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Earth-moving machinery — Roll-over protective structures — Laboratory tests and performance requirements

Engins de terrassement — Structures de protection au retournement — Essais de laboratoire et exigences de performance

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3471 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

This fourth edition cancels and replaces the third edition (ISO 3471:1994), which has been technically revised. It also incorporates the Amendment ISO 3471:1994/Amd 1:1997 and the Technical Corrigendum ISO 3471:1994/Cor 1:2000.

Introduction

A review of the initial work on the criteria for roll-over protective structures (ROPS) indicated that these criteria were based on requirements for machines now identified as mid-range size machines. Since the ROPS criteria were established, both smaller and larger machines have become common within the size range of earth-moving machines.

The criteria are a combination of linear and exponential, with respect to mass. For small machines, the exponential criterion has been changed to a linear function with respect to machine mass. For larger machines, the exponential criterion was excessive at very large machine masses, and thus was changed to become a linear function with respect to machine mass.

The longitudinal force criteria were added as new data became available. Situations could arise where ROPS designs would meet the lateral and vertical loading requirements, but yet be considered as lacking sufficient performance capability in the longitudinal load direction. For this reason, this International Standard incorporates a ROPS longitudinal force criterion. The longitudinal force criterion has been established at 80 % of the lateral force requirement.

The evaluation procedure will not necessarily duplicate structural deformations due to a given actual roll. However, specific requirements are derived from investigations on ROPS that have performed the intended function in a variety of actual roll-overs, as well as analytical considerations based upon the compatibility of ROPS and the machine frame to which it is attached.

Earth-moving machinery — Roll-over protective structures — Laboratory tests and performance requirements

1 Scope

This International Standard specifies performance requirements for metallic roll-over protective structures (ROPS) for earth-moving machinery, as well as a consistent and reproducible means of evaluating the compliance with these requirements by laboratory testing using static loading on a representative specimen.

NOTE 1 The structure can also provide FOPS (falling-object protective structure) protection.

This International Standard is applicable to ROPS intended for the following mobile machines with seated operator as defined in ISO 6165 and with a mass greater than or equal to 700 kg:

- dozer;
- loader;
- backhoe loader;
- dumper;
- pipelayer;
- tractor section (prime mover) of a combination machine (e.g. tractor scraper, articulated frame dumper);
- grader;
- landfill compactor;
- roller;
- trencher.

This International Standard is not applicable to training seats or additional seats for operation of an attachment.

NOTE 2 It is expected that reasonable crush protection for a seat-belted operator will be provided under at least the conditions of an initial forward velocity of 0 km/h to 16 km/h on a hard clay surface of 30° maximum slope in the direction of roll, and 360° of roll about the longitudinal axis of the machine without loss of contact with the slope.

NOTE 3 This International Standard can be used to provide guidance to the manufacturers of roll-over protective structures should it be decided to provide such protection for these or other machines for a particular application.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1:2006, *Metallic materials — Charpy pendulum impact test (V-notch) — Part 1: Test method*

ISO 898-1:1999, *Mechanical properties of fasteners made of carbon steel and alloy steel — 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 5353:1995, *Earth-moving machinery, and tractors and machinery for agriculture and forestry — Seat index point*

ISO 6165:2006, *Earth-moving machinery — Basic types — Identification and terms and definitions*

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
bedplate
substantially rigid part of the test fixture to which the machine frame is attached to conduct the test

3.2
boundary plane
BP
plane defined as the vertical projected plane of the back, side, or knee area of the DLV

NOTE The boundary planes are used to determine the load application point.

3.3
deflection-limiting volume
DLV
orthogonal approximation of a large, seated, male operator wearing normal clothing and a protective helmet

NOTE Adapted from ISO 3164:1995.

3.4
deflection of ROPS
movement of the ROPS, mounting system and frame section as measured at the load application point (LAP), excluding the effect of any movement of the test fixture(s)

3.5
falling-object protective structure
FOPS
system of structural members arranged in such a way as to provide operators with reasonable protection from falling objects (e.g. trees, rocks, small concrete blocks, tools)

3.6
head portion of DLV
upper 270 mm by 330 mm rectangular section of the DLV, whose dimensions are in accordance with ISO 3164

3.7
lateral simulated ground plane
LSGP
plane defined as where the machine comes to rest on its side, where the plane is 15° away from the DLV.

NOTE It is created by rotating a vertical plane parallel to the machine's longitudinal centreline about a horizontal line through the outermost point of the upper ROPS member, to which the lateral load is applied (see Figure 6). The LSGP is established on an unloaded ROPS and moves with the member to which the load is applied while maintaining its 15° angle with respect to the vertical.

3.8
load distribution device
LDD
device used to prevent localized penetration of the ROPS members at the load application point (LAP)

3.9
load application point
LAP
point (or a point within a defined range) on the ROPS structure at which the test load force (F) is applied

3.10
machine frame
metallic main chassis or main metallic load-bearing member(s) of the machine that extend(s) over a major section of the machine and upon which the ROPS is directly mounted

3.11
mounting system
all brackets, weldments, fasteners or other devices whose function is to attach the ROPS to the machine frame

3.12
representative specimen
ROPS, mounting system and machine frame (complete or partial) used for test purposes that is within the range of material and manufacturing variances designated by the manufacturer's production specifications

NOTE The intent is that all ROPS manufactured to these specifications be capable of meeting or exceeding the stated levels of performance.

3.13
roll-over protective structure
ROPS
system of structural members whose primary purpose is to reduce the possibility of a seat-belted operator being crushed in the event of a machine roll-over

NOTE 1 See Figures 1 to 5 and ISO 6683.

NOTE 2 It can include components such as sub-frame, bracket, mount, bolt, pin, suspension or flexible shock absorber.

NOTE 3 Non-load-carrying members (posts) are not considered.

3.13.1
rollbar ROPS
ROPS having one or two posts, formed or fabricated, and having no cantilevered structural member(s)

3.13.2
one-post [two-post] ROPS
ROPS having one or two posts, formed or fabricated, and having one or more cantilevered load-carrying structural members

3.13.3
multiple-post ROPS
ROPS having more than two posts, formed or fabricated, and joining load-carrying structural members

NOTE It can have cantilevered load-carrying structural members.

3.14
ROPS structural member
metallic member designed to withstand an applied force or absorb energy

3.15
simulated ground plane
SGP
plane simulating the flat ground surface on which a machine is assumed to come to rest after rolling over

3.16
Socket
S
test component that allows unrestricted point loading of the load distribution device (LDD)

3.17
vertical projection of DLV
cross-sectional area of the column formed by vertically projecting the outside corners of the deflection limiting volume (DLV), with dimensions according to ISO 3164, excluding the foot section

3.18
vertical simulated ground plane
VSGP
plane defined by contact with a top cross-member of the ROPS and that front or rear part of the machine capable of supporting an overturned machine

See Figure 16

NOTE The VSGP applies to the rollbar ROPS, as well as to the one-post and two-post ROPS. The VSGP can change with the deformation of the ROPS.

4 Symbols

For the purposes of this document, the following symbols apply.

U energy absorbed by the structure, related to the manufacturer's maximum recommended mass, m, and expressed in joules

F load force, expressed in newtons

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 ROPS. It excludes towed equipment such as rollers and drawn scrapers.

- For the tractor scraper and articulated frame dumper, it is the maximum recommended mass of the tractor section (prime mover) only. In most cases, it is the tractor section, but shall be the ROPS-bearing section or ROPS-carrying section of the machine. Kingpins, hitches and articulated-steering components that attach to hitches or towed units are excluded from the mass of these machines.

- For rigid frame dumpers, m excludes the mass of the dump body and the payload when the "excluding dump body" criteria are selected. When the "including dump body" criteria are selected, m includes the mass of the dump body but excludes the mass of the payload.

  NOTE See Table 1 for examples.

- For rollers and landfill compactors, loosely contained ballast that would separate from the machine in the event of a roll-over is also excluded from m.

  NOTE Soil, mud, rocks, branches, debris, etc. that commonly adhere to, or lie on, machines in use are not considered 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.

L length of the ROPS, in millimetres

- L is not applicable to rollbar ROPS.
- For one- or two-post ROPS with cantilevered load-carrying structural members, L is the longitudinal distance from the outer surface of the ROPS post(s) to the outer surface of the furthest cantilevered load-carrying members at the top of the ROPS (see Figures 1, 4 and 5). It is not necessary for the ROPS structural members to cover the complete vertical projection of the DLV.
- For multiple-post ROPS, L is the greatest longitudinal distance from the outer surface of the front to the outer surface of the rear posts. See Figure 2.
- For ROPS with shaped structural members, L, is the vertical projection of H with the outer surface of the structural members. See Figure 3.
- For ROPS with curved structural members, L is defined by the intersection of plane A with the outer surface of the vertical member. Plane A is defined as the bisector of the angle formed by the intersection of planes B and C. B is the tangent line at the outer surface parallel to plane D. Plane D is the plane intersecting the intersections of the curved ROPS members with the adjacent members. Plane C is the projection of the top surface of the upper ROPS structural member. See Figure 3.

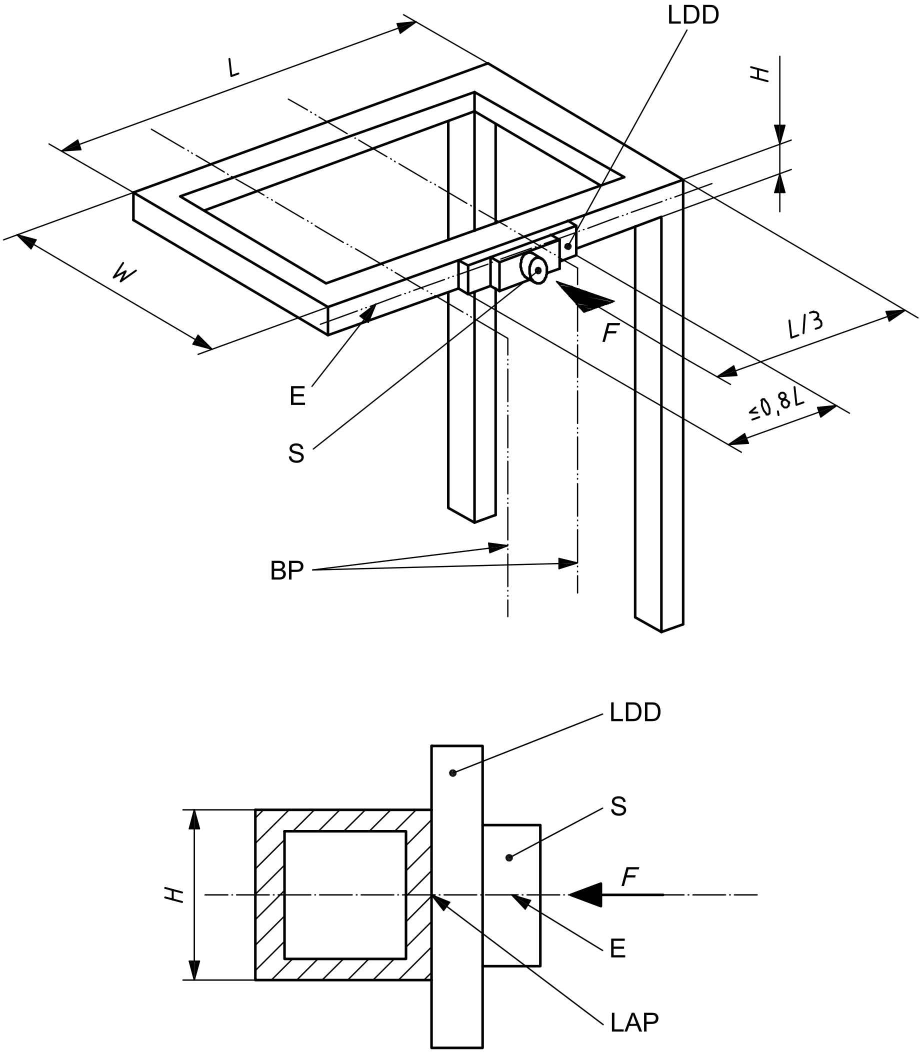
W width of the ROPS, in millimetres

- For a rollbar ROPS, W is the width to the outermost points of the structural member(s).
- For a one- or two-post ROPS with cantilevered load-carrying structural members, the width, W is that portion of the cantilevered load-carrying members (See Figures 1, 4 and 5) that covers at least the vertical projection of the width of the DLV as measured at the top of the ROPS, from the outside faces of the cantilevered load-carrying members.
- For all other ROPS, the width, W, is the greatest total width between the outsides of the left and right ROPS posts as measured at the top of the ROPS, from the outside faces of the load-carrying members. See Figure 3.
- For ROPS with shaped structural members, W is the vertical projection of H with the outer surface of the structural members. See Figure 3.
- For ROPS with curved structural members, W is defined by the intersection of plane A with the outer surface of the vertical member. Plane A is defined as the bisector of the angle formed by the intersection of planes B and C. B is the tangent line at the outer surface parallel to plane D. Plane D is the plane intersecting the intersections of the curved ROPS members with the adjacent members. Plane C is the projection of the top surface of the upper ROPS structural member. See Figure 3.

Δ deflection of the ROPS, expressed in millimetres

H Height of the load application zone, expressed in millimetres

- For a straight member, H is the distance from the top to the bottom of the member, as shown in Figure 1.
- For a curved member, H is the vertical distance from the top of the member to the vertical plane at the end of L where it intersects the inner surface of the curved member at Y, as shown in Figure 3.
- For a shaped member, H is three times the vertical width of the top member, as shown in Figure 3.

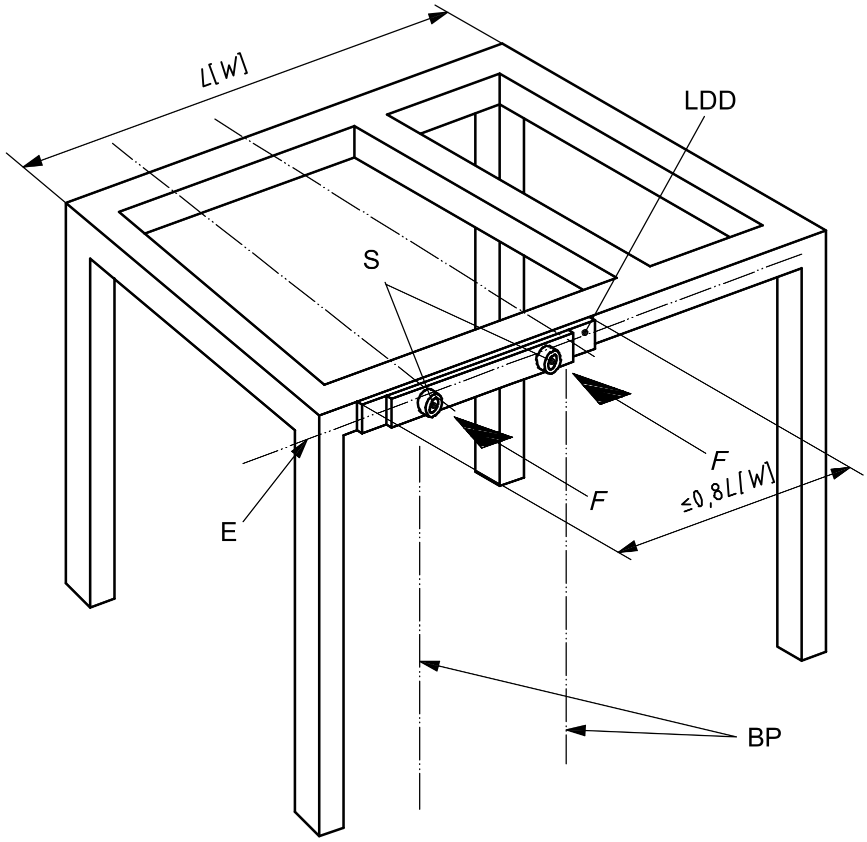


Key

BP boundary planes of DLV
E horizontal mid-point of upper ROPS structural member
F load force
H height of upper ROPS structural member
L length of ROPS
LAP load application point
LDD load distribution device
S socket
W width of ROPS

NOTE The LDD can extend beyond the dimension *H*.

Figure 1 — Example of lateral load application point (LAP) of two-post ROPS



Key

BP boundary planes of DLV

E horizontal mid-point of upper ROPS structural member

F load force

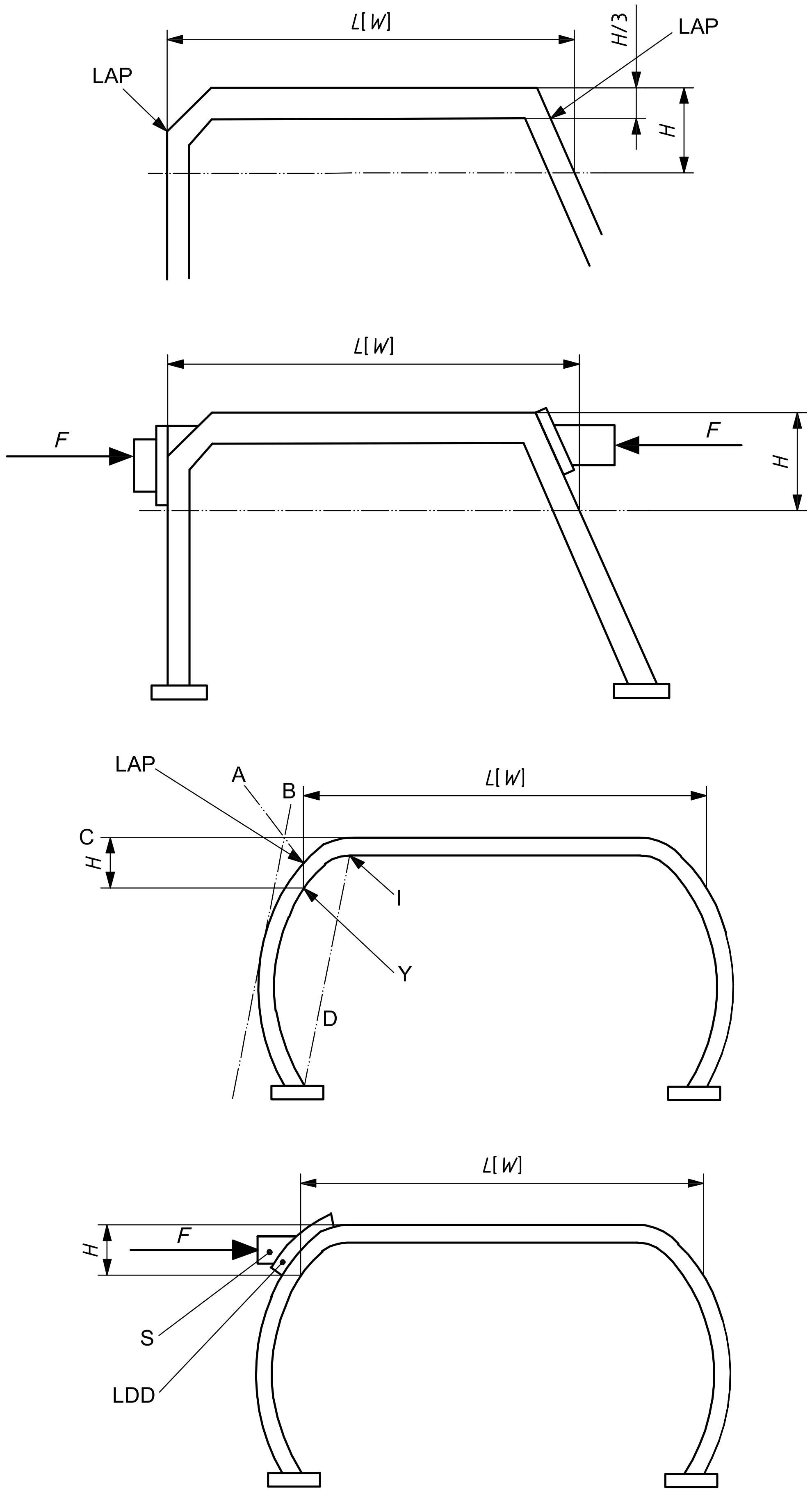
L [*W*] length [width] of ROPS

LDD load distribution device

S socket

NOTE See Figure 1 for an example of LAP and LDD details. Two sockets are shown in this example to illustrate that more than one may be used simultaneously to apply the required force.

Figure 2 — Example of load application point (LAP) of four-post ROPS


L[W]
H/3
LAP
LAP
H
L[W]
F
F
H
LAP
A
B
L[W]
C
H
I
Y
D
L[W]
H
F
S
LDD

Key

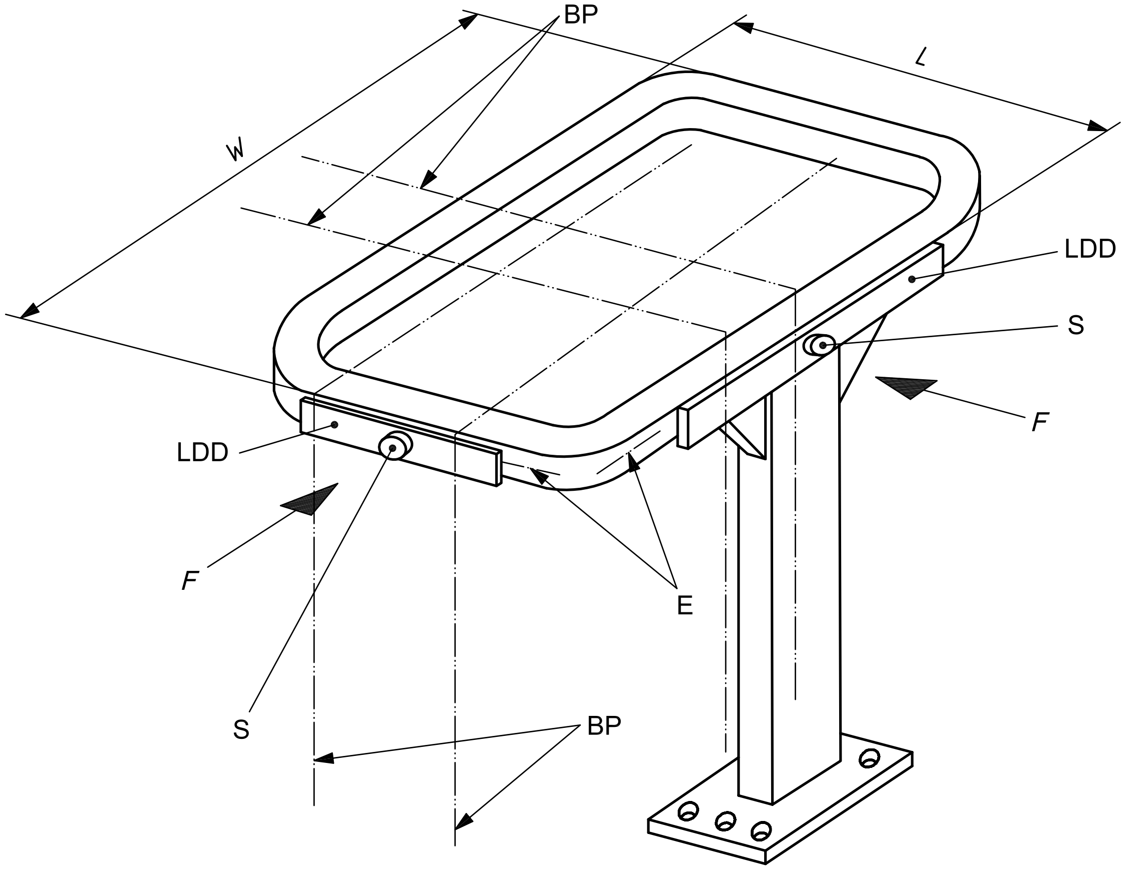
A angle bisector of two tangent lines (B and C)
B tangent line parallel to D on outer surface of curved ROPS structural member
C projection of top surface of upper ROPS structural member
D straight line intersecting ends of curved ROPS structural member with mating members
F load force
H height of load application zone
I intersection of curved surface with flat surface
LDD load distribution device
L [*W*] length [width] of ROPS for LAP determination
LAP load application point
S socket
Y intersection of vertical line from LAP to inner surface of vertical member

NOTE 1 The angle between A and B is equal to the angle between A and C.

NOTE 2 See Figure 1 for an example of LAP and LDD details.

NOTE 3 See Clause 4, *H* for a curved member and 6.4.3.

Figure 3 — Examples of curved and shaped ROPS structural members



Key

BP boundary planes of DLV

E horizontal mid-point of upper ROPS structural member

F load force

L length of ROPS

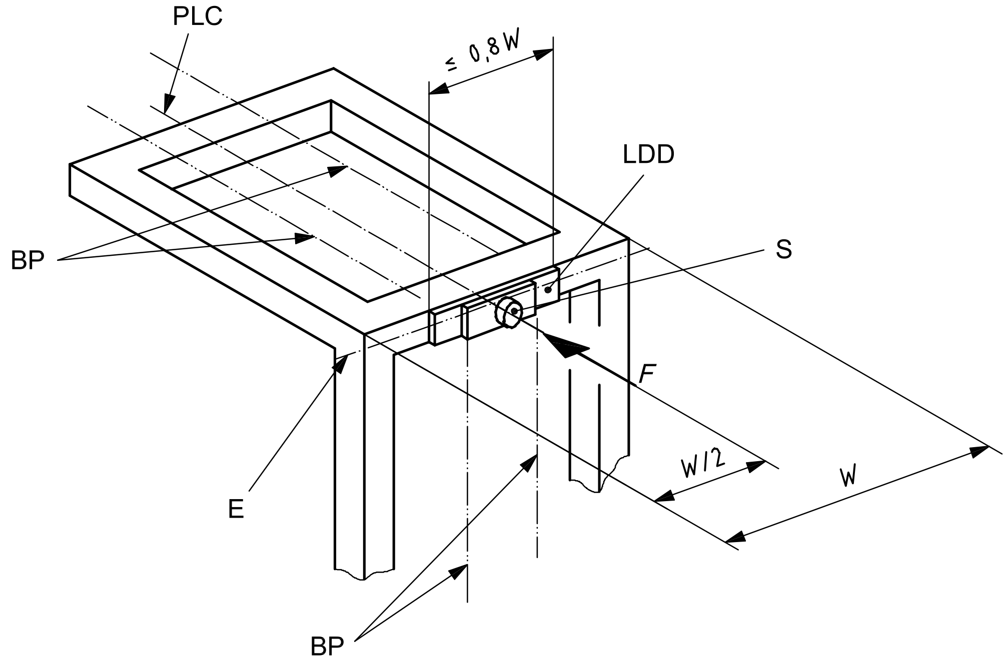
LDD load distribution device

S socket

W width of ROPS

NOTE See Figure 1 for an example of LAP and LDD details.

Figure 4 — Example of single-post ROPS



Key

BP boundary planes of DLV

E horizontal mid-point of upper ROPS structural member

F load force

LDD load distribution device

PLC parallel to longitudinal centreline of machine

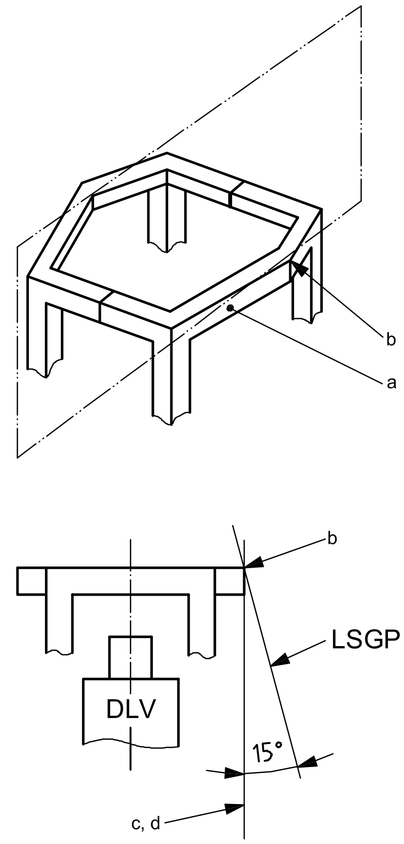
S socket

W width of ROPS

NOTE 1 The load distribution device (LDD) prevents local penetration of the ROPS members at the load application point (LAP). The socket (S) provides unrestricted point loading at the designated location. See Figure 1 for an example of LAP and LDD details.

NOTE 2 Typical, but not mandatory, layout applicable to any ROPS.

Figure 5 — Longitudinal force



Key

a upper ROPS frame member to which lateral load is applied

b outermost point from end view of frame member a

c vertical line through point b

d vertical plane parallel to the machine longitudinal centreline through line c

LSGP lateral simulated ground plane

Figure 6 — Determination of lateral simulated ground plane (LSGP)

5 Test method and test facilities

5.1 General requirements

The requirements are force resistance in the lateral, vertical and longitudinal directions, and energy absorption in the lateral direction. There are limitations on deflections under the lateral, vertical and longitudinal loading.

5.2 Instrumentation

Systems used to measure mass, force and deflection shall be in accordance with ISO 9248, except that the force and deflection measurement capability shall be within ± 5% of the maximum values.

5.3 Test facilities

Fixtures shall be adequate to secure the representative specimen to a bedplate and to apply the required lateral, vertical and longitudinal loads as determined by the formulae given in Table 1.

Table 1 — Force and energy equations

Machine mass m kg	Lateral load force F N	Lateral load energy U J	Vertical load force F N	Longitudinal load force F N
1) Crawler earth-moving machine: dozer, loader, pipelayer and trencher type				
$700 < m \leqslant 4\ 630$	$6m$	$13\ 000\ (m/10\ 000)^{1,25}$		$4{,}8m$
$4\ 630 < m \leqslant 59\ 500$	$70\ 000\ (m/10\ 000)^{1,2}$	$13\ 000\ (m/10\ 000)^{1,25}$	$19{,}61m$	$56\ 000\ (m/10\ 000)^{1,2}$
$m > 59\ 500$	$10m$	$2{,}03m$		$8m$
2) Grader				
$700 < m \leqslant 2\ 140$	$6m$	$15\ 000\ (m/10\ 000)^{1,25}$		$4{,}8m$
$2\ 140 < m \leqslant 38\ 010$	$70\ 000\ (m/10\ 000)^{1,1}$	$15\ 000\ (m/10\ 000)^{1,25}$	$19{,}61m$	$56\ 000\ (m/10\ 000)^{1,1}$
$m > 38\ 010$	$8m$	$2{,}09m$		$6{,}4m$
3) Wheeled earth-moving machine: loader, tractor-dozer, pipelayer, landfill compactor, skid-steer loader, backhoe loader and trencher type				
$700 < m \leqslant 10\ 000$	$6m$	$12\ 500\ (m/10\ 000)^{1,25}$		$4{,}8m$
$10\ 0000 < m \leqslant 128\ 600$	$60\ 000\ (m/10\ 000)^{1,2}$	$12\ 500\ (m/10\ 000)^{1,25}$	$19{,}61m$	$48\ 000\ (m/10\ 000)^{1,2}$
$m > 128\ 600$	$10m$	$2{,}37m$		$8m$
4) Tractor section of combined earth-moving machine: tractor scraper, articulated frame dumper				
$700 < m \leqslant 1\ 010$	$6m$	$20\ 000\ (m/10\ 000)^{1,25}$		$4{,}8m$
$1\ 010 < m \leqslant 32\ 160$	$95\ 000\ (m/10\ 000)^{1,2}$	$20\ 000\ (m/10\ 000)^{1,25}$	$19{,}61m$	$76\ 000\ (m/10\ 000)^{1,2}$
$m > 32\ 160$	$12m$	$2{,}68m$		$9{,}6m$
5) Roller [a]				
$700 < m \leqslant 10\ 000$	$5m$	$9\ 500\ (m/10\ 000)^{1,25}$		$4m$
$10\ 000 < m \leqslant 53\ 780$	$50\ 000\ (m/10\ 000)^{1,2}$	$9\ 500\ (m/10\ 000)^{1,25}$	$19{,}61m$	$40\ 000\ (m/10\ 000)^{1,2}$
$m > 53\ 780$	$7m$	$1{,}45m$		$5{,}6m$
6) Rigid frame dumper — Excluding dump body [b]				
$700 < m \leqslant 1\ 750$	$6m$	$15\ 000\ (m/10\ 000)^{1,25}$		$4{,}8m$
$1\ 750 < m \leqslant 22\ 540$	$85\ 000\ (m/10\ 000)^{1,2}$	$15\ 000\ (m/10\ 000)^{1,25}$		$68\ 000\ (m/10\ 000)^{1,2}$
$22\ 540 < m \leqslant 58\ 960$	$10m$	$1{,}84m$	$19{,}61m$	$8m$
$58\ 960 < m \leqslant 111\ 660$	$413\ 500\ (m/10\ 000)^{0,2}$	$61\ 450\ (m/10\ 000)^{0,32}$		$330\ 800\ (m/10\ 000)^{0,2}$
$m > 111\ 660$	$6m$	$1{,}19m$		$4{,}8m$
7) Rigid frame dumper — Including dump body [c]				
$700 < m \leqslant 10\ 000$	$6m$	$6\ 000\ (m/10\ 000)^{1,25}$		$4{,}8m$
$10\ 000 < m \leqslant 21\ 610$	$60\ 000\ (m/10\ 000)^{1,2}$	$6\ 000\ (m/10\ 000)^{1,25}$		$48\ 000\ (m/10\ 000)^{1,2}$
$21\ 610 < m \leqslant 93\ 900$	$7m$	$0{,}73m$	$19{,}61m$	$5{,}6m$
$93\ 900 < m \leqslant 113\ 860$	$420\ 000\ (m/10\ 000)^{0,2}$	$16\ 720\ (m/10\ 000)^{0,63}$		$336\ 000\ (m/10\ 000)^{0,2}$
$m > 113\ 860$	$6m$	$0{,}68m$		$4{,}8m$

Table 1 (*continued*)

Machine mass m kg	Lateral load force F N	Lateral load energy U J	Vertical load force F N	Longitudinal load force F N
8) Rigid frame dumper — Combination of ROPS and dump body [d]				
$700 < m \leqslant 10\ 000$	$3{,}6m$	$3\ 600\ (m/10\ 000)^{1{,}25}$	$11{,}77m$	$2{,}9m$
$10\ 000 < m \leqslant 21\ 610$	$36\ 000\ (m/10\ 000)^{1{,}2}$	$3\ 600\ (m/10\ 000)^{1{,}25}$		$28\ 800\ (m/10\ 000)^{1{,}2}$
$21\ 610 < m \leqslant 93\ 900$	$4{,}2m$	$0{,}44m$		$3{,}4m$
$93\ 900 < m \leqslant 113\ 860$	$252\ 000\ (m/10\ 000)^{0{,}2}$	$10\ 000\ (m/10\ 000)^{0{,}63}$		$202\ 000\ (m/10\ 000)^{0{,}2}$
$m > 113\ 860$	$3{,}6m$	$0{,}41m$		$2{,}9m$

[a] Mass m excludes mass of loosely contained ballast, which can separate from machine in the event of a roll-over.

[b] Mass m includes machine mass but not dump body or payload mass.

[c] Mass m includes machine and dump body mass but not payload mass. The body sections on which the loads are applied shall totally cover the vertical projection of the DLV. Lateral and vertical LAP shall be on the body overhang portion in the same relative locations outlined for separate ROPS. Longitudinal load shall be applied at that face producing the greatest change of deformation toward the operator.

[d] Mass m includes machine and dump body mass but not payload mass. Lateral, longitudinal or vertical loading of the ROPS and/or body need not be applied simultaneously to both members of a combination. The only limitation on the order of the six loadings is that the vertical loading of members shall be applied after the lateral loading and the longitudinal loading of members shall be applied after the vertical loading. See Figures 12 and 13.

5.4 Representative specimen attachment to bedplate

5.4.1 The ROPS shall be attached to the machine frame as it would be on an operating machine. A complete machine is not required for the evaluation. The machine frame and mounted ROPS test specimen shall represent the structural configuration of an operating installation, including those portions of the frame that can absorb energy in a machine roll-over. All normally detachable windows, panels, doors and other non-structural elements shall be removed so that they do not influence the results of the ROPS evaluation. A cab that is not an integral part of the ROPS is not required to be part of the evaluation arrangement.

Where not practicable to use the full machine frame for the physical testing of a ROPS or FOPS, a partial frame may be used. The partial frame may be fabricated, but it shall duplicate as closely as possible the strength and stiffness of the original frame.

The minimum portion of the machine frame or facsimile required shall be determined by evaluating the rigidity and strength of the machine frame to ensure that it is capable of absorbing the energy transmitted to the machine frame via the ROPS during the test without failure.

The representative specimen shall be mounted to a substantially rigid bedplate so as to have a stiffness which is at least equal to that of a complete machine frame.

An evaluation of the rigidity and strength of the machine frame shall be performed for each test where a partial frame or facsimile of a frame is used. A copy of the evaluation shall be retained by the manufacturer.

5.4.2 The representative specimen shall be secured to the bedplate so that the members connecting the assembly and bedplate experience minimal deflection during testing. The representative specimen shall not receive any support from the bedplate, other than that due to the initial attachment. The fixture arrangement shall not inhibit possible machine frame deformation in the ROPS mounting areas. The intent is that the energy be absorbed by the representative specimen and not by the fixture arrangement.

5.4.3 The test shall be conducted with any machine/ground suspension element blocked externally so that it does not contribute to the load-deflection behaviour of the test specimen. Suspension elements used to attach the ROPS to the machine frame and that act as a load path shall be in place and functional at the start of the test.

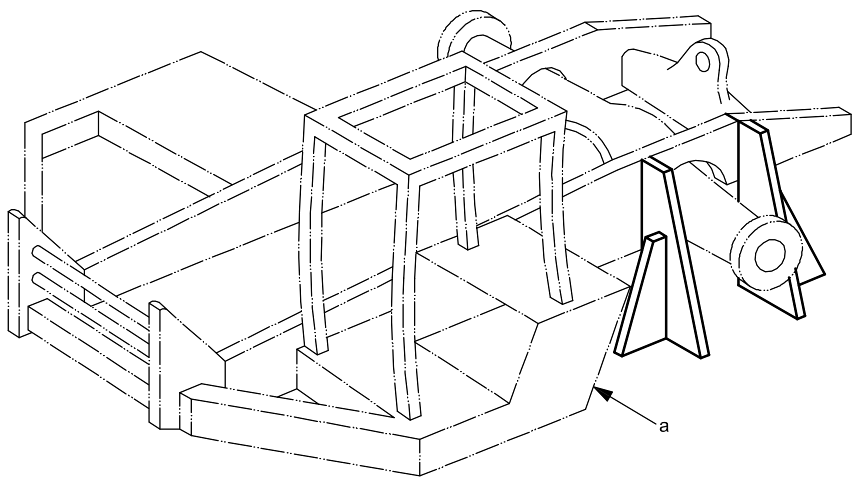
5.4.4 Frame connections to the bedplate shall be directly from the machine frame at or near the front and rear axle supports.

For articulated machines, the hinge shall be locked with no articulation if both frames are used in the evaluation. If only the frame on which the ROPS is mounted is used, the connections shall be at or near the articulation joint and axle support or at the outside end of the frame.

For single-axle prime movers, the support shall be at the drive axle.

Crawler machines shall be connected to the bedplate through the main drive housing and/or track frames.

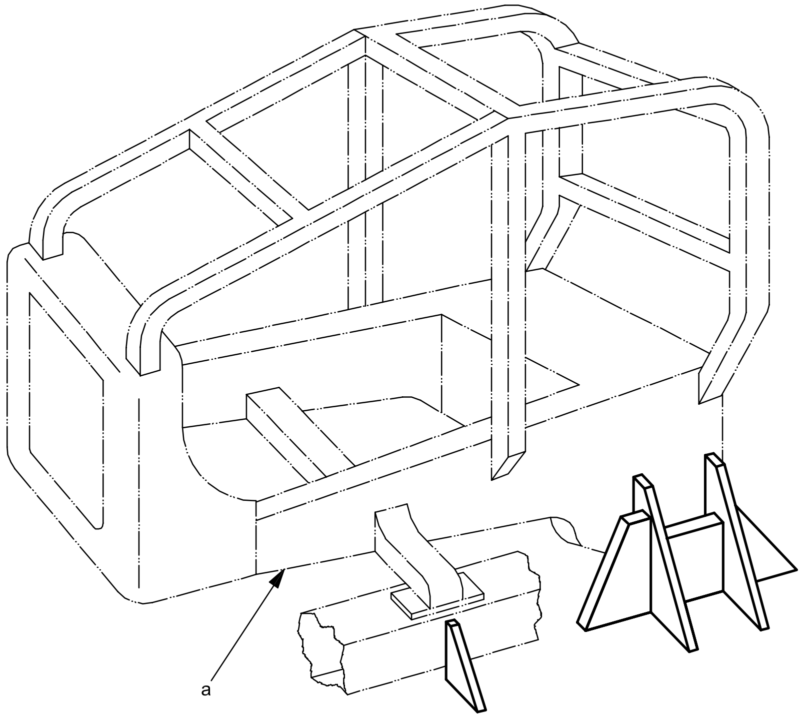
See the examples shown in Figures 7 to 13.



NOTE The layout illustrated is typical, but not mandatory.

a Not in contact with the bedplate.

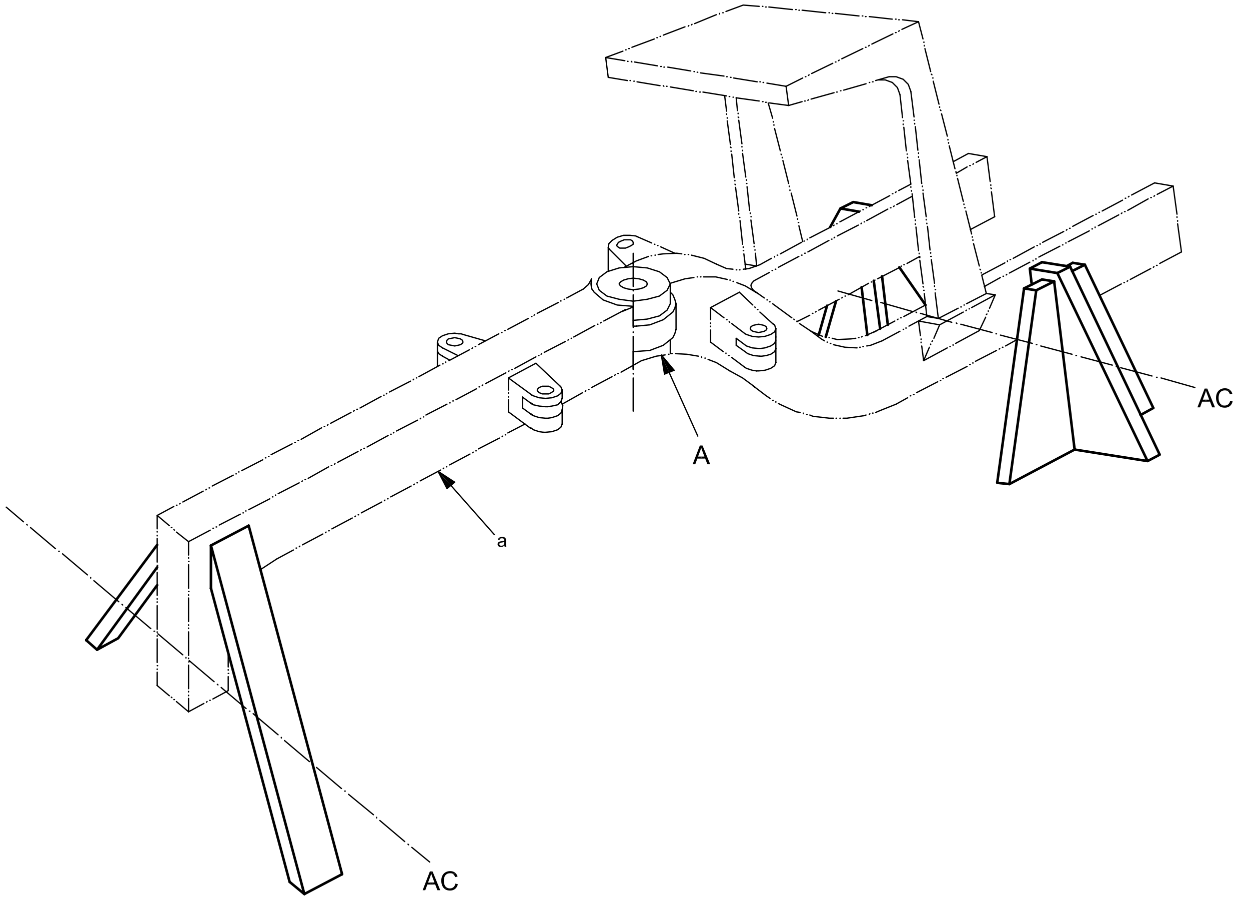
Figure 7 — Example of test bed anchorage of tractor section (prime mover)



NOTE The layout illustrated is typical, but not mandatory.

[a] Not in contact with the bedplate.

Figure 8 — Example of test bed anchorage of crawler dozer



Key

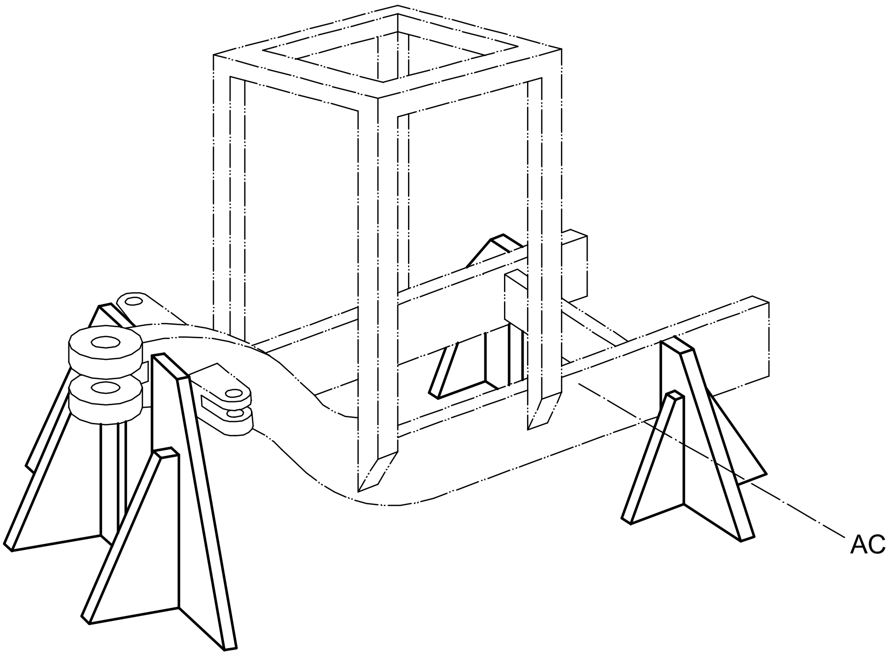
A any articulation to be blocked

AC axle centreline

NOTE The layout illustrated is typical, but not mandatory.

[a] Not in contact with the bedplate.

Figure 9 — Example of anchorage of articulated motor grader (complete frame)

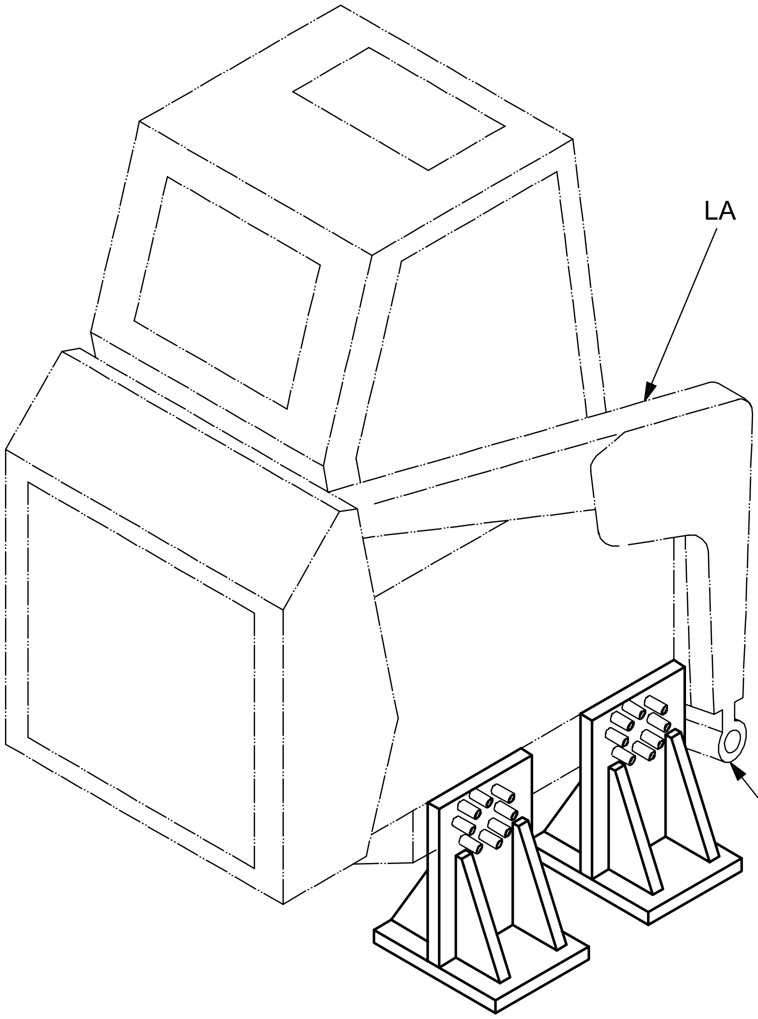


Key

AC axle centreline

NOTE The layout illustrated is typical, but not mandatory.

Figure 10 — Example of test bed anchorage of half-articulated frame



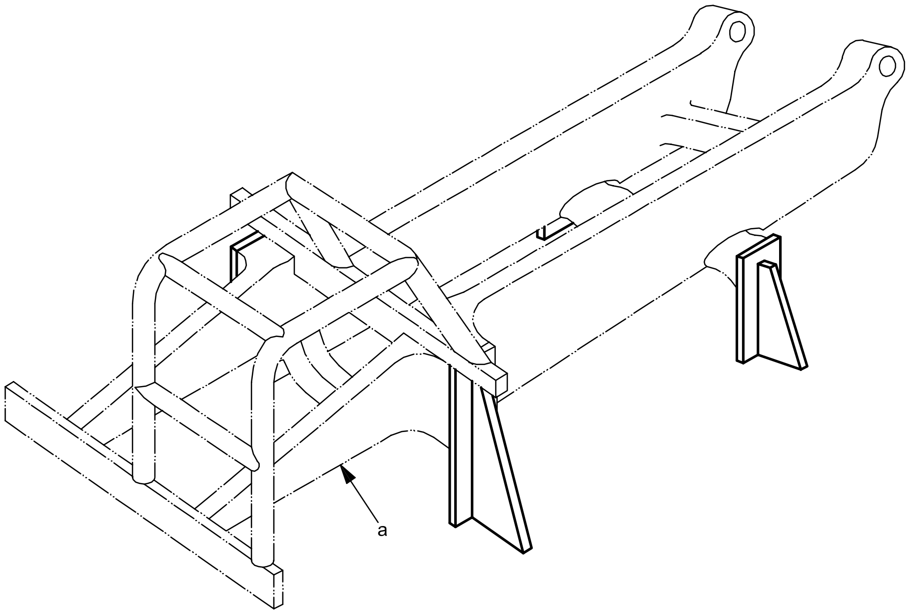
Key

LA lift arm (if installed) fully lowered

NOTE The layout illustrated is typical, but not mandatory.

[a] Not in contact with the bedplate.

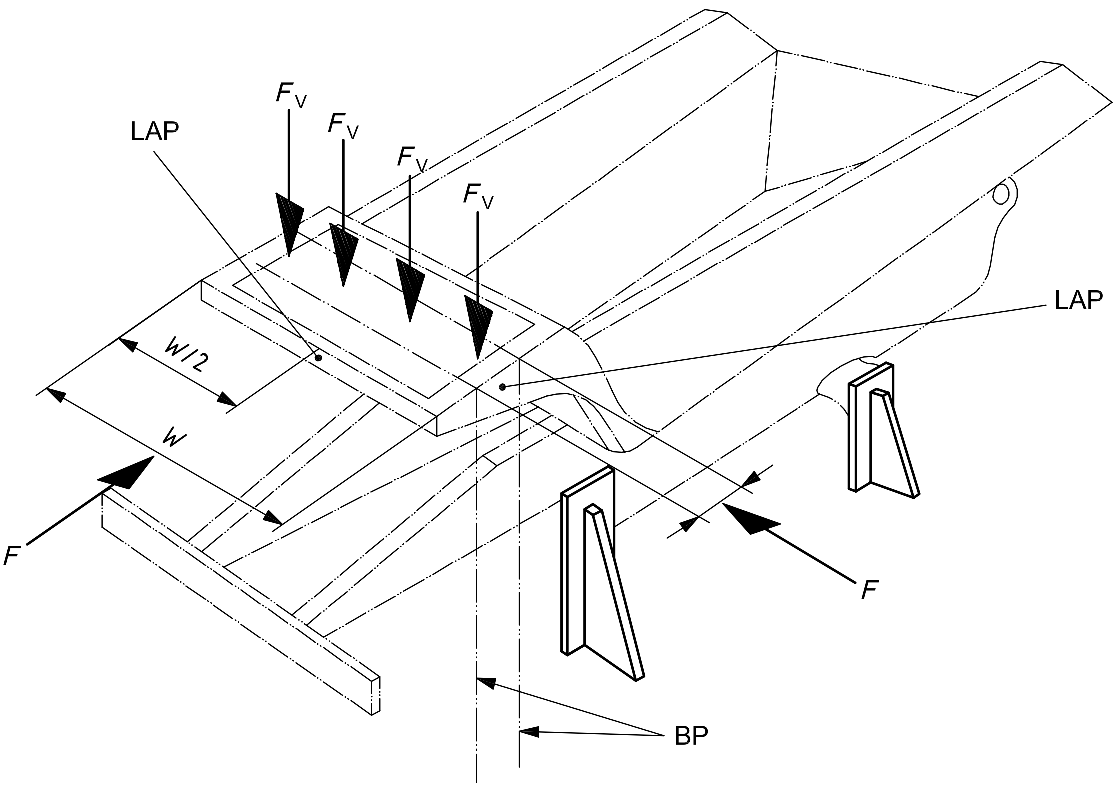
Figure 11 — Example of anchorage of skid-steer loader



NOTE The layout illustrated is typical, but not mandatory.

a Not in contact with the bedplate.

Figure 12 — Example of anchorage of dumper frame — Excluding dump body option



Key

BP boundary planes of DLV

F load force

F_v vertical load force equally distributed across LDD

LAP load application point

W width of ROPS

NOTE The layout illustrated is typical, but not mandatory.

Figure 13 — Example of loading of rigid frame dumper — Including dump body option

6 Test loading procedure

6.1 General requirements

6.1.1 All LAP shall be determined and marked on the structure before any loading is applied.

6.1.2 The loads shall be calculated according to Table 1 and the loading sequence shall be lateral, vertical and longitudinal.

6.1.3 No straightening or repair is permitted during or between loading sequences.

6.1.4 The load shall be applied through S and LDD. The socket shall provide unrestricted movement of the ROPS during the loading process. LDD is used to prevent localized penetration of ROPS structural members. S and LDD shall not impede rotation of the ROPS.

6.1.5 LDD shall not contact a ROPS structural member beyond H.

6.2 Lateral loading

6.2.1 LDD shall span L, in cases where no rear cross-member exists that would be capable of transferring the load without buckling. In all other cases, the device shall not distribute the load over a length greater than 80 % of the ROPS length L. For the length, L, of curved surfaces, see Figures 3.

6.2.2 For rollbar ROPS, the LAP shall be on the same plane with the upper lateral cross-member.

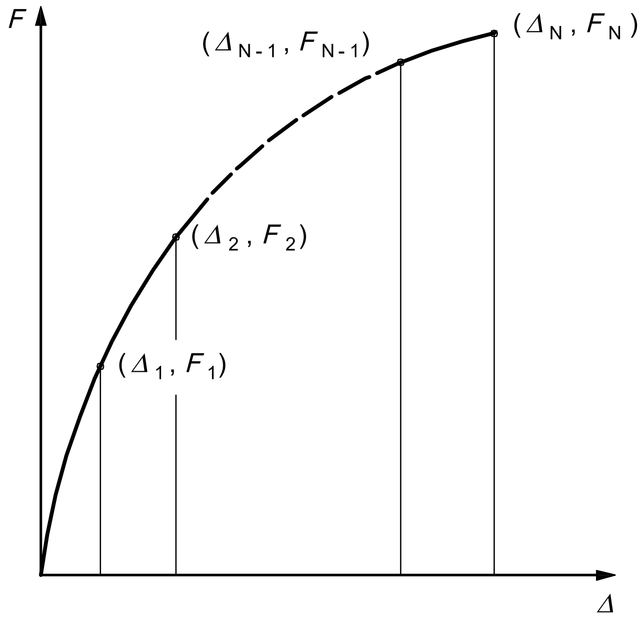
6.2.3 For all other one-post or two-post ROPS, the LAP shall be dictated by the length, L, and the vertical projection of the closest side or edge of the DLV. The LAP shall not be within a distance $L/3$ measured from the rear outside face of the ROPS structure. If the $L/3$ point is situated between the back face of the ROPS at the post side and the intersection of the DLV boundary plane (BP) closest to the post(s) with the lateral structural member, the LAP shall be moved away from the post side until it reaches at least the BP of the DLV (see Figure 1).

6.2.4 For a ROPS with more than two posts, the LAP shall be located between vertical projections of the front and rear BP of the DLV (see Figure 2).

6.2.5 Where the operator's seat is off the machine longitudinal centreline, the loading shall be against the external side of the lateral structural member closest to the seat. Where the operator's seat is on the machine longitudinal centreline, if the ROPS structure and mounting are such that different force-deflection results are likely by loading from left or right, the side that is loaded shall be that which will place the most severe loading requirements on the representative specimen.

6.2.6 The initial direction of the loading shall be horizontal and perpendicular to a vertical plane through the machine longitudinal centreline. As loading continues, representative specimen deformations can cause the direction of loading to change. This is permissible.

6.2.7 The loading may be considered static if the rate of deflection at the LAP is not greater than 5 mm/s. The values of force and deflection, at the LAP, shall be recorded at deflection increments no greater than 15 mm. The loading is to continue until the force and energy levels in accordance with Table 1 have been reached. The method of calculating the energy, U, is shown in Figure 14. The measured deflection used in calculating the energy is that of the ROPS along the line of the applied force. Deflection of the ROPS mounting system and machine frame may be included in the total deflection; however, deflection of all test fixture arrangements shall be excluded.



Key

F force

Δ deflection

U energy

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

Figure 14 — Force-deflection curve for loading test

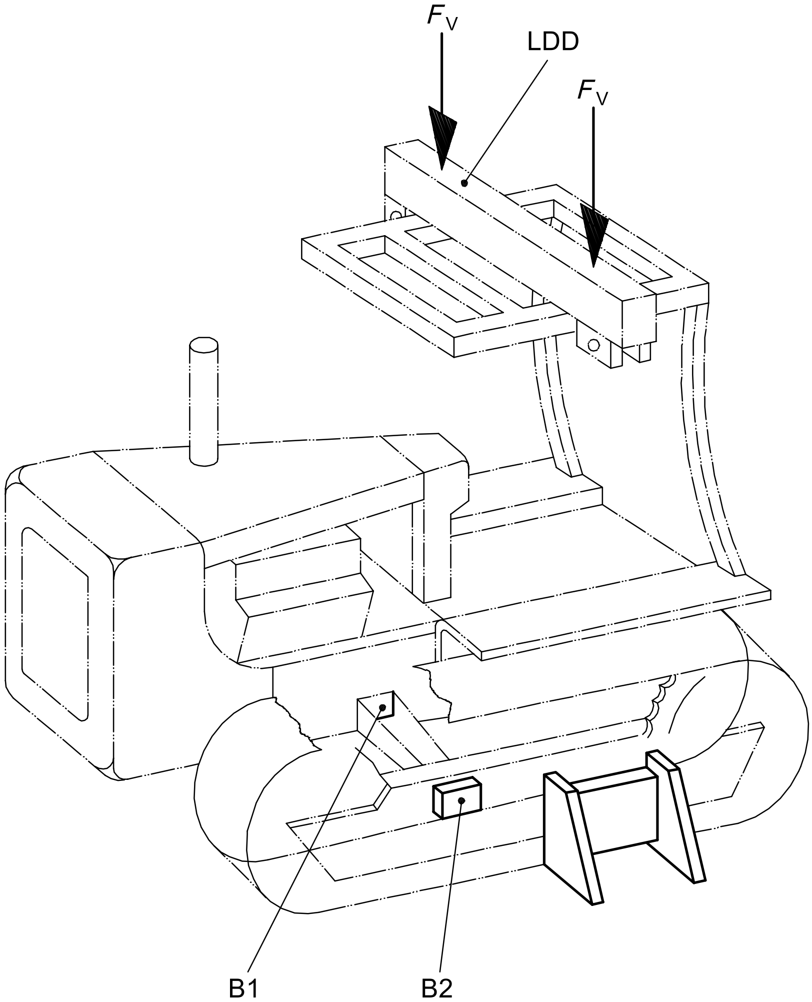
6.3 Vertical loading

6.3.1 After completion of the lateral loading, a vertical load shall be applied to the top of the ROPS.

6.3.2 For all ROPS, the centre of the vertical load shall be applied in the same vertical plane, perpendicular to the longitudinal centreline of the ROPS structure, defined on the structure before deformation from the lateral loading.

6.3.3 The load on the ROPS is applied without limitation on the manner of distribution, provided it is applied symmetrically with the longitudinal centreline of the deformed ROPS structure. Figure 15 shows an example of vertical load application.

6.3.4 The rate of deflection shall be such that the loading may be considered static according to the criteria defined in 6.2.7. The loading is to continue until the force level specified in Table 1 has been reached. The structure shall support this load for a period of 5 minutes or until any deformation has ceased, whichever is shorter.



Key

B1, B2 blocks positioned against both sets of track frames to prevent motion

F_v vertical load force equally distributed across LDD

LDD load distribution device

Figure 15 — Vertical loading example

6.4 Longitudinal loading

6.4.1 After completion of the vertical loading, a longitudinal load shall be applied to the ROPS.

6.4.2 The longitudinal load shall be applied to the upper structural members of the ROPS along the longitudinal centreline of the ROPS. The LAP is determined using the intersecting planes of the front and top surfaces. If surfaces are curved, determine the intersecting plane by using the tangent line at the mid-point of the arc segment of the top or front member (see Figure 3).

6.4.3 The longitudinal load shall be applied at a location consistent with Figures 1 to 5, established prior to lateral loading. The load distribution device shall span the width in cases where no rear (front) cross-member exists that would be capable of transferring the load without buckling. In all other cases, the device shall not distribute the load over a length greater than 80 % of the width, W, of the ROPS (see Figure 3).

6.4.4 For all machines, the direction of loading (fore or aft) shall be selected in order to place the most severe requirements on the representative specimen. The initial direction of loading shall be horizontal and parallel to the original longitudinal centreline of the machine. Some factors to consider in deciding on the direction to apply the longitudinal load are the following:

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

b) machine characteristics, e.g. other structural members of the machine that could resist longitudinal deflection of the ROPS and which can limit the direction of the longitudinal component of loading on the ROPS;

c) experience that could 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 roll-over.

6.4.5 The rate of deflection shall be such that the loading may be considered static according to the criteria given in 6.2.7. This loading is to continue until the force level specified in Table 1 has been reached.

7 Temperature and material criteria

7.1 General ROPS requirements

In addition to the loading requirements, there are material and temperature requirements needed to ensure that the ROPS will have resistance to brittle fracture. The preferred method of meeting this requirement is to fabricate all ROPS structural members from materials that meet the mechanical requirements specified in 7.2 and 7.3. In this case, the ROPS test may be carried out at any desired temperature. In any case, fasteners shall fulfil the requirements of 7.4.

7.2 ROPS structural members

ROPS structural members — except those made of thin steels — shall be made of steels that meet or exceed one of the Charpy V-notch (CVN) impact strengths in accordance with Table 2. Any thin-steel structural member shall meet the requirements of 7.3. Alternatively, the temperature and material requirements may be met by applying the static loadings with all ROPS structural members at, or below, −18 °C if material specifications and procurement guarantee that materials in ROPS subsequently manufactured will have toughness characteristics similar to those in the representative specimen tested.

NOTE The Charpy V-notch evaluation is primarily a quality control check and the indicated temperature does not directly relate to operating conditions.

Supplier or manufacturer certifications can be used as evidence of acceptability. Supplier or manufacturer records shall be maintained for all production materials used in structural members.

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

7.3 Thin steels

The following shall be considered as meeting the Charpy requirement:

— steel less than or equal to 2,5 mm in thickness with a maximum carbon content of 0,20 %;

— fully killed, fine grained steel of thickness greater than 2,5 mm but lower than or equal to 4,0 mm, with a maximum carbon content of 0,20 %.

7.4 Fasteners

Bolts used structurally shall be metric property class 8.8, 9.8 or 10.9 in accordance with ISO 898-1, or equivalent. Nuts used structurally shall be metric property class 8 or 10 in accordance with ISO 898-2, or equivalent.

NOTE Bolts exceeding metric property class 10.9 (see ISO 898-1), or equivalent, can require strict quality control to avoid brittle or delayed fracture.

Table 2 — Minimum Charpy V-Notch impact strength

Specimen size mm	Energy requirement	
	at −30 °C J	at −20 °C J [b]
10 × 10 [a]	11	27,5
10 × 9	10	25
10 × 8	9,5	24
10 × 7,5 [a]	9,5	24
10 × 7	9	22,5
10 × 6,7	8,5	21
10 × 6	8	20
10 × 5 [a]	7,5	19
10 × 4	7	17,5
10 × 3,3	6	15
10 × 3	6	15
10 × 2,5 [a]	5,5	14

[a] Indicates preferred size. Specimen size shall be no less than the largest preferred size that the material will permit.

[b] The energy requirement at −20 °C is 2,5 times the value specified for −30 °C. Other factors affect impact energy strength, e.g., direction of rolling, yield strength, grain orientation, and welding. These shall be considered in selecting steel.

8 Acceptance criteria

They are as follows.

a) The specific lateral force and lateral energy, vertical load-carrying capacity and the longitudinal force 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.

b) The force and energy requirements under lateral loading need not be attainable simultaneously. One may be significantly exceeded before the other is attained. If the force is attained before the energy, the force may decrease but shall again attain the required level when the lateral energy requirement is met or exceeded.

c) No part of the ROPS shall enter the DLV at any time during the lateral, vertical or longitudinal loading phases of the test. The limitations on the deflections are absolute.

d) Except for the situation as described in 8 f), the LSGP, as illustrated in Figure 6, shall not enter the DLV (upright mode) at any time during the lateral loading phase of the test.

e) The VSGP shall not enter the DLV at any time during the vertical loading phase of the test for a rollbar ROPS, or one-post or two-post ROPS (see Figure 16).

f) During lateral loading with a side-facing operator seat mounted off the machines longitudinal centreline or for longitudinal loading with the operator facing the direction that the ROPS will deflect under load application, it is permissible for the upper portion of the DLV to be rotated “forward” up to 16° about its seat index point (SIP), as defined in ISO 5353, to prevent intrusion of ROPS members or the LSGP in lateral loading only. Forward rotation of the DLV shall be limited to less than 16° if interference with any machine components or intrusion by controls occurs at a lesser angle (see Figure 17).

g) If a longitudinal load is applied in the direction opposite to that indicated in 8.1 f (i.e., with the operator facing the direction opposite that which the ROPS will deflect towards under load application), no rotation of the DLV is allowed. The force requirement shall be attained within the same conditions as required to achieve the lateral energy requirement.

h) The ROPS shall not break away from the machine frame due to separation of the ROPS, its mounting system, or the machine frame. In the event of a partial separation, the ROPS must demonstrate the capability of preventing total separation from the machine at the required force and energy levels.

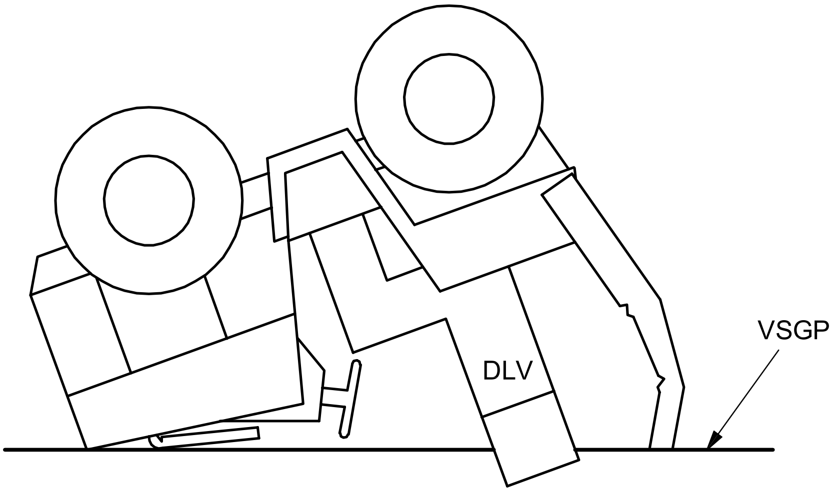
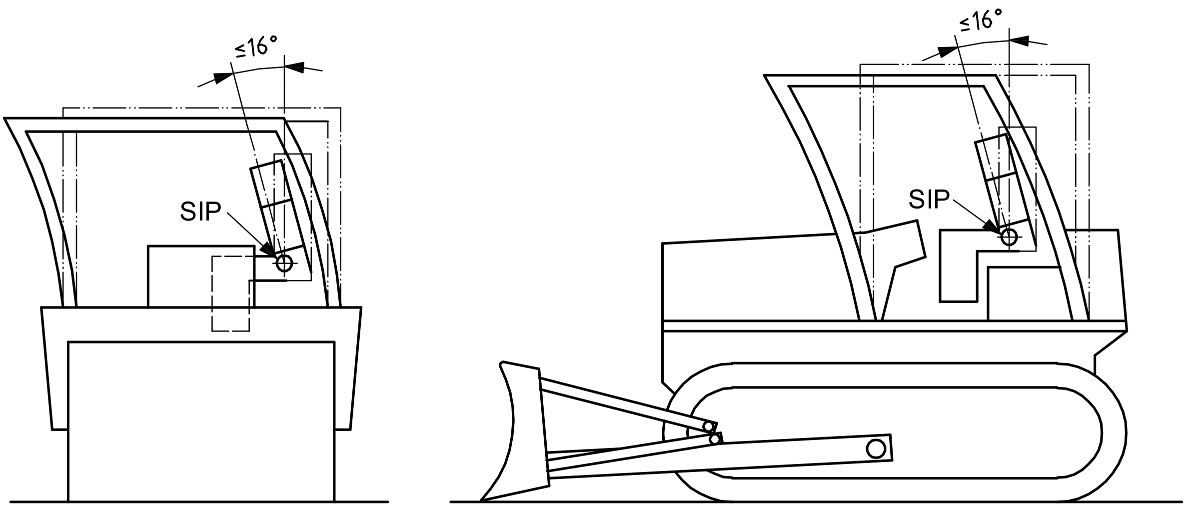


Figure 16 — Example of unacceptable intrusion of VSGP into DLV



a) Lateral load on roller with sideways mounted seat

b) Longitudinal load on dozer

Key

SIP seat index point

Figure 17 — Allowable rotation of upper DLV about SIP

9 Labelling of ROPS

9.1 General

ROPS meeting the requirements of this International Standard shall be labelled according to 9.2 and 9.3. FOPS information may be included on the label.

9.2 Label specifications

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

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

9.3 Label content

The label shall indicate the following:

a) the business name and full address of the ROPS manufacturer, and, where applicable, his authorized representative;

b) designation of the ROPS, if any [1)];

c) mandatory marking, if applicable [1) 2)];

1) Applies to ROPS sold by a ROPS manufacturer other than the original machine manufacturer.

2) For machines and their related products intended to be put on the market in the EEA, this is the CE marking as defined in the applicable European Directive(s), e.g. Machinery.

d) designation of series or type/model of machine for which the ROPS is intended;

e) serial number, if any [3];

f) year of construction, i.e. year in which the manufacturing process was completed [3];

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

h) International Standard number(s) for which the structure meets all of the performance requirements;

i) other such information as is deemed appropriate (e.g. installation, repair or replacement information).

10 Reporting results

The results of the tests shall be reported using a test report such as the example presented in Annex A.

3) Applies to ROPS sold by a ROPS manufacturer other than the original machine manufacturer.

Annex A
(normative)

ROPS test report

A.1 General

The following is an example presentation. All information in this annex shall be included in the report.

A.2 Identification

A.2.1 Machine

Type: ....

Manufacturer: ....

Model number: ....

Serial number: ....

Machine frame part number: ....

A.2.2 ROPS

Manufacturer: ....

Model: ....

Serial number: ....

ROPS part number: ....

A.3 Information supplied by manufacturer

Maximum recommended mass: .... kg

Location of DLV: ....

A.4 Criteria

Lateral load force: .... N

Lateral load energy: .... J

Vertical load force: .... N

Longitudinal load force: .... N

A.5 Test results

The following force and energy levels were achieved or exceeded with no penetration by the ROPS structural member or the SGP (where applicable) into the DLV.

A.5.1 Lateral loading

Maximum force attained after the energy requirement was achieved or exceeded: .... N

Absorbed energy attained: .... J

A.5.2 Vertical loading

Maximum force attained: .... N

A.5.3 Longitudinal loading

Maximum force attained: .... N

A.5.4 Temperature and material

The test was performed with ROPS and machine frame members soaked to .... °C

(To be completed only if the above temperature is over −18 °C).

The Charpy V-notch impact strength requirements for ROPS structural metallic members were tested on a specimen of size ………….. mm × ………….. mm. The absorbed energy was .... J

Nut property class: ....

Bolt property class: ....

A.5.5 Use of special suspension or shock-absorption system

Manufacturer: ....

Model: ....

Product Identification Number: ....

A.5.6 Force-deflection curve for loading test

A force-deflection curve based on the actual test results shall be included in the test report.

A.5.7 Photo of specimen

Photographs illustrating the test specimen before and after each of the test criteria (lateral, vertical, and longitudinal) shall be included.

A.6 Attestation statement

The minimum performance requirements of ISO 3471:2008 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)

Design changes, physical testing and alterations

B.1 Design changes

Any changes to the design of the ROPS or machine frame require physical testing, unless

a) it can be determined that this is a minor change to an existing design which was physically tested, and

b) the changes have no adverse effect on the performance of the ROPS and machine frame.

B.2 Alterations or repairs

Any ROPS structure which has discernible deformation shall not be reused.

No alterations or repairs to a protective structure shall be permitted except where authorized by the manufacturer. Structures which have been altered or repaired without proper authorization are not in compliance with this International Standard.

B.3 Alternatives to physical testing

Theoretical performance analysis of major new design ROPS is not permitted as an alternative to physical testing.

Bibliography

[1] ISO 6683, *Earth-moving machinery — Seat belts and seat belt anchorages — Performance requirements and tests*

ICS 53.100

Price based on 33 pages