen size mm	**Energy at – 30 °C**[1] J
10 × 10[2]	11
10 × 9	10
10 × 8	9,5
10 × 7,5[2]	9,5
10 × 7	9
10 × 6,7	8,5
10 × 6	8
10 × 5[2]	7,5
10 × 4	7
10 × 3,3	6
10 × 3	6
10 × 2,5[2]	5,5

1) An alternative energy requirement may be allowed at –20 °C. The energy requirement at – 20 °C is 2.5 times the value specified for – 30 °C. Other factors affect impact energy strength, i.e. direction of rolling, yield strength, grain orientation, and welding. These shall be considered in selecting a steel.
2) Indicates preferred size. Specimen size shall be no less than the largest preferred size that the material will permit.

8.2 The limitations on the deflections are absolute; no part of the TOPS shall enter the DLV at any time during the lateral loading phase of the test.

8.3 The lateral simulated ground plane (LSGP) shall not enter the DLV at any time during the lateral loading phase of the test, except as noted in 8.4.

8.4 During lateral loading with a side-mounted operator seat facing the direction that the TOPS will deflect under load application, it is permissible for the upper portion of the DLV to be inclined forward up to 15° about its locating axis (LA), as defined in ISO 3164, to prevent intrusion of TOPS members (or the LSGP). Forward inclination of the DLV shall be limited to less than 15° if interference with any machine components or controls occurs at a lesser angle [see figure 6 a)].

8.5 The lateral loading portion of the deflection-limiting volume (DLV) above the locating axis (LA) (see ISO 3164) is allowed to deviate or lean up to 15° laterally as shown [see figure 6 b)] when the minimum energy requirement is met. The portion of the DLV below the LA can be disregarded.

8.6 The TOPS shall not break away from the swing frame due to failure of the swing frame or mounting.

9 Labelling of the TOPS

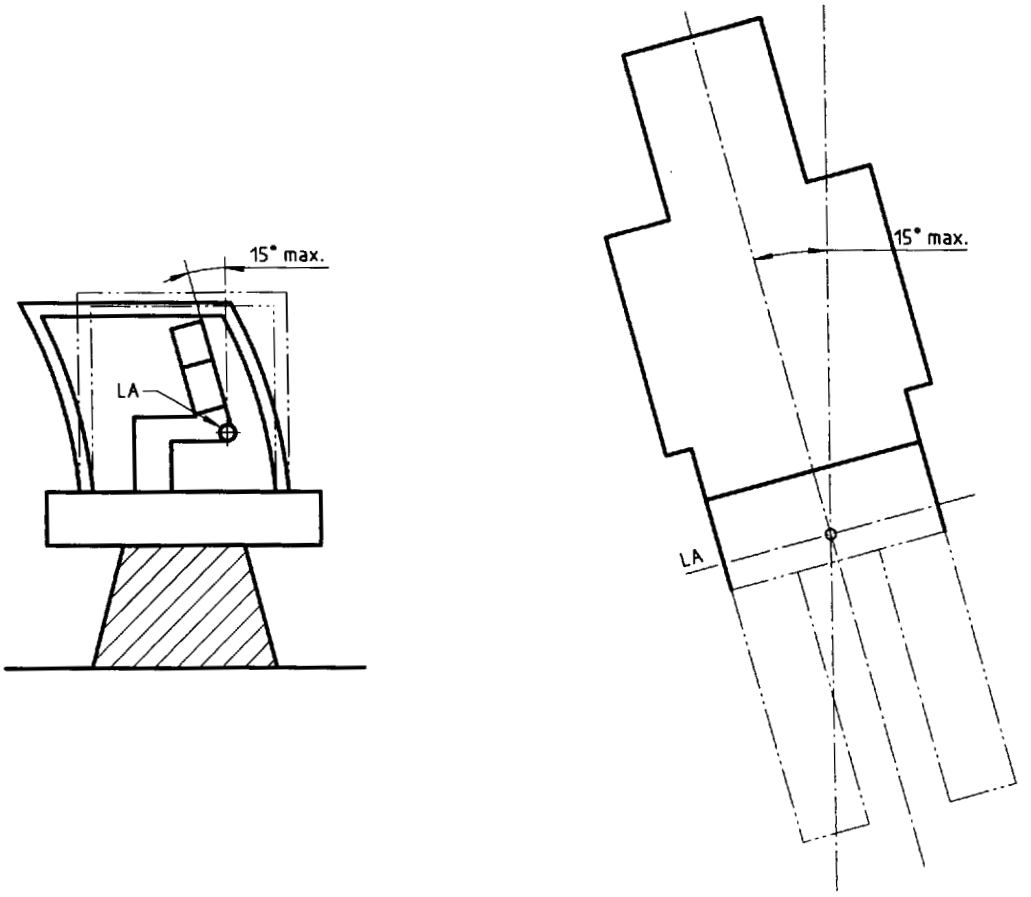
9.1 TOPS meeting the requirements of this International Standard shall be labelled in accordance with the provisions in clauses 9.2 and 9.3.

NOTE — Information concerning the FOG may be included on the label.

9.2 Label specifications

9.2.1 The label shall be of a permanent type and permanently attached to the structure of the TOPS.

9.2.2 The label shall be located on the structure so that it can be easily read and is protected from weather defacing.



a) Allowable inclination of the upper DLV about the locating axis (LA)

b) Lateral inclination of the upper DLV

Figure 6 — Inclination of the upper DLV

9.3 Label content

The label shall indicate the following:

a) the name and address of the manufacturer of the TOPS;

b) TOPS identification number, if any;

c) machine make, model(s), or serial number(s) of the machines that the TOPS is designed to fit;

d) maximum machine mass, m, for which the TOPS structure meets all of the performance requirements of this International Standard;

e) International Standard number(s) for which the structure meets all of the performance requirements (national regulations may be included);

f) the manufacturer may include other information as deemed appropriate (for example, installation, repair or replacement information).

10 Reported results

The results of the test shall be reported using the typical test report presented in annex A.

Annex A
(normative)

Test report for TOPS conforming to ISO 12117

A.1 Identification

A.1.1 Machine

Type: .....

Manufacturer: .....

Model: .....

Serial number: .....

Swing frame part number: .....

A.1.2 TOPS

Manufacturer: .....

Model: .....

Serial number: .....

TOPS frame part number: .....

A.2 Information supplied by the manufacturer(s)

Maximum recommended mass: ..... kg

Location of DLV: .....

A.3 Criteria

Lateral load energy: ..... J

A.4 Test results

A.4.1 Lateral loading

The following energy level was achieved or exceeded with no penetration by the TOPS structural member or the simulated ground plane into the DLV.

The maximum energy attained: ..... J

A.4.2 Temperature and material

A.4.2.1 The test was performed with TOPS and swing frame members at ..... °C.

A.4.2.2 (To be completed only if the temperature in A.4.2.1 is over – 18 °C.)

The Charpy V-notch impact strength requirements for TOPS structural metallic members were tested on specimen size ..... mm × ..... mm.

The absorbed energy was ..... J

Nut property class: .....

Bolt property class: .....

A.5 Attestation statement

The minimum performance requirements of ISO 12117:1996 were met in this test for a maximum machine mass of ..... kg.

Date of test: .....

Name and address of test facility: .....

Test engineer: .....

Date of test report: .....

Annex B
(informative)

Longitudinal loading test of TOPS

B.1 Test procedure

B.1.1 After removal of the lateral load, a longitudinal load shall be applied to the TOPS.

B.1.2 The longitudinal load shall be applied at the deformed location of the originally established point (the lateral loading of the TOPS is likely to result in permanent deformation of the structure). The load distribution device may span the width in cases where no rear or front cross-member exists. In all other cases, the device shall not distribute the load over a length greater than 80 % of the width (W) of the TOPS (see figure 2 and figure 3).

B.1.3 The longitudinal load shall be applied to the upper structural members of the TOPS, along the longitudinal centerline of the TOPS.

B.1.4 The direction of loading (fore or aft) must be selected to place the most severe requirements on the TOPS/swing frame assembly. The initial direction of loading shall be horizontal and parallel to the original longitudinal centerline of the machine. The following additional factors are to be considered before deciding in which direction to apply the longitudinal load:

a) location of TOPS relative to the DLV and the effect that longitudinal deflection of the TOPS would have on providing crush protection for the operator;

b) machine characteristics, (for example, other structural members of the machine which may resist longitudinal deflection of the TOPS) that can limit the direction of the longitudinal component of loading on the TOPS;

c) experience which may indicate the possibility of longitudinal tipping or the tendency of a particular classification of machine to skew as it rotates about a longitudinal axis during an actual tip-over.

B.1.5 The rate of deflection shall be such that the loading can be considered static. This loading is to continue until the TOPS has achieved the energy requirements given in table 1.

B.2 Test report

B.2.1 Identification

B.2.1.1 Machine

Type: .....

Manufacturer: .....

Model: .....

Serial number: .....

Swing frame part number: .....

B.2.1.2 TOPS

Manufacturer: .....

Model: .....

Serial number: .....

TOPS part number: .....

B.2.2 Information supplied by the manufacturer

Maximum recommended mass: ..... kg

Location of DLV: .....

B.2.3 Criteria

Longitudinal load energy: ..... J

B.2.4 Test results

B.2.4.1 Longitudinal loading

The following energy levels were achieved or exceeded with no penetration by the TOPS structural member or the simulated ground planes into the DLV.

The maximum energy attained: ..... J

B.2.4.2 Temperature and material

B.2.4.2.1 The test was performed with TOPS and machine frame members at a temperature of ..... °C.

B.2.4.2.2 (to be completed only if the temperature in B.2.4.2.1 is over – 18 °C)

The Charpy V-notch impact strength requirements for TOPS structural metallic members were tested on a specimen size ..... mm × ..... mm.

The absorbed energy was ..... J

Nut property class: .....

Bolt property class: .....

B.2.5 Attestation statement

The minimum performance requirements of ISO 12117:1996 were met in this test for a maximum machine mass of ..... kg.

Date of test: .....

Name and address of test facility: .....

Test engineer: .....

Date of test report: .....

ICS 53.100

Descriptors: earth-moving equipment, excavating equipment, excavators, accident prevention, operator protection, protection against mechanical hazards, overturning (vehicles), safety devices, specifications, performance, tests, laboratory tests, estimation, effectiveness.

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