

Mobile elevating work platforms — Design calculations, safety requirements and test methods

ICS 53.020.99

National foreword

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- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
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Mobile elevating work platforms — Design calculations, safety requirements and test methods

*Plates-formes élévatrices mobiles de personnel — Calculs de
conception, exigences de sécurité et méthodes d'essai*



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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 16368 was prepared by Technical Committee ISO/TC 214, *Elevating work platforms*.

Introduction

The object of this International Standard is to define rules for safeguarding persons and objects against the risk of accidents associated with the operation of mobile elevating work platforms (MEWPs).

This International Standard does not repeat all the general technical rules applicable to every electrical, mechanical or structural component.

The safety requirements of this International Standard have been drawn up on the basis that MEWPs are periodically maintained according to manufacturers' instructions, working conditions, frequency of use and national regulations.

It is assumed the MEWPs are checked for function daily before start of work and are not put into operation unless all required control and safety devices are available and in working order.

If a MEWP is seldom used, the checks may be made before start of work.

Annex A explains the choice of Beaufort Scale 6 as maximum wind speed.

Where for clarity an example of a safety measure is given in the text, this is not intended as the only possible solution. Any other solution leading to the same risk reduction is permissible if an equivalent level of safety is achieved.

As no satisfactory explanation could be found for the dynamic factors used for stability calculations in previous national standards, the results of the tests carried out by the European Committee for Standardization (CEN), former TC 98/WG1, to determine a suitable factor and stability calculation method for MEWPs have been adopted. The test method is described in Annex B as a guide for manufacturers wishing to use higher or lower operating speeds and to take advantage of developments in control systems.

Similarly, to avoid the unexplained inconsistencies in coefficients of utilization for wire ropes found in other standards for lifting devices, appropriate extracts of the widely accepted German standard DIN 15020 (all parts) have been included in 5.5.2 and Annex C, with a worked example in Annex D.

Mobile elevating work platforms — Design calculations, safety requirements and test methods

1 Scope

This International Standard specifies technical safety requirements and measures for all types and sizes of mobile elevating work platforms (MEWPs) intended to move persons to working positions.

This International Standard is applicable to the structural design calculations and stability criteria, construction, safety examinations and security tests before MEWPs are first put into service. It identifies the hazards arising from the use of MEWPs and describes methods for the elimination or reduction of these hazards.

It does not cover the hazards arising from

- operation by radio and other wireless controls,
- use in potentially explosive atmospheres,
- electromagnetic incompatibility,
- work on live electrical systems (see IEC 61057),
- use of compressed gases for load-bearing components.

This International Standard is not applicable to

- a) permanently installed personnel-lifting appliances serving defined levels (see EN 81-1 and EN 81-2);
- b) fire-fighting and fire rescue appliances (see EN 1777);
- c) unguided work cages suspended from lifting appliances (see EN 1808);
- d) elevating operator position on rail-dependent storage and retrieval equipment (EN 528);
- e) tail lifts (see EN 1756-1 and prEN 1756-2);
- f) mast-climbing work platforms (see ISO 16369);
- g) fairground equipment;
- h) lifting tables with a lifting height of less than 2 m (see EN 1570);
- i) builders' hoists for persons and materials (see EN 12159);
- j) aircraft ground-support equipment (see EN 1915-1 and EN 1915-2);
- k) digger derricks (see ANSI A10.31);
- l) elevating operator positions on industrial trucks (see EN 1726-2);

- m) under-bridge inspection and maintenance devices (see ANSI A92.8);
- n) stock-picking or order-picking type equipment.

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 2408:1985, *Steel wire ropes for general purposes — Characteristics*

ISO 3864 (all parts), *Graphical symbols — Safety colours and safety signs*

ISO 4302, *Cranes — Wind load assessment*

ISO 4305, *Mobile cranes — Determination of stability*

ISO 4309, *Cranes — Wire ropes — Care, maintenance (including installation), inspection*¹⁾

ISO 12100-1, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology*

ISO 12100-2, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles and specifications*

ISO 13850, *Safety of machinery — Emergency stop — Principles for design*

ISO 13854, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body*

ISO 18893, *Mobile elevating work platforms — Safety requirements, inspection, maintenance and operation*¹⁾

ISO 20381 *Mobile elevating work platforms — Symbols for operator controls and other displays*¹⁾

IEC 60204-1:2000, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

IEC 60707, *Flammability of solid non-metallic materials when exposed to flame sources — List of test methods*

IEC 60947-5-1:2000, *Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices*

IEC 61057:1991, *Aerial devices with insulating boom used for live working*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18893 and the following apply.

3.1

access position

normal position which provides access to and from the work platform

NOTE The access, stowed (3.30), lowered travel (3.12) and transport (3.32) positions can be identical.

¹⁾ To be published.

3.2**chain-drive system**

system that comprises one or more chain(s) running on chain sprockets and on or over chain pulleys as well as any associated chain sprockets, chain pulleys and compensating pulleys

3.3**chassis**

base of the MEWP

See Figure 1.

NOTE The chassis may be pulled, pushed, self-propelled, etc.

3.4**critical component**

load-supporting element which supports or stabilizes the work platform or the extending structure

3.5**elevated travel position**

configuration of the MEWP for travel on a work site outside of the lowered travel position

3.6**extending structure**

structure which is connected to the chassis and supports the work platform and allows movement of the work platform to its required position

See Figure 1.

NOTE It may, for example, be a single or a telescoping or an articulating boom or ladder, or a scissor mechanism or any combination of them, and may or may not slew on the base.

3.7**finite element analysis model****FEA model**

computerized method of idealizing a real model for the purposes of performing structural analysis

3.8**indoor use**

use of a MEWP in areas shielded from wind so there is no wind force acting on the MEWP

3.9**load cycle**

cycle starting from a position, carrying out work and returning to the same position

3.10**load-sensing system**

system of monitoring the vertical load and vertical forces on the work platform

NOTE The system includes the measuring device(s), the method of mounting the measuring devices and the signal processing system.

3.11**lowering, noun**

all operations, other than travelling, to move the work platform to a lower level

See Figure 1.

3.12**lowered travel position**

configuration of the MEWP for travel on a work site where the work platform height is 3 m or less

NOTE The access (3.1), stowed (3.30), lowered travel and transport (3.32) positions can be identical.

3.13

manufacturer

person or entity with overall responsibility for the design, specification, procurement, fabrication, assembly and testing of a ready-for-use MEWP

3.14 MEWP group classification

3.14.1

group A

MEWPs whose vertical projection of the centre of gravity of the load is always inside the tipping lines

3.14.2

group B

MEWPs whose vertical projection of the centre of gravity of the load may be outside the tipping lines

3.15 MEWP types

3.15.1

type 1 MEWP

MEWP for which travelling is only allowed with the MEWP in its stowed position

3.15.2

type 2 MEWP

MEWP for which travelling with work platform in elevated travel position is controlled from a point on the chassis

3.15.3

type 3 MEWP

MEWP for which travelling with work platform in elevated travel position is controlled from a point on the work platform

NOTE Types 2 and 3 can be combined.

3.16

mobile elevating work platform

MEWP

machine (device) that is intended to displace persons, tools and material to working positions and consists of at least a work platform with controls, an extending structure and a chassis

3.17

moment-sensing system

system of monitoring the moment acting about the tipping line tending to overturn the MEWP

NOTE The system includes the measuring device(s), the method of mounting the measuring devices and the signal processing system.

3.18

off-slab

surface that is not necessarily levelled, paved, or of concrete or an equivalent material, but does not include uncompacted soil

3.19

outdoor use

use of a MEWP in an environment which may be exposed to wind

3.20

paved slab surface

substantially level surface of asphalt, concrete or equivalent

3.21**pedestrian-controlled MEWP**

MEWP whose controls for powered travel can be operated by a person walking close to the MEWP

3.22**rail-mounted MEWP**

MEWP whose travel is guided by rails

3.23**raising**, noun

any operation, other than travelling, which moves the work platform to a higher level

See Figure 1.

3.24**rated load**

load for which the MEWP has been designed for normal operation and is composed of persons, tools and material acting vertically on the work platform

NOTE A MEWP can have more than one rated load.

3.25**rotation**

circular movement of the work platform about a vertical axis

See Figure 1.

3.26**secondary work platform**

platform attached to the work platform (3.39) or the extending structure, and able to be moved separately

3.27**self-propelled MEWP**

MEWP whose travelling controls are located on the work platform

3.28**slewing**, noun

circular movement of the extending structure about a vertical axis

See Figure 1.

3.29**stabilizer**

any device or system used to stabilize MEWPs by supporting and/or levelling the complete MEWP or the extending structure

See Figure 1.

EXAMPLES Outriggers, jacks, suspension-locking devices, extending axles.

3.30**stowed position**

configuration of the MEWP as defined by the manufacturer, in which the extending structure is lowered and retracted and stabilizers are retracted

NOTE The access (3.1), stowed, lowered travel (3.12) and transport (3.30) positions can be identical.

3.31

totally manually operated

MEWP whose movement is powered only by manual effort

3.32

transport position

position of the work platform in which the MEWP is delivered to the work site

NOTE The access (3.1), stowed (3.30), lowered travel (3.12) and transport positions can be identical.

3.33

transporting

delivery of the MEWP to or from the work site

3.34

travelling

any movement of the chassis except transporting

See Figure 1.

3.35

type test

test on a representative model of a new design or one incorporating significant changes to an existing design, carried out by or on behalf of the manufacturer or his authorized representative

3.36

vehicle-mounted MEWP

MEWP whose travelling controls are located within the cab of the vehicle

3.37

wire rope drive system

system that comprises one or more wire rope(s) running on rope drums and on or over rope pulleys, as well as any associated rope drums, rope pulleys and compensating pulleys

3.38

working envelope

space in which the work platform is designed to work within the specified loads and forces, under normal operation conditions

NOTE MEWPS can have more than one working envelope.

3.39

work platform

movable component of the MEWP, other than the chassis, intended for carrying personnel (with or without material)

EXAMPLES Cages, buckets and baskets.

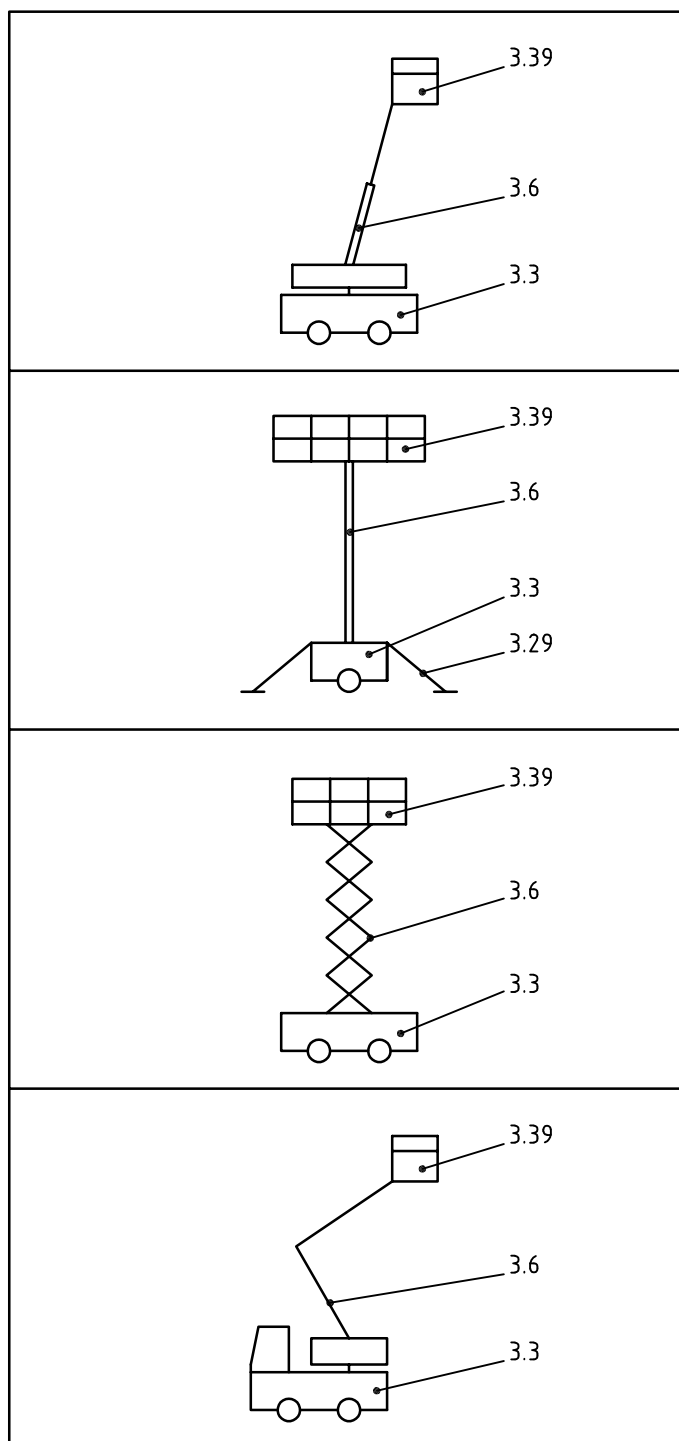


Figure 1 — Illustration of some definitions (*continued*)

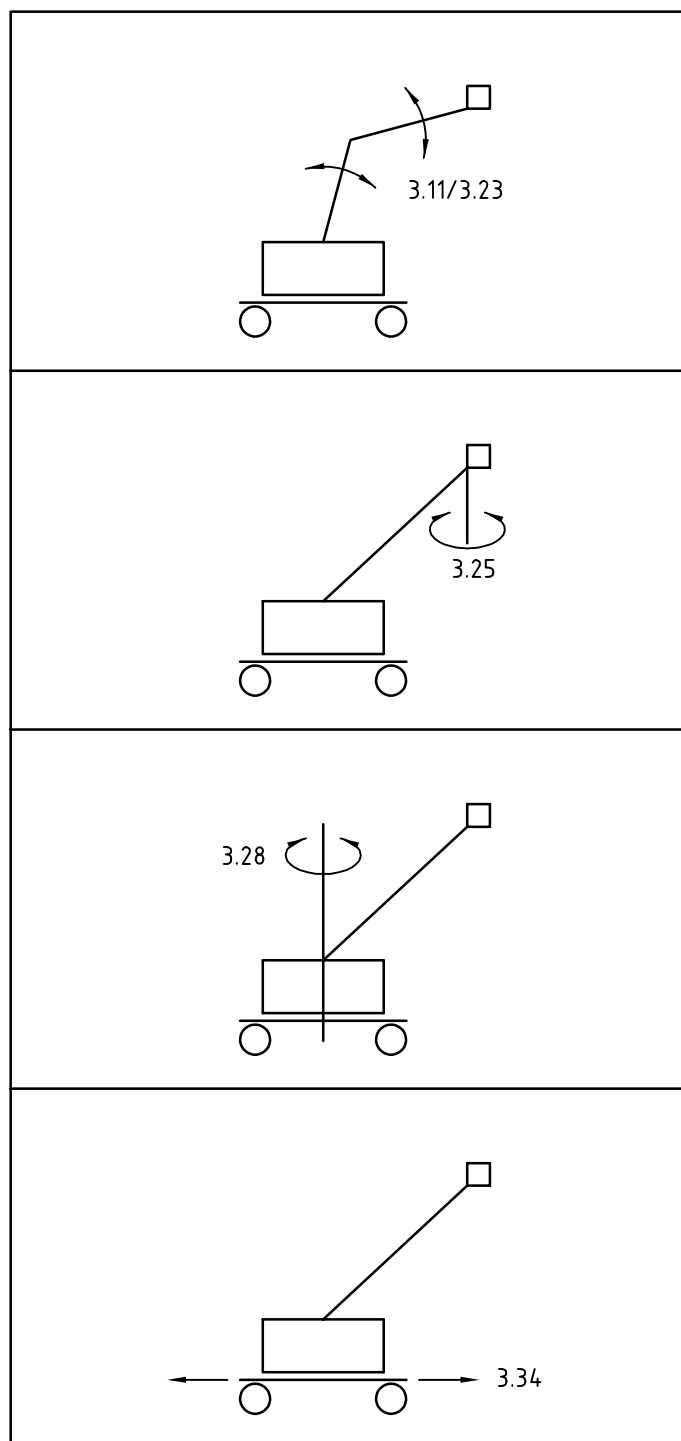


Figure 1 — Illustration of some definitions (*continued*)

4 List of hazards

Hazards have been identified by the risk assessment procedure and are listed in Table 1.

A hazard which is not significant and for which, therefore, no relevant clause is given in this International Standard is designated as NS (not significant).

Table 1 — List of hazards (continued)

Hazards		Relevant clauses in this International Standard
1	Mechanical hazards	
1.1	crushing hazard	5.2.4, 5.3.4, 5.3.5, 5.3.21, 5.4.4, 5.6.9, 5.7.1, 7.3.13
1.2	shearing hazard	5.4.4, 5.7.1, 7.3.13
1.3	cutting or severing hazard	NS
1.4	entanglement hazard	5.3.18, 7.3.13
1.5	drawing-in or trapping hazard	5.3.18, 7.3.13
1.6	impact hazard	5.3.5, 5.3.22, F.2.1 h)
1.7	stabbing or puncture hazard	NS
1.8	friction or abrasion hazard	F.2.5 e)
1.9	high-pressure fluid injection hazard	5.9.1, 5.9.2, 5.9.3, 5.9.4, 5.9.5, 5.9.10
1.10	ejection of parts	NS
1.11	loss of stability (of machinery and machine parts)	5.2, 5.3.2, 5.3.6, 5.3.7, 5.3.9, 5.3.10
1.12	slip, trip and fall hazards	5.6.2, 5.6.3, 5.6.4, 5.6.5, 5.6.6, 5.6.7, 7.3.13
2	Electrical hazards caused, for example, by	
2.1	electrical contact (direct or indirect)	5.8, F.2.1 g)
2.2	electrostatic phenomena	NS
2.3	thermal radiation	NS
2.4	external influences on electrical equipment	5.8.1
3	Thermal hazards resulting, for example, in	
3.1	burns and scalds by possible contact of persons with flames or explosions and also with radiation from heat sources	5.3.19
3.2	health-damaging effects from hot or cold work environment	5.3.19
4	Hazards generated by noise resulting, for example, in	
4.1	hearing loss (deafness), other physiological disorders (e.g. loss of balance, loss of awareness, etc.)	NS
4.2	interference with speech communication, acoustic signals, etc.	NS
5	Hazards generated by vibration (resulting in a variety of neurological and vascular disorders)	F.2.1 l)
6	Hazards generated by radiation, especially by	
6.1	electrical arcs	F.2.1 g)
6.2	lasers	NS
6.3	ionizing radiation sources	NS
6.4	machines using high-frequency electromagnetic fields	5.8.1
7	Hazards generated by materials and substances processed, used or exhausted by machinery, for example	
7.1	hazards resulting from contact with or inhalation of harmful fluids, gases, mists, dusts and fumes	5.3.19

Table 1 — List of hazards (continued)

Hazards		Relevant clauses in this International Standard
7.2	fire or explosion hazard	5.3.20
7.3	biological and microbiological (viral or bacterial) hazards	NS
8	Hazards generated by neglecting ergonomic principles in machine design (mismatch of machinery with human characteristics and abilities) caused, for example, by	
8.1	unhealthy postures or excessive efforts	5.6.6, 5.6.7
8.2	inadequate consideration of human hand-arm or foot-leg anatomy	NS
8.3	neglected use of personal protection equipment	NS
8.4	inadequate area lighting	NS
8.5	mental overload or underload, stress, etc.	NS
8.6	human error	5.7.1, 5.7.2
9	Hazard combinations	
10	Hazards caused by failure of energy supply, breakdown of machinery parts, and other functional disorders, for example	
10.1	failure of energy supply (of energy and/or control circuits)	5.3.11, 5.7.6, 5.7.7, 5.7.8, 5.7.9
10.2	unexpected ejection of machine parts or fluids	NS
10.3	failure/malfunction of control system	5.7.7
10.4	errors of fitting	5.8.1, 5.9.11
10.5	overturn, unexpected loss of machine stability	5.2, 5.3.2, 5.3.6, 5.3.7, 7.3.1 k)
11	Hazards caused by (temporary) missing and/or incorrectly positioned safety-related measures/means, for example	
11.1	all kinds of guards	5.3.18
11.2	all kinds of safety-related (protection) devices	5.3.9
11.3	starting and stopping devices	5.3.1, 5.4.5, 5.5.2.7, 5.5.3.7, 5.5.5.2, 5.6.3, 5.7.1, 5.7.2, 5.7.3, 5.7.4, 5.7.5, 5.7.6, 5.7.7, 5.7.8, 5.11.3, 5.11.6
11.4	safety signs and signals	5.3.2, 5.6.10, 5.7.2, 5.9.10
11.5	all kinds of information or warning devices	5.3.2, 5.3.13, 5.6.11, 7.2, F.2.1 c), F.2.2
11.6	energy supply disconnecting devices	5.8.2
11.7	emergency devices	5.7.4
11.8	feeding/removal means of work pieces	NS
11.9	essential equipment and accessories for safe adjusting and/or maintaining	5.4.5, 5.9.1, F.2.5 a), F.2.5 i)
11.10	equipment evacuating gases, etc.	5.3.19
12	Inadequate lighting of moving/working area	NS
13	Hazards due to sudden movement/instability during handling	5.2, 5.3.2, 5.3.3, 5.3.6, 5.3.7, 5.3.8, 5.3.9, 5.3.12, 5.6.1, 5.7.1, 5.7.3, 5.7.4, 5.7.5, 5.7.9
14	Inadequate/non-ergonomic design of driving/operating position	5.6.9
14.1	hazards due to dangerous environments (contact with moving parts exhaust gases, etc.)	5.3.18, 5.3.19
14.2	inadequate visibility from driver's/operator's position	5.3.2, 5.3.21

Table 1 — List of hazards

Hazards		Relevant clauses in this International Standard
14.3	inadequate seat/seating (seat index point)	NA
14.4	inadequate/inergonomic design/positioning of controls	5.6.9
14.5	starting/moving of self-propelled machinery	5.3.13, 5.3.14, 5.3.15, 5.3.16, 5.3.17, 5.3.21, 5.7.1, 5.7.3
14.6	road traffic of self-propelled machinery	5.3.11, 5.3.15, 5.3.16, 5.3.18
14.7	movement of pedestrian-controlled machinery	5.3.17
15	Mechanical hazards	
15.1	hazards to exposed persons due to uncontrolled movement	5.2.4, 5.4.5, 5.7.1
15.2	hazards due to break-up and/or ejection of parts	NS
15.3	hazards due to rolling over (ROPs)	NS
15.4	hazards due to falling objects (FOPs)	NS
15.5	inadequate means of access	5.6.6, 5.6.7
15.6	hazards caused due towing, coupling, connecting, transmission	NS
15.7	hazards due to batteries, fire, emissions, etc.	5.3.19, 5.3.20
16	Hazards due to lifting operation	
16.1	lack of stability	5.2, 5.3.2, 5.3.6, 5.3.7, 5.3.9, 5.3.10, 5.4.1
16.2	derailment of machinery	5.3.23
16.3	loss of mechanical strength of machinery and lifting accessories	5.2.5, 5.4.1, 5.4.7, 5.6.13, 7.2.2 (b, F.2 a), F.2.2 b)
16.4	uncontrolled movements	5.3.3, 5.3.4, 5.3.5, 5.4, 5.5, 5.6.1
17	Inadequate view of trajectories of the moving parts	5.3.21
18	Hazards caused by lightning	NS
19	Hazards due to loading/overloading	5.4.1
20	Hazards due to lifting persons	
20.1	mechanical strength	5.2, 5.5.2, 5.5.3
20.2	loading control	5.4.1
21	Controls	
21.1	movement of work platform	5.4, 5.6.1, 5.7.1, 5.7.3, 5.7.4, 5.7.9, Annex C
21.2	safe travel control	5.7.1, 5.7.3, 5.7.4
21.3	safe speed control	5.3.1, 5.3.16, 5.3.17, 5.4.6
22	Falling of persons	
22.1	personal protective equipment	5.6.2
22.2	trapdoors	5.6.8
22.3	work platform tilt control	5.6.1
23	Work platform falling/overturning	
23.1	falling/overturning	5.2, 5.3.2, 5.3.3, 5.3.6, 5.3.7, 5.3.9, 5.3.10, 5.3.12, 5.4.1, 5.4.2, 5.6.12, 5.9, 5.10
23.2	acceleration/braking	5.3.16, 5.4.6, 5.5.1.6
24	Markings	7.3

5 Safety requirements and/or measures

5.1 Compliance

The manufacturer shall meet the requirements detailed in this clause.

The requirements of this International Standard shall apply except where national or local regulations are more stringent.

In addition, machines shall comply, as appropriate, with ISO 12100-1 and ISO 12100-2 for hazards which are not covered by this International Standard.

5.2 Structural and stability calculations

5.2.1 Manufacturer's responsibility

The manufacturer is responsible for

- a) structural calculations, to evaluate the individual loads and forces in their positions, directions and combinations which produce the most unfavourable stresses in the components,
- b) stability calculations, to identify the various positions of the MEWP and combinations of loads and forces which together create conditions of minimum stability, and
- c) structural and stability calculations, to include the greater dynamic effects arising if a higher speed, as permitted in 5.4.6, is used.

5.2.2 Loads and forces

The following loads and forces shall be taken into account:

- a) rated load (see 5.2.3.1);
- b) structural loads (see 5.2.3.2);
- c) wind loads (see 5.2.3.3);
- d) manual forces (see 5.2.3.4);
- e) special loads and forces (see 5.2.3.5).

5.2.3 Determination of loads and forces

5.2.3.1 Rated load

The rated load (equivalent to a mass m) is determined from the following equation:

$$m = (n \times m_p) + m_e \quad (1)$$

where

m_p is the mass of a person (≥ 80 kg);

m_e is the mass of tools and material (≥ 40 kg);

n is the number of persons permitted on the work platform.

The mass of each person is assumed to act as a point load on the work platform at a horizontal distance of 0,1 m from the upper inside edge of the top rail. The distance between the point loads shall be 0,5 m (see Figure 2 as an example).

The mass of equipment is assumed to act as an evenly distributed load on 25 % of the floor of the work platform. If the resulting pressure exceeds 3 kN/m², the value of 25 % may be increased to give a pressure of 3 kN/m² (see Figure 3 as an example).

All these loads are assumed to be located in the positions giving the worst-case results.

Dimensions in metres

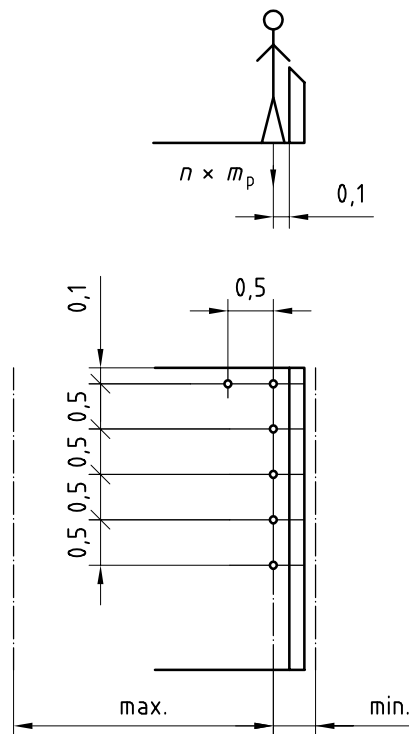
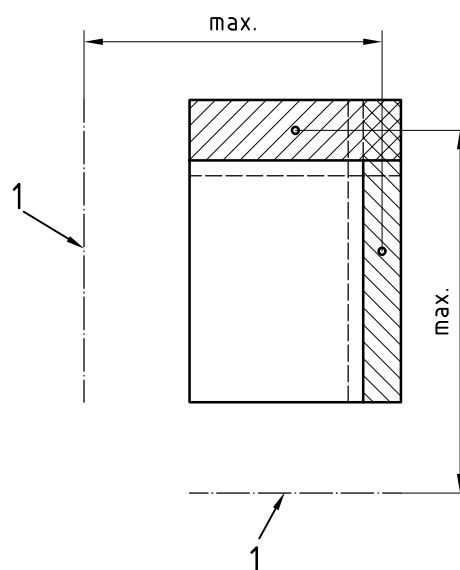


Figure 2 — Rated load — Persons



Key

1 tipping line

Figure 3 — Rated load — Equipment

5.2.3.2 Structural loads

The masses of the components of the MEWP when they are not moving shall be taken to be static structural loads.

The masses of the components of the MEWP when they are moving shall be taken to be dynamic structural loads.

5.2.3.3 Wind loads

5.2.3.3.1 Outdoor MEWPS

All MEWPs used outdoors are regarded as being affected by wind at a pressure of 100 N/m^2 , equivalent to a wind speed of $12,5 \text{ m/s}$ (Beaufort Scale 6).

Wind forces are assumed to act horizontally at the centre of surface of the parts of the MEWP, of persons and equipment on the work platform, and shall be taken to be dynamic forces.

This does not apply to MEWPs intended for indoor use only (see 7.3.6).

5.2.3.3.2 Shape factors applied to surfaces exposed to wind

The following shape factors are applicable to surfaces exposed to wind:

- | | |
|---|---------|
| a) L-, U-, T-, I-sections | 1,6 |
| b) box sections | 1,4 |
| c) large flat areas | 1,2 |
| d) circular sections, according to size | 0,8/1,2 |
| e) persons directly exposed | 1,0 |

If additional information is needed, especially concerning shielded structural areas, see ISO 4302. For shielded persons, see 5.2.3.3.3.

5.2.3.3.3 Surface area of persons on a work platform exposed to wind

The full surface area of one person shall be $0,7 \text{ m}^2$ ($0,4 \text{ m}$ average width $\times$ $1,75 \text{ m}$ height) with the centre of area $1,0 \text{ m}$ above the work platform floor.

The exposed surface area of one person standing on a work platform behind an imperforate (not perforated) section of fencing $1,1 \text{ m}$ high shall be $0,35 \text{ m}^2$, with the centre of area $1,45 \text{ m}$ above the work platform floor.

The number of persons directly exposed to the wind shall be calculated as follows:

- the length of the side of the work platform exposed to the wind, rounded to the nearest $0,5 \text{ m}$, and divided by $0,5 \text{ m}$, or
- the number of persons allowed on the work platform, if less than the number calculated in a).

If the number of persons allowed on the work platform is greater than in a) above, a shape factor of $0,6$ shall be applied to the extra number of persons.

5.2.3.3.4 Wind force

The wind force on exposed tools and materials on the work platform shall be calculated as 3 % of their mass, acting horizontally at a height of 0,5 m above the work-platform floor.

5.2.3.4 Manual force

The minimum value for the manual force M shall be taken as 200 N for MEWPs designed to carry only one person, and 400 N for MEWPs designed to carry more than one person, applied at a height of 1,1 m above the work platform floor. Any greater force permitted shall be specified by the manufacturer.

5.2.3.5 Special loads and forces

Special loads and forces are created by special working methods and conditions of use of the MEWP, such as objects carried on the outside of the work platform, wind forces on large objects carried on the work platform and forces imposed by winches or material handling devices (see also Annex A).

If a user asks for such special working methods and/or conditions of use, the resulting loads and forces shall be taken into consideration as a modification to the rated load, structural load, wind load and/or manual forces, as appropriate

5.2.4 Stability calculations

5.2.4.1 Forces created by structural masses and rated load

Forces created by structural masses and rated load, causing overturning or stabilizing moments, shall be multiplied by a factor of 1,0 and calculated as acting vertically downwards. For operation of the extending structure, these forces shall be multiplied by a factor of 0,1 and taken to be acting in the direction of movement creating the greatest overturning moment.

Manufacturers may use factors lower than 0,1 provided they have been verified by measurement of the effects of acceleration and deceleration. Factors higher than 0,1 shall be used if higher acceleration/deceleration is used (see 5.4.6).

For the travelling movements of MEWP of types 2 and 3, the factor of 0,1 shall be replaced by a factor z representing the forces produced by acceleration and deceleration or the kerb test (see 6.1.4.2.2.2). This factor shall be determined by calculation or tests (see Annex E for a calculation example).

5.2.4.2 Wind forces

Wind forces shall be multiplied by a factor of 1,1 and taken to be acting horizontally.

5.2.4.3 Manual forces

Manual forces applied by persons on the work platform shall be multiplied by a factor of 1,1 and taken to be acting in the direction creating the greatest overturning moment (see examples in Figure 4).

5.2.4.4 Special loads and forces

Special loads and forces, as determined by the manufacturer, shall be included in the calculation.

5.2.4.5 Calculation of overturning and stabilizing moments

The maximum overturning and corresponding stabilizing moments shall be calculated about the most unfavourable tipping lines.

Tipping lines shall be determined as shown in ISO 4305; however for solid and foam-filled tyres, the tipping lines may be taken at point on the tyre ground contact which is at a distance from the outside edge of 1/4 of the ground contact width.

The calculations shall be made with the MEWP in the most unfavourable extended and/or retracted positions at the maximum allowable ground slope plus an allowance of 0,5° for inaccuracy in setting up the MEWP. All loads and forces, which can act simultaneously shall be taken into account in their most unfavourable combinations. For example, when the load has a stabilizing effect, an additional stability calculation shall be made, assuming only one person (80 kg) is on the work platform. Examples are shown in Table 2 and Figure 4. Graphical methods may be used.

In each case, the calculated stabilizing moment shall be greater than the calculated overturning moment.

In the calculation, the following influences shall be taken into account:

- a) tolerances in the manufacture of the components;
- b) play in the connections of the extending structure;
- c) elastic deformations due to the effects of forces;
- d) failure of any one tyre in the case of MEWPs supported by pneumatic tyres in the working position;
- e) performance characteristics (accuracy) of the load-sensing system, moment-sensing system and position control; these may be affected by, for example,
 - peaks caused by short-term dynamic effects,
 - hysteresis,
 - slope of the MEWP,
 - ambient temperature,
 - different positions and distribution of load on work platform (see 5.2.3.1).

The determination of elastic deformations shall be obtained by experiment or by calculation.

Table 2 — Examples of load and force directions and combinations for stability calculations (see Figure 4)

Example	Working condition	Rated load		Structural loads S_n		Manual force M		Wind loads W		Diagram
		× 1,0	× 0,1	× 1,0	× 0,1	× 1,0	× 0,1	× 1,0	× 0,1	
1	Raising (lowering)	V	A	V	A	—	—	H	H	
2	Travelling	V	S	V	S	—	—	H	H	
3	Travelling	V	S	V	S	—	—	H	H	
4	Forwards stability, stationary on slope	V	—	V	—	A	A	H	H	
5	Backwards stability, stationary on slope	80 kg V	—	V	—	A	A	H	H	
6	With limited reach, forward stability, stationary on slope, lowering	V	S	V	A	—	—	H	H	
7	On slope, stationary	V	—	V	—	A	A	H	H	
8	Level ground, stationary	80 kg V	—	V	—	A	A	H	H	
Key: V = vertical, H = horizontal, A = angular, S = at slope angle.										
NOTE — This table is not exhaustive.										

5.2.5 Structural calculations

5.2.5.1 General

The calculations shall conform with the laws and principles of applied mechanics and strength of materials. If special formulas are used, the sources shall be given, if they are generally available. Otherwise the formulas shall be developed from first principles, so that their validity can be checked.

Except where otherwise stated, the individual loads and forces shall be taken to act in the positions, directions and combinations which produce the most unfavourable conditions.

For all load-bearing components and joints, the required information on stresses or safety factors shall be included in calculations in a clear and easily verifiable form. If necessary for checking the calculations, details of the main dimensions, cross-sections and materials for the individual components and joints shall be given.

5.2.5.2 Calculation methods

The method of calculation shall comply with any one of the recognized international or national design standards, such as those of the EEA countries for lifting appliances, which includes fatigue-stress calculation methods.

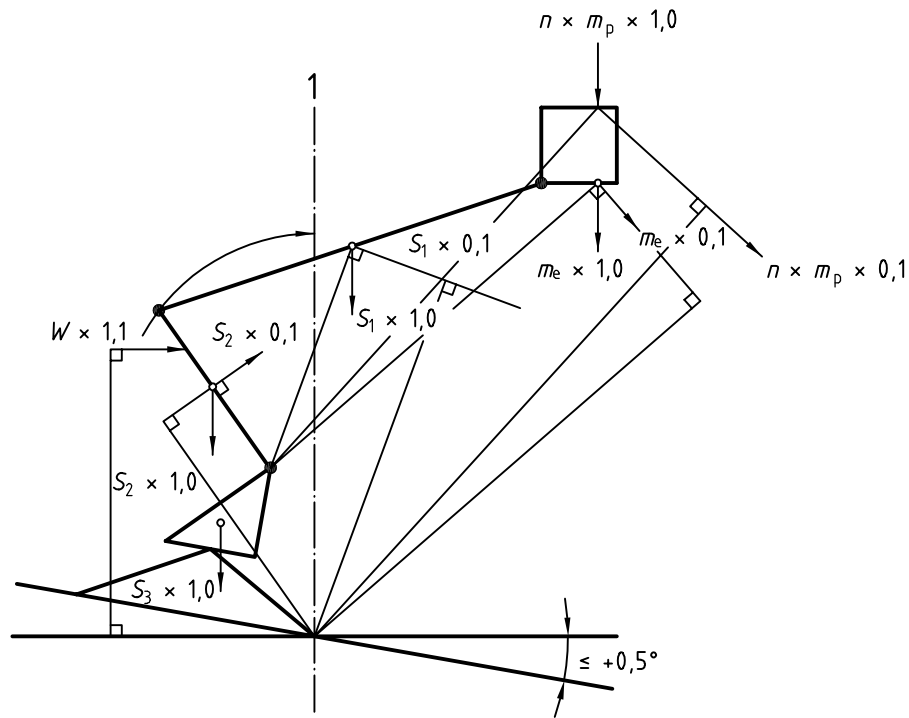
Requirements given in 5.2.2 and 5.2.4 above shall be considered for the determination of loads and forces to be used in the calculations. The use of a national standard shall not alter these requirements.

The elastic deformations of slender components shall be taken into account.

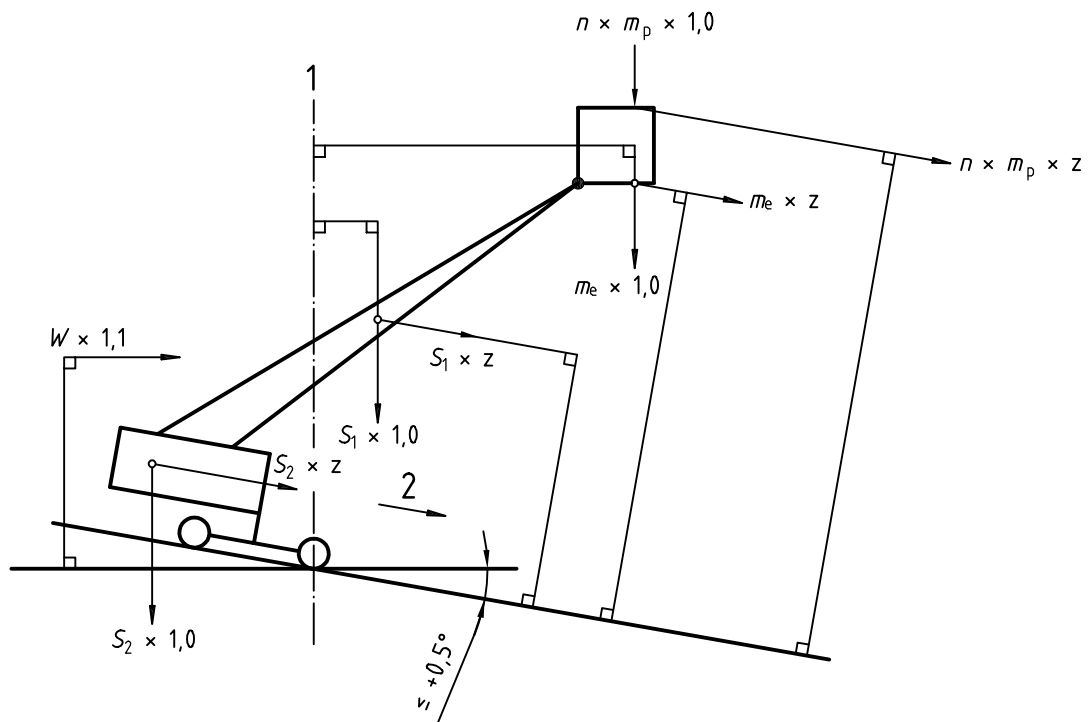
The analysis shall be made for the worst-case load combinations. Stresses imposed by the static test (see 6.1.4.2.1) and the overload test (see 6.1.4.3) shall not exceed 90 % of the elastic limit of the materials.

The calculated stresses shall not exceed the permissible values. The calculated safety factors shall not fall below the required values.

The permissible values of stresses and the required values of safety factors depend on the material, the load combination and the calculation method.



a) Example 1



b) Example 2

Key

- 1 tipping line
- 2 travelling direction

Figure 4 — Examples of maximum overturning load and force moment combination
(see Table 2) (continued)