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

Plates-formes élévatrices mobiles de personnel — Conception, calculs, 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*.

This second edition cancels and replaces the first edition (ISO 16368:2003), which has been technically revised.

Introduction

The object of this International Standard is to define rules for safeguarding persons and objects against the risk of accident associated with the operation of mobile elevating work platforms (MEWPs). MEWPs are assemblies of one or more sub-assemblies produced by one or more manufacturers. A MEWP is the product of activities that include design, production and testing, as well as the provision of information on the MEWP itself.

This International Standard does not repeat all the general technical rules applicable to every electrical, mechanical or structural component. Its safety requirements have been drawn up on the basis that MEWPs are periodically maintained according to given instructions, working conditions, frequency of use and national or other regulations. It is assumed that MEWPs are checked for function before start of work, whether used daily or seldom used, and are not put into operation unless all the required control and safety devices are available and in working order. Where, for clarity, an example of a safety measure is given in the text, it 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.

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

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 former TC 98/WG 1 of the European Committee for Standardization (CEN) to determine a suitable factor and stability calculation method for MEWPs have been adopted. That test method is described in Annex B as a guide for the responsible entity 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 from the widely accepted DIN 15020[31] have been included both in the body of this International Standard and in Annex C, with a worked example given in Annex D.

Annex E gives kerb test calculations, Annex F provides information on the instruction handbook, and Annex G specifies additional requirements for cableless controls and control systems.

Annex H presents the list of significant hazards dealt with by this International Standard.

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

1 Scope

This International Standard specifies safety requirements and preventive measures, and the means for their verification, for all types and sizes of mobile elevating work platforms (MEWPs) intended for moving persons to working positions. It gives the structural design calculations and stability criteria, construction, safety examinations and security tests to be applied before a MEWP is first put into service, identifies the hazards arising from the use of MEWPs and describes methods for the elimination or reduction of those hazards.

This International Standard is not applicable to

a) permanently installed personnel-lifting appliances serving defined levels,

b) fire-fighting and fire rescue appliances,

c) unguided work cages suspended from lifting appliances,

d) elevating operator position on rail-dependent storage and retrieval equipment,

e) tail lifts,

f) mast-climbing work platforms (see ISO 16369),

g) fairground equipment,

h) lifting tables with a lifting height of less than 2 m,

i) builder's hoists for persons and materials,

j) aircraft ground-support equipment,

k) digger derricks,

l) elevating operator positions on industrial trucks,

m) under-bridge inspection and maintenance devices,

n) certain requirements for insulating aerial devices on a chassis for use in live work on electrical installations.

It does not cover hazards arising from

— use in potentially explosive atmospheres,

— use of compressed gases for load-bearing components,

— work on live electrical systems.

NOTE 1 Hazards arising from work on live electrical systems are addressed in IEC 61057. MEWPs equipped with certain non-conductive (insulating) components can provide some protection from hazards associated with inadvertent contact with such systems (see ISO 16653-2).

NOTE 2 For MEWPs that employ aerial devices used for live working, this International Standard will need to be used in conjunction with IEC 61057, taking into consideration the potential exceptions from this International Standard that are specified in IEC 61057.

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

ISO 4305, *Mobile cranes — Determination of stability*

ISO/TR 11688-1:1995, *Acoustics — Recommended practice for the design of low-noise machinery and equipment — Part 1: Planning*

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 principles, inspection, maintenance and operation*

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

IEC 60068-2-64, *Environmental testing — Part 2-64: Tests — Test Fh: Vibration, broadband random and guidance*

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

IEC 60204-32:2008, *Safety of machinery — Electrical equipment of machines — Part 32: Requirements for hoisting machines*

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

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

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** (3.40)

NOTE The access position, **lowered travel position** (3.18), **stowed position** (3.34) and **transport position** (3.35) can be identical.

3.2
aerial device
any device, extensible, articulating or both, which is primarily designed and used to position personnel

NOTE This does not include the **chassis** (3.5). When an aerial device is mounted on a mobile chassis it becomes a component of a **MEWP** (3.19). The device can also be used to handle material, if designed and equipped for that purpose.

3.3
cableless control
means by which an operator's commands are transmitted without any physical connection for at least part of the distance between the control console and the **MEWP** (3.19)

3.4
chain-drive system
system that comprises one or more chains running on chain sprockets and on or over chain pulleys, as well as any associated chain sprockets, chain pulleys and compensating pulleys

3.5
chassis
base of a **MEWP** (3.19)

See Figure 1.

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

3.6
ductile material
material that has a minimum elongation before failure of 10 % and adequate notch impact strength at the lowest operating temperature for which the **MEWP** (3.19) is rated

3.7
elevated travel position
configuration of the **MEWP** (3.19) for travel outside of the **lowered travel position** (3.18)

3.8
extending structure
structure connected to the **chassis** (3.5) that supports the **work platform** (3.40) and allows the work platform's movement to the required position

See Figure 1.

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

3.9
fall arrest system
fall protection system designed to arrest a fall by a worker

3.10
fall restraint system
fall protection system that restrains or prevents a worker from being exposed to a fall from the **work platform** (3.40)

3.11
finite element analysis model
FEA model
computerized method of idealizing a real model for the purposes of performing structural analysis

3.12
indoor use
operation in areas shielded from wind so that there is no wind force acting on the **MEWP** (3.19) being operated

3.13
instability
condition of a **MEWP** (3.19) in which the sum of the moments tending to overturn the unit exceeds the sum of the moments tending to resist overturning

3.14
installer
entity that installs an aerial device on a **chassis** (3.5)

NOTE The installer can also be the **responsible entity** (3.27).

3.15
load cycle
cycle starting from an **access position** (3.1) and completed by the carrying out of work and return to the same access position

3.16
load-sensing system
system of monitoring the vertical load and vertical forces on the **work platform** (3.40)

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

3.17
lowering, noun
all operations, other than **travelling** (3.36), for moving the **work platform** (3.40) to a lower level

See Figure 1.

3.18
lowered travel position
configuration(s) of the **MEWP** (3.19), as defined by the **responsible entity** (3.27), for travel at maximum travel speed

NOTE The lowered travel position, **access position** (3.1), **stowed position** (3.34), and **transport position** (3.35) can be identical.

3.19
mobile elevating work platform
MEWP
machine/device intended for moving persons, tools and material to working positions, consisting of at least a **work platform** (3.40) with controls, an **extending structure** (3.8) and a **chassis** (3.5)

3.19.1
group A
MEWPs on which the vertical projection of the centre of the platform area, in all platform configurations at the maximum **chassis** (3.5) inclination specified by the manufacturer, is always inside the tipping lines

3.19.2
group B
MEWPs not in **group A** (3.19.1)

3.19.3
type 1 MEWP
MEWP for which **travelling** (3.36) is only allowed when in the **stowed position** (see 3.34)

3.19.4
type 2 MEWP
MEWP for which **travelling** (3.36) with the **work platform** (3.40) in the **elevated travel position** (3.7) is controlled from a point on the **chassis** (3.5)

NOTE Type 2 and type 3 MEWPs can be combined.

3.19.5
type 3 MEWP
MEWP for which **travelling** (3.36) with the **work platform** (3.40) in the **elevated travel position** (3.7) is controlled from a point on the work platform

NOTE Type 2 and type 3 MEWPs can be combined.

3.19.6
pedestrian-controlled MEWP
MEWP whose controls for powered travel can be operated by a person walking close to the MEWP

3.19.7
rail-mounted MEWP
MEWP whose travel is guided by rails

3.19.8
self-propelled MEWP
MEWP whose **travelling** (3.36) controls are located on the **work platform** (3.40)

3.19.9
totally manually operated MEWP
MEWP whose movement is powered only by manual effort

3.19.10
vehicle-mounted MEWP
MEWP whose aerial device is designed for and installed on a vehicle chassis

3.20
moment-sensing system
system of monitoring the moment acting about the tipping line tending to overturn the **MEWP** (3.19)

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

3.21
non-conductive components
insulating components
components composed of materials selected for their electrical properties, used on a **MEWP** (3.19) for the purpose of potentially providing electrical protection from inadvertent contact of certain parts of the MEWP with overhead electrical lines

NOTE See ISO 16653-2.

3.22
non-ductile materials
brittle materials
fibreglass reinforced plastic materials and other materials that do not meet the requirement for ductile materials

3.23
oscillating axle
supporting structure which allows mainly vertical movement of the end wheel assemblies independently or in relation to each other

3.24
outdoor use
use of a **MEWP** (3.19) in an environment that can be exposed to wind

3.25
raising, noun
any operation, other than **travelling** (3.36), that moves the **work platform** (3.40) to a higher level

See Figure 1.

3.26
rated load
load for which the **MEWP** (3.19) has been designed in normal operation, comprising persons, tools and materials, acting vertically on the **work platform** (3.40)

NOTE A MEWP can have more than one rated load.

3.27
responsible entity
person or entity with responsibility for the design, specification, procurement, fabrication, manufacture, assembly, provision of information and testing of a **MEWP** (3.19) sub-assembly or ready-for-use MEWP.

NOTE Depending on national regulations or local practice, this term can refer to one or more of the following entities: manufacturer, installer, custodian, dealer, designer or entity placing the product on the market.

3.28
rotation
circular movement of the **work platform** (3.40) about a vertical axis

See Figure 1.

3.29
secondary work platform
platform attached to the **work platform** (3.40) or the **extending structure** (3.8), and able to be moved separately

3.30
slab
substantially level surface of asphalt, concrete or equivalent supporting material

3.31
slewing, noun
circular movement of the **extending structure** (3.8) about a vertical axis

See Figure 1.

3.32
stability
condition of a **MEWP** (3.19) in which the sum of the moments which tend to overturn the unit is less than or equal to the sum of the moments tending to resist overturning

3.33
stabilizer
any device or system used to stabilize a **MEWP** (3.19) by supporting and/or levelling the complete MEWP or the **extending structure** (3.8)

See Figure 1.

EXAMPLE Outrigger, jack, suspension-locking device, extending axle, torsion bar.

3.34
stowed position
configuration of the **MEWP** (3.19) as defined by the responsible entity, in which the **extending structure** (3.8) is lowered and retracted and **stabilizers** (3.33) are retracted

NOTE The stowed position, **access position** (3.1), **lowered travel position** (3.18) and **transport position** (3.35) can be identical.

3.35
transport position
configuration of the **MEWP** (3.19) prescribed by the responsible entity in which the MEWP is to be transported

NOTE The transport position, **access position** (3.1), **lowered travel position** (3.18) and **stowed position** (3.34) can be identical.

3.36
travelling
any movement of the **chassis** (3.5) except when the MEWP is being transported

See Figure 1.

3.37
type test
test on a representative model of a new design, or a model incorporating significant changes to an existing design, carried out by or on behalf of the **responsible entity** (3.27) or his authorized representative

3.38
wire rope drive system
system that comprises one or more wire ropes running on rope drums and on or over rope pulleys, as well as any associated rope drums, rope pulleys and compensating pulleys

3.39
working envelope
space in which the **work platform** (3.40) is designed to work within the specified loads and forces, under normal operation conditions

NOTE A **MEWP** (3.19) can have more than one working envelope.

3.40
work platform
movable component of the **MEWP** (3.19), other than the **chassis** (3.5), intended for carrying personnel with or without material

EXAMPLE Cage, bucket, basket.

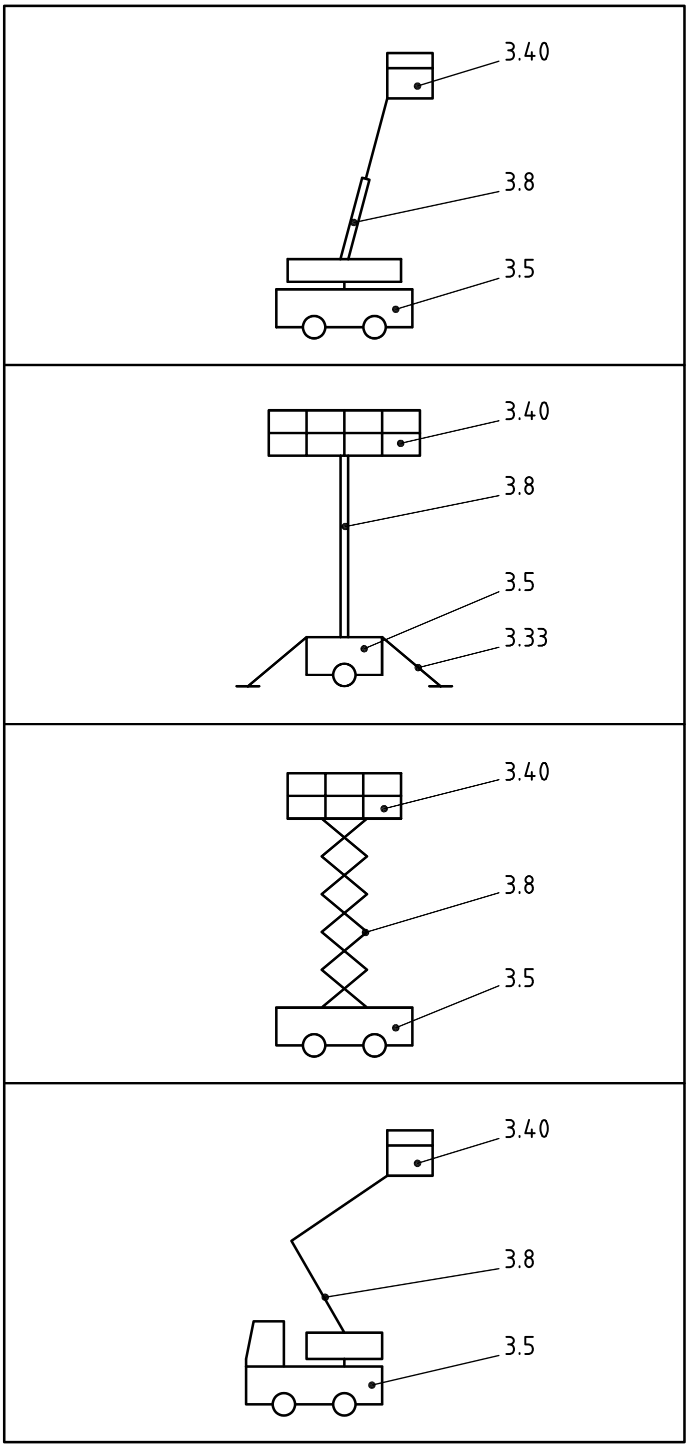


Figure 1 — Illustration of key terms (*continued*)

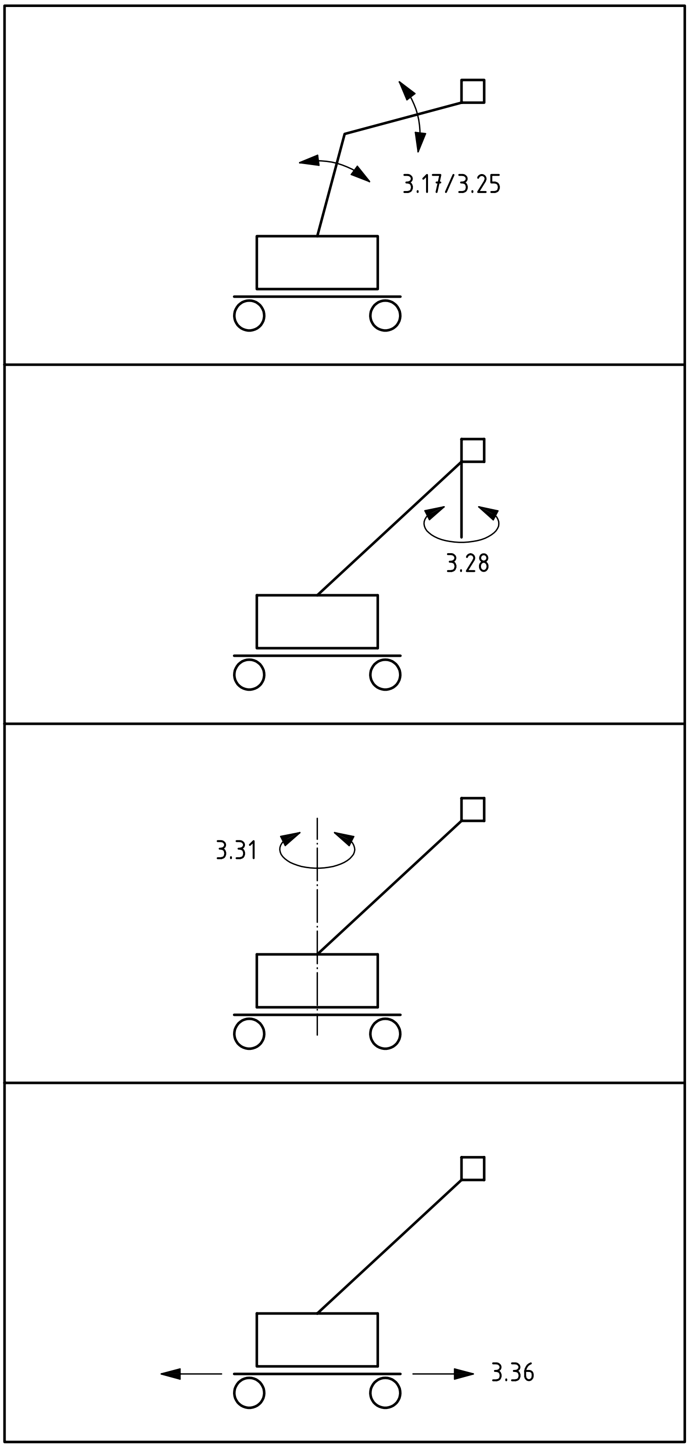


Figure 1 — Illustration of key terms

4 Safety requirements and/or protective measures

4.1 Compliance

MEWPs shall comply with the safety requirements and/or protective measures of this clause.

NOTE National or local requirements can apply which could be more stringent.

4.2 Structural and stability calculations

4.2.1 Calculations and rated load

The responsible entity shall perform

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, and

b) stability calculations, to identify the various positions of the MEWP and combinations of loads and forces which together create conditions of minimum stability.

The rated load, equivalent to a mass, m, shall be determined from:

$$m = \left(n \times m_{\mathrm{p}}\right) + m_{\mathrm{e}}$$

where

m_{p} is equal to 80 kg (mass of a person);

m_{e} is equal to 40 kg or greater, representing the mass of tools and materials;

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

The minimum rated load of a MEWP shall be 120 kg.

4.2.2 Loads and forces acting on MEWP structure

4.2.2.1 General

The following loads and forces shall be taken into account:

a) forces created by rated load and structural masses (4.2.2.2);

b) wind forces (4.2.2.3);

c) manual forces (4.2.2.4);

d) special loads and forces (see 4.2.2.5).

4.2.2.2 Forces created by rated load and structural masses

4.2.2.2.1 Gravitational and dynamic forces

Gravitational forces created by the rated load and structural masses shall be taken to act vertically downwards at the component centres of mass. The forces shall be calculated by multiplying the component masses by 1,0 g.

NOTE The factor g represents the acceleration due to gravity (9,81 m/s^2).

Dynamic forces created by acceleration and deceleration of structural masses and rated load shall be represented by forces acting in the line of motion of the component centres for mass.

Dynamic forces created by extension or retraction of the extending structure shall be calculated by multiplying the structural masses by 0,1g (see Annex B).

Dynamic forces created by travelling movements of type 2 and type 3 MEWPs shall be calculated by multiplying the structural masses by z times g. Factor zg represents the acceleration/deceleration of the MEWP due to travel and its angular acceleration/deceleration due to travel over ground obstacles such as that which occurs during the kerb test (see 5.1.4.3.2.2). Factor z shall be a minimum of 0,1 unless determined by calculation or testing (see Annex E for an example of the calculation of z).

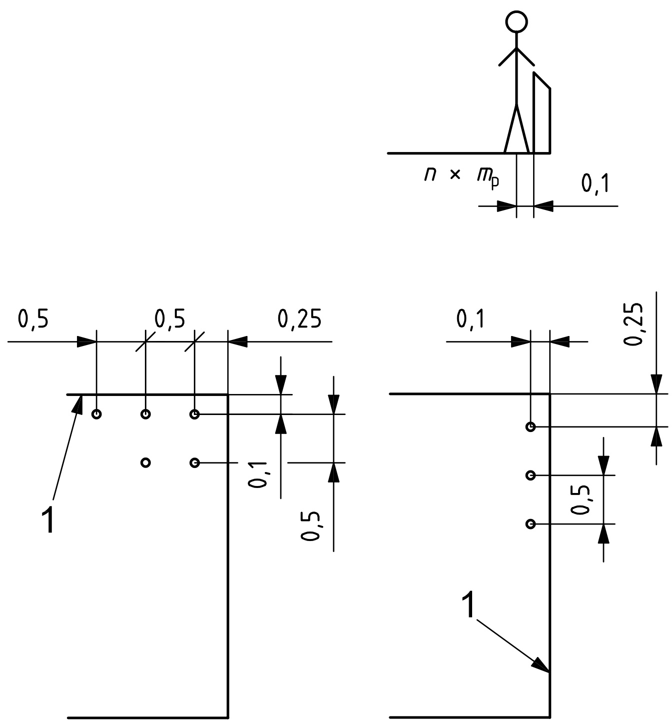
4.2.2.2.2 Load distribution on work platform

Each person is assumed to act as a point load on the work platform and any platform extension 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. The width of a person shall be taken to be 0,5 m (see Figure 2).

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/m^2, the value of 25 % may be increased to give a pressure of 3 kN/m^2.

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

Dimensions in metres



Key

1 edge of work platform

Figure 2 — Rated load — Person

4.2.2.3 Wind forces

4.2.2.3.1 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 m/s (Beaufort Scale 6, see Annex A).

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

NOTE This does not apply to MEWPs intended for indoor use only.

4.2.2.3.2 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 4.2.2.3.3.

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

The full surface area of one person shall be 0,7 m^2 (0,4 m average width $\times$ 1,75 m height) with the centre of area 1,0 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 m high shall be 0,35 m^2, with the centre of area 1,45 m above the work platform floor.

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

a) the length of the side of the work platform exposed to the wind, rounded to the nearest 0,5 m, divided by 0,5 m, or

b) 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 for a) above, a shape factor of 0,6 shall be applied to the extra number of persons.

4.2.2.3.4 Tools and equipment on work platform exposed to wind

The wind force on exposed tools and materials on the work platform shall be calculated as 0,03 g, acting horizontally at a height of 0,5 m above the work platform floor.

4.2.2.4 Manual forces

The minimum value for a manual force, F_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. Manual forces are to be applied at a height of 1,1 m above the work platform floor. Any greater force permitted shall be specified by the responsible entity.

4.2.2.5 Special loads and forces

Special loads and forces are created by special working methods and conditions of use of MEWPs, 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.

4.2.3 Stability calculations

4.2.3.1 Forces created by structural masses and rated load

The MEWP shall be taken to be operating in the most adverse stability situation with respect to the combination of chassis inclination, structural configuration, position, structural motions and vehicle travel motion (see examples in Figure 3).

The maximum allowable chassis inclination shall be increased by 0,5° to allow for inaccuracy in setting up the MEWP.

4.2.3.2 Wind forces

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

4.2.3.3 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 Figure 3 a) to d) for examples].

4.2.3.4 Special loads and forces

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

4.2.3.5 Calculation of overturning and stabilizing moments

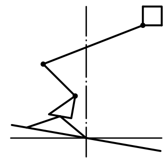
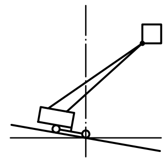
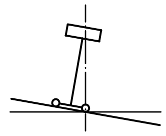
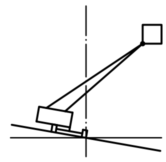
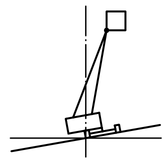
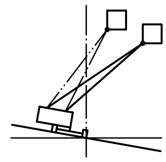
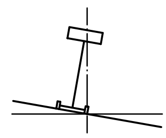
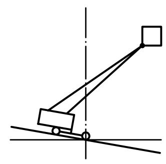
The maximum overturning and corresponding stabilizing moments shall be calculated about the least favourable tipping lines. Tipping lines shall be determined in accordance with ISO 4305; however, for solid and foam-filled tyres, the tipping lines may be taken at a point on the tyre ground contact at a distance from the outside edge of 1/4 of the ground contact width.

All forces shall be taken to act in their allowable direction that will produce the least stable outcome. Forces that can act simultaneously shall be taken into account in their least favourable combinations.

When the load has a stabilizing effect, additional stability calculations shall be made assuming the least favourable load combination on the work platform.

For examples, see Table 1 and Figure 3 a) to d). Graphical methods may be used.

Table 1 — Examples of load and force directions and combinations for stability calculations
[see also Figure 3 a) to d)]

Example	Working condition	Rated load m		Structural force S_n		Manual force F_m		Wind force W		Illustration
		× 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	Forward stability, stationary with chassis inclined	V	—	V	—	A	A	H	H	
5	Backward stability, stationary with chassis inclined	80 kg V	—	V	—	A	A	H	H	
6	With limited reach, forward stability, stationary with chassis inclined, lowering	V	A	V	A	—	—	H	H	
7	With chassis inclined, stationary	V	—	V	—	A	A	H	H	
8	Level ground, stationary	80 kg V	—	V	—	A	A	H	H	

V vertical

H horizontal

A angular

S at chassis inclination angle

S_n represents the mass of the structural component, n

NOTE This table is not exhaustive.

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, unless the MEWP is equipped with stabilizers that eliminate the dependence on tyres for stability or with a direct tyre monitoring system that warns the operator when tyre pressure has reached at least 25 % below the desired inflation pressure;

e) performance characteristics (accuracy) of the load-sensing system, moment-sensing system and position control, which can be affected by, for example,

   — peaks caused by short-term dynamic effects,

   — hysteresis,

   — chassis inclination of the MEWP,

   — ambient temperature,

   — different positions and distribution of load on the work platform (see 4.2.2.2.2).

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

4.2.3.5.1 Dynamic stability

The MEWP shall be assessed to determine that it will remain stable when subjected to the braking test (5.1.4.3.2.3) and the kerb and depression test (5.1.4.3.2.2).

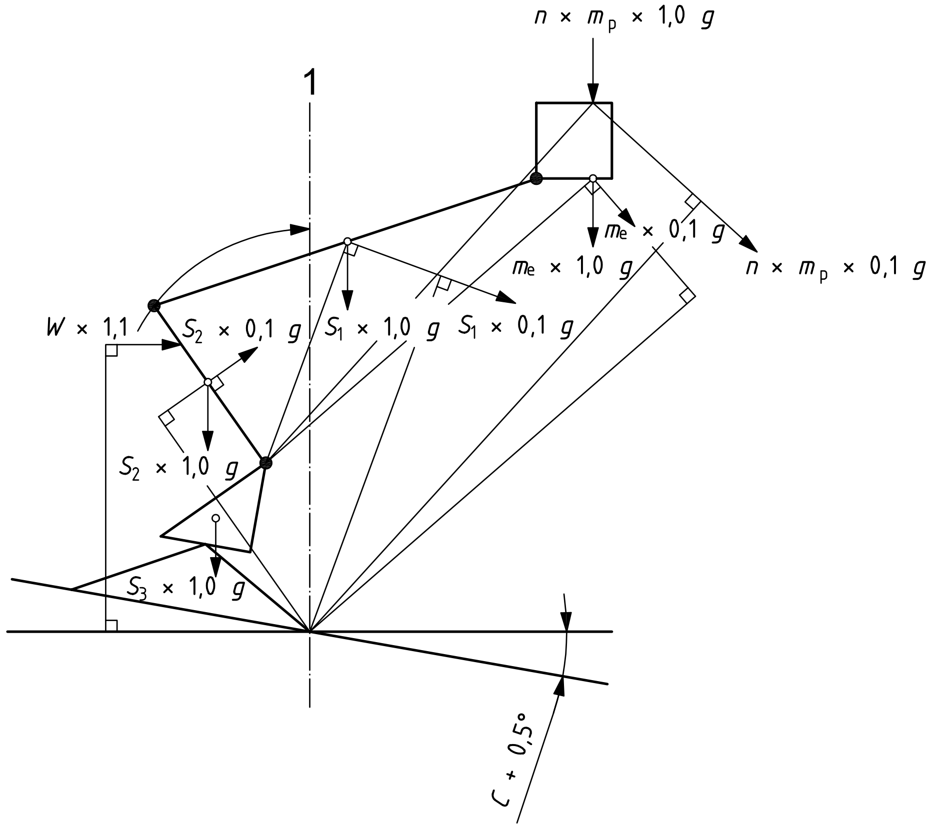
4.2.4 Structural calculations

4.2.4.1 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, or otherwise the formulas shall be developed from first principles, so that their validity can be checked.

Requirements given in 4.2.2 and elsewhere above shall be considered for the determination of loads and forces to be used in the calculations.

Except where otherwise stated, the individual loads and forces shall be taken to act in the positions, directions and combinations that produce the least favourable conditions.



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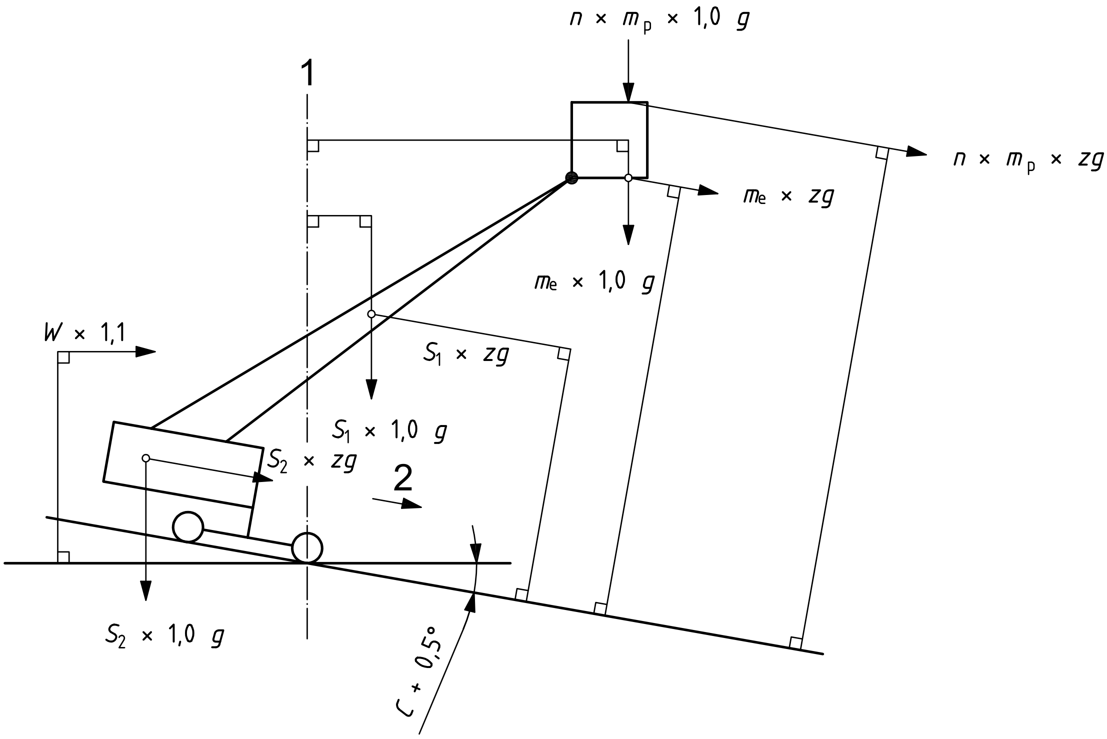
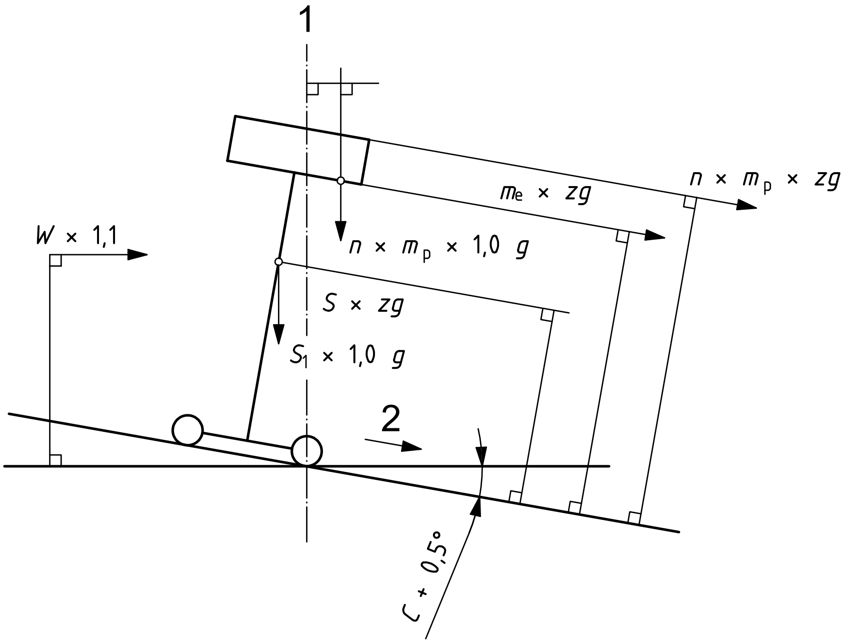


b)

Figure 3 — Examples of maximum overturning load and force moment combination (*continued*)



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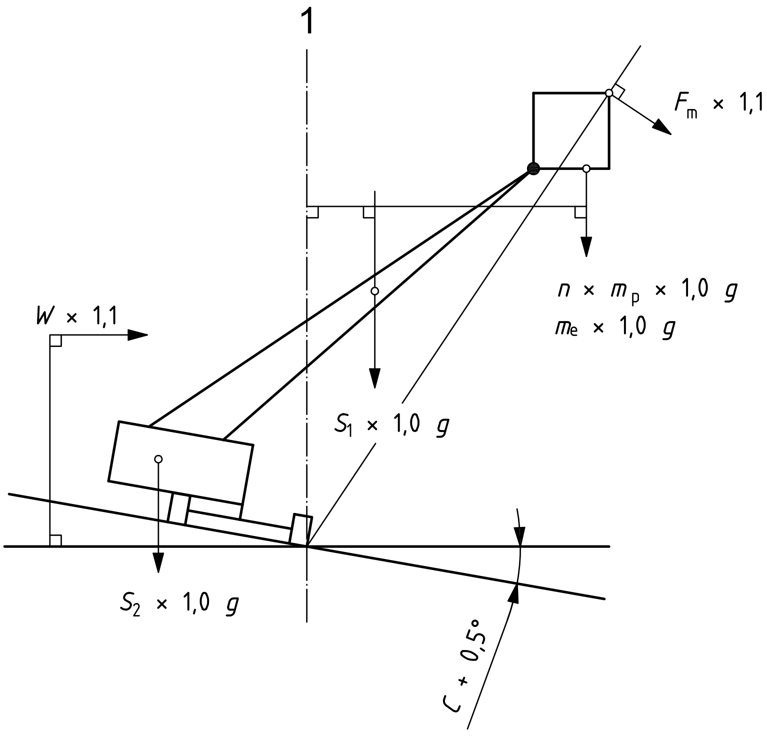

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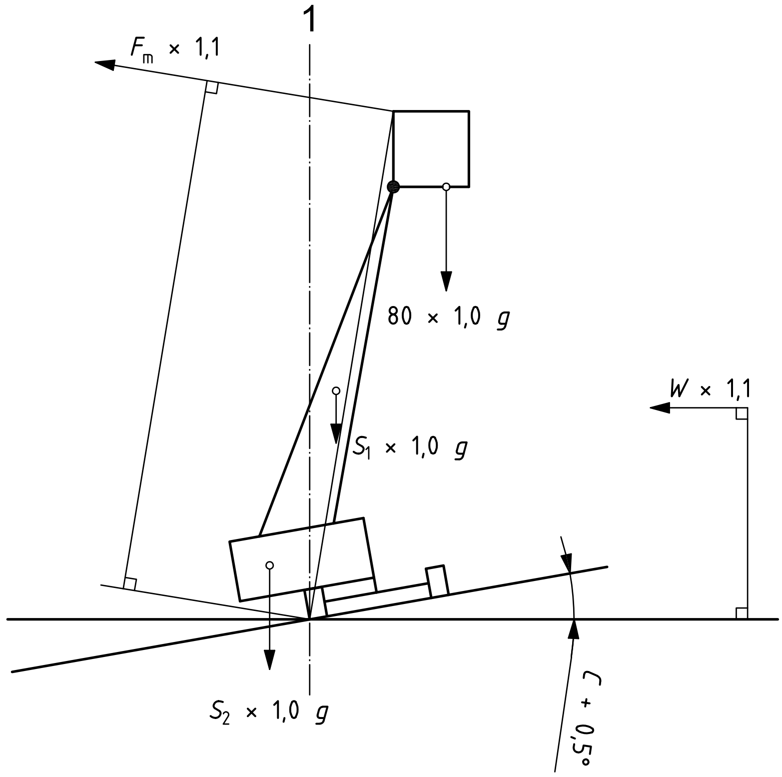
Figure 3 — Examples of maximum overturning load and force moment combination (*continued*)



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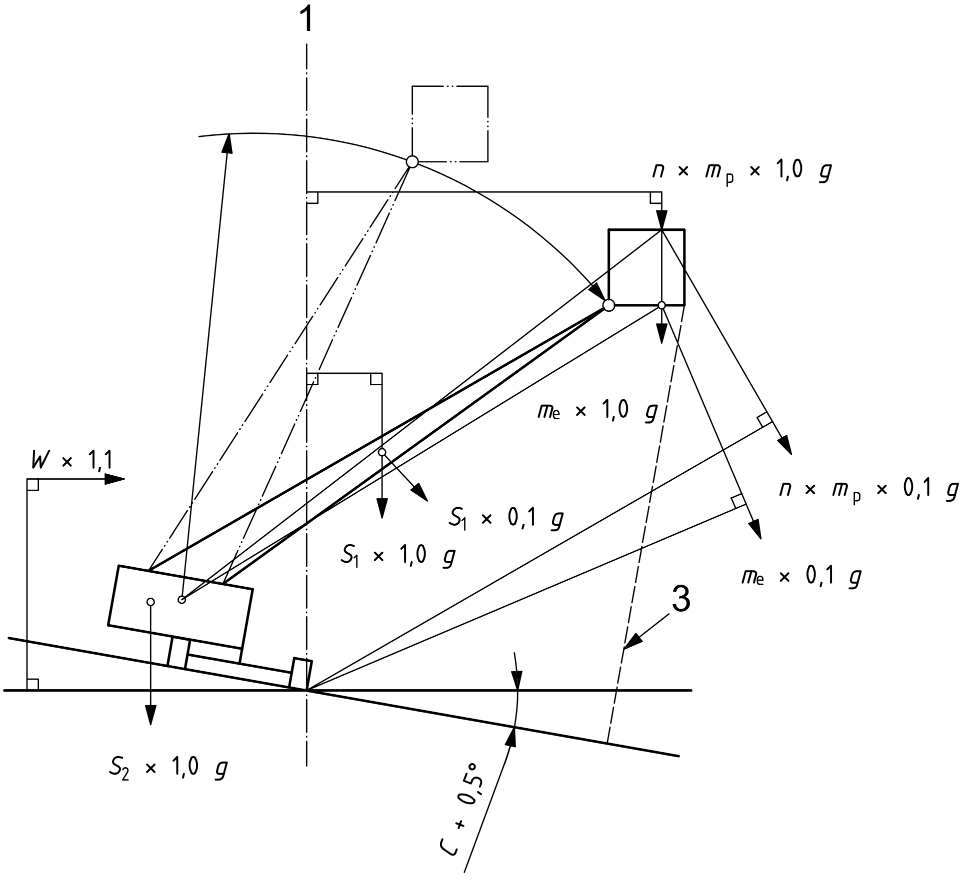

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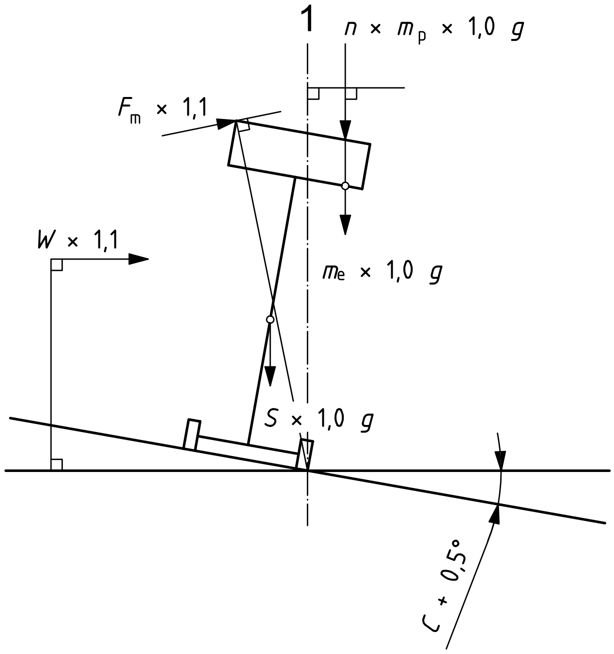
Figure 3 — Examples of maximum overturning load and force moment combination (*continued*)



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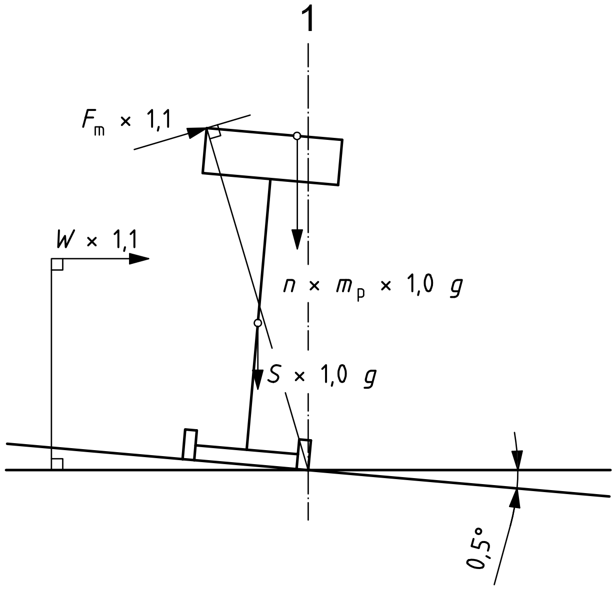


h)

Key

1 tipping line

2 direction of travel

3 limited reach

C maximum chassis inclination

Figure 3 — Examples of maximum overturning load and force moment combination
(see also Table 1)

4.2.4.2 Analysis

4.2.4.2.1 General stress analysis

The general stress analysis is the proof against failure by yielding or fracturing. This analysis shall be made for all load-bearing components and joints.

The required information on stresses or safety factors shall be included in the analysis in a clear and easily verifiable form. Details of the main dimensions, cross-sections and materials for the individual components and joints shall be given.

Finite element analysis (FEA) modelling may be used to meet this requirement. The FEA model shall be specified and include an explanation of the loading areas, load types, constraint areas and constraint types.

Stresses imposed by the static test (see 5.1.4.3.1) and overload test (5.1.4.4) shall not exceed 90 % of the elastic limit of the ductile materials.

Non-ductile structural elements of the MEWP shall have a design stress of no more than 20 % of the minimum ultimate strength of the material.

The allowable design stress may need to be decreased based on the evaluation given in 4.2.4.

4.2.4.2.2 Elastic stability analysis

Elastic stability analysis is the proof against failure by elastic instability (e.g. buckling, crippling). This analysis shall be made for all load-bearing components subjected to compressive loads.

4.2.4.2.3 Fatigue-stress analysis

Fatigue-stress analysis is the proof against failure by fatigue due to stress fluctuations. This analysis shall be made for all load-bearing components and joints critical to fatigue, taking into account the construction details, the degree of stress fluctuation and the number of stress cycles. The number of stress cycles may be a multiple of the number of load cycles.

As the number of stress fluctuations during transport cannot be calculated with any degree of accuracy, the stress in the transport position in components subject to vibration during transport shall be low enough to ensure virtually infinite fatigue life (see also 4.4.6 and 4.6.15).

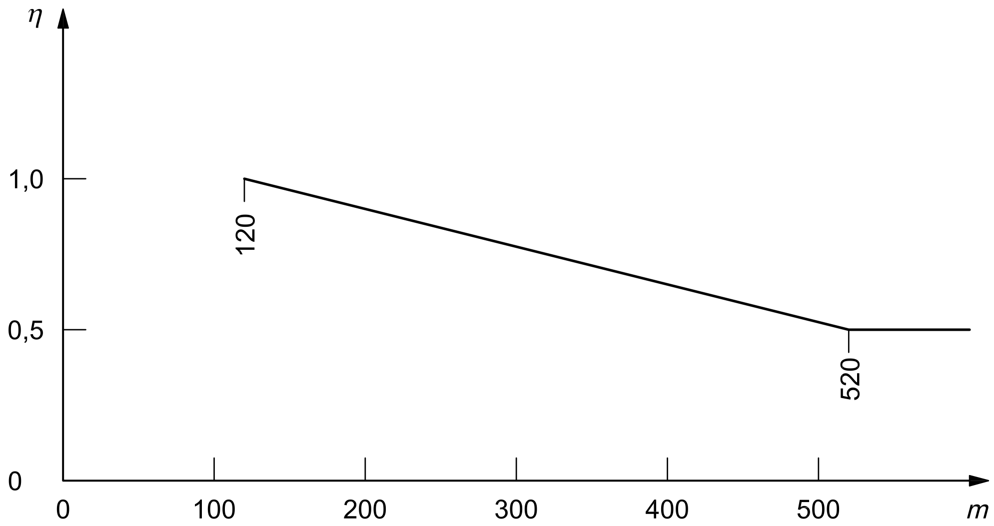
The number of load cycles for a MEWP is normally the following:

a) light intermittent duty (e.g. 10 years, 40 weeks per year, 20 h per week, 5 load cycles per hour): 4×10^4 cycles;

b) heavy duty (e.g. 10 years, 50 weeks per year, 40 h per week, 5 load cycles per hour): 10^5 cycles.

When determining the load combinations, it is permissible for the rated load to be reduced by the load spectrum factor in accordance with Figure 4; wind loads need not be taken into account.

NOTE For the design of wire-rope drive systems, see Annex D.



Key

m mass, kg

η load spectrum factor

Figure 4 — Load spectrum factor

4.2.4.2.4 Effects of stress concentration and ambient temperature

The analysis shall consider the effects of stress concentration, and the effects of ambient temperature in the temperature range for which the MEWP has been designed.

4.2.5 Verification

Verification of the requirements of 4.2 shall be carried out by design check, static tests and overload tests.

4.3 Chassis and stabilizers

4.3.1 Automatic safety device

An automatic safety device in accordance with 4.11 shall be fitted to prevent the travel of pedestrian-controlled MEWPs and power-driven type 1 MEWPs when the work platform is out of the transport or stowed position.

Any travel speed restriction for self-propelled MEWPs, when the work platform is out of the lowered travel position, shall be automatic.

Verification shall be carried out by means of a design check and functional testing.

4.3.2 Chassis inclination

Every MEWP shall have a device to indicate whether the inclination of the chassis is within the limits permitted by the responsible entity. This device shall be automatic, in accordance with 4.11, and shall be protected against damage and accidental change of its setting. The adjustment of the device shall require the use of tools and be capable of being sealed.

The device shall also prevent elevation beyond the lowered travel position or between various configurations when the chassis inclination is beyond that specified by the responsible entity for that configuration.

For type 1 MEWPs, the device can be replaced by a spirit level. For those MEWPs with power-driven stabilizers, the indication shall be clearly visible from each control position.

For type 2 MEWPs, when travelling out of the transport configuration, an audible warning shall be given at each control position before reaching the maximum limits specified by the responsible entity.

For type 3 MEWPs, when travelling out of the lowered travel position, upon reaching the limits specified by the responsible entity, the device shall prevent the MEWP from continuation of travel and, for group A MEWPs, further elevation shall not be allowed. If travel is interrupted due to an exceeding of the chassis inclination limit, travel is allowed provided that stability is maintained or improved. An audible warning shall be given when the chassis has reached the limits of inclination.

Verification shall be carried out by means of functional testing.

4.3.3 Locking pins

Any locking pins shall be secured against unintentional disengagement (e.g. spring pin) and loss (e.g. chain).

Verification shall be carried out by visual examination.

4.3.4 Control bars

Control bars of pedestrian-controlled MEWPs and tow bars shall be securely fastened to the chassis.

Verification shall be carried out by visual examination and testing.

4.3.5 Control bars held in vertical position

If control bars and tow bars, when not in use, are raised to the vertical position, an automatic device (e.g. hook) shall be provided to hold the bars in this position; sudden fall shall be prevented.

For multi-axle chassis, the minimum clearance between the fully lowered control bar or tow bar and the ground shall be 120 mm.

Verification shall be carried out by visual examination, testing and measurement.

4.3.6 Stabilizer feet

The stabilizer feet shall be constructed to accommodate ground unevenness of at least 10°.

Verification shall be carried out by visual examination and measurement.

4.3.7 Permitted work platform positions

MEWPs shall be fitted with a safety device in accordance with 4.11 that prevents the work platform operating outside permitted positions, unless the stabilizers are set in accordance with the operating instructions.

MEWPs constructed for operation without stabilizers for a limited range of operation shall be equipped with safety devices in accordance with 4.11 that prevent operation outside that limited range without stabilizers.

Verification shall be carried out by means of a design check and functional testing.

4.3.8 Prevention of powered stabilizer or levelling system movement

MEWPs with powered stabilizers or a levelling system shall be fitted with a safety device in accordance with 4.11 to prevent movement of the stabilizers or levelling system, unless the extending structure and the work platform are in the stowed or transport position or within the limited range specified in 4.3.7. When the extending structure and the work platform are inside the limited range, the operation of the stabilizers or levelling system shall not create an unstable situation.

Verification shall be carried out by means of a design check and functional testing.

4.3.9 Manually operated stabilizers

Manually operated stabilizers shall be designed to prevent unintentional movement.

Verification shall be carried out by means of a design check and functional testing.

4.3.10 Movement of stabilizers

The movements of stabilizers shall be limited by mechanical stops. Hydraulic cylinders fulfil this requirement if designed for that purpose.

A mechanical means shall be provided to prevent uncontrolled movements of stabilizers from the transport position. The stabilizers shall be locked in the transport position by two separate locking devices for each stabilizer, at least one of which operates automatically, e.g. a gravity locking pin plus a detent. Powered stabilizers meeting the requirements of 4.3.8 and 4.10 are regarded as meeting this requirement. This applies to MEWPs with permanently attached stabilizers that increase their width or length and to all vehicle-mounted and trailer-mounted MEWPs.

Verification shall be carried out by means of a design check.

4.3.11 Vehicle-mounted MEWP stabilizer indicator

Vehicle-mounted MEWPs shall be equipped with one or more indicators visible from the travelling controls to indicate if all parts of the stabilizers, the extending structure, the access ladders and the work platform of the MEWP are in the transport positions.

Verification shall be carried out by means of functional testing.

4.3.12 Visual contact at control positions

Any control position shall provide the operator with visual contact with the resulting movements.

The operator positions for powered stabilizers that deploy beyond the width of the chassis shall allow a clear view of the movement of each stabilizer until it reaches the supporting surface. Once surface contact of all stabilizers is established, further movement no longer requires visual observation of them.

Travel controls fixed to the chassis and operated from ground level shall be positioned so as to cause the operator to stand at least 1 m from the vertical tangent of the wheels or crawlers.

Verification shall be carried out by visual examination.

4.3.13 Totally manually operated MEWPs

The requirements of 4.3.7 are not applicable to MEWPs that are totally manually operated and have a work platform floor height less than or equal to 5 m above ground level (see 6.3.15).

These MEWPs are also exempt from all safety requirements that cannot be met without power supply.

Verification shall be carried out by means of a design check.

4.3.14 Oscillating axle lock or control systems

MEWPs equipped with one or more oscillating axles, in systems that lock or control the oscillating axle(s) to maintain stability, shall satisfy the following requirements:

a) on type 1 MEWPs, a safety device in accordance with 4.11 shall prevent deployment of the extending structure until oscillation of the axle(s) is locked or controlled;

b) on type 2 and type 3 MEWPs that have a means of locking or control of the oscillating axle(s), safety devices in accordance with 4.11 shall be incorporated; where hydraulic cylinders are used as positional locking or control devices, these shall comply with 4.10.

4.3.15 Self-propelled MEWP brakes

Self-propelled MEWPs shall be equipped with brakes on at least two wheels on the same axis that engage automatically when power to the brakes is removed or fails, and that shall be able to stop the MEWP in accordance with 4.3.18 and keep it in the stopped position. Such brakes shall not rely on hydraulic or pneumatic pressure or electrical power to remain engaged.

Verification shall be carried out by means of a design check and functional testing.

4.3.16 Unauthorized use

MEWPs shall be equipped with a device to prevent unauthorized use.

EXAMPLE Lockable switch.

Verification shall be carried out by means of functional testing.

4.3.17 Maximum travel speeds in elevated travel position

Travel speeds for type 2 and type 3 MEWPs in the elevated travel position shall not exceed the following values:

a) 1,5 m/s for vehicle-mounted MEWPs when using the travelling controls;

b) 3,0 m/s for rail-mounted MEWPs;

c) 0,7 m/s for all other self-propelled type 2 and type 3 MEWPs.

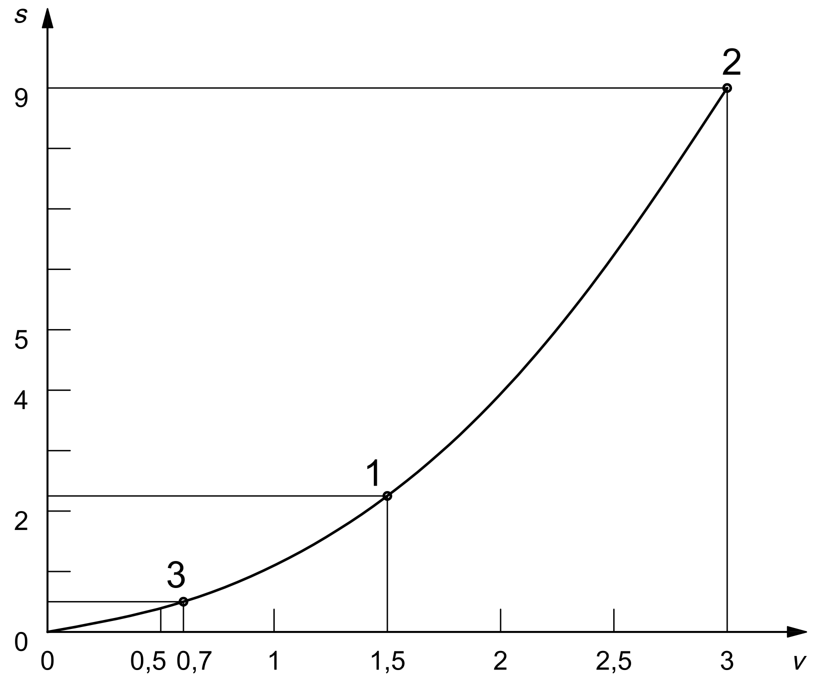
Verification shall be carried out by means of a design check and functional testing.

4.3.18 Stopping distances

MEWPs travelling at the maximum speeds listed in 4.3.17 on the maximum chassis inclination allowed by the responsible entity shall be capable of being stopped over distances not greater than those given in Figure 5. The values from Figure 5 are based on an average deceleration of 0,5 m/s^2 and do not include the operator's reaction time.

NOTE Minimum braking distances depend on factor z (see 4.2.2.2.1).

Verification shall be carried out by means of functional testing.



Key

v speed, m/s

s stopping distance, m

1 for vehicle-mounted MEWPs

2 for rail-mounted MEWPs

3 for all other MEWPs

Figure 5 — Maximum braking distance for type 2 and type 3 MEWPs

4.3.19 Maximum travel speed of pedestrian-controlled MEWPs

The maximum travel speed of a pedestrian-controlled MEWP with its work platform in the transport or stowed position shall not exceed 1,7 m/s.

Verification shall be carried out by measurement.

4.3.20 Guards for persons at control positions

Guards shall be provided to protect persons at control positions or standing adjacent to the MEWP at ground level or at other points of access, against thermal or mechanical hazards. The opening or removal of these guards shall only be possible by means of devices stored in fully enclosed and lockable enclosures (e.g. cabs, compartments) or by the use of tools or keys provided with the MEWP.

This requirement does not apply to the exhausts of vehicles conforming with road traffic regulations.

Verification shall be carried out by visual examination.

4.3.21 Engine exhaust

The exhaust from internal combustion engines shall be directed away from control positions.

Verification shall be carried out by visual examination.

4.3.22 Filling points for fluids

The filling points of gas and fluid reservoirs (other than for fire-resistant fluids) shall be positioned so as to avoid any fire from spillage onto very hot parts (e.g. engine exhausts).

Verification shall be carried out by visual examination.

4.3.23 Battery constraint

Batteries and battery containers of all MEWPs shall be constrained to prevent displacement that gives rise to danger. A means shall be provided that, in the event of overturning, will constrain the battery assembly so as to avoid the risk of injury to the operator by the battery being displaced or electrolyte being ejected.

Suitable ventilation holes shall be provided in the battery container, compartment or cover so that dangerous accumulations of gases do not occur in places occupied by operators.

NOTE Experience has indicated that when openings are positioned such that gases can escape freely, ventilation apertures are usually satisfactory if they provide a cross-section, in square millimetres, of 0,5 × the number of cells × the 5 h rated capacity, in ampere-hours. This level is, however, not intended to cover the charging condition.

Verification shall be carried out by visual examination.

4.3.24 Derailment and run-away prevention

4.3.24.1 General

The following requirements relate to the prevention of derailment of rail-mounted MEWPs during running and when moving along the track in working configuration.

When moving along the track in running and working configurations, rail-mounted MEWPs shall have all rail wheels loaded sufficiently to avoid derailment.

4.3.24.2 Proof against derailment

MEWPs with structures that are movable and influence the potential to derail shall have proof against derailment.

a) For MEWPs with only one suspension in stationary or running modes, proof against derailment in the foreseen working conditions is deemed to have been shown if, simultaneously,

   — the suspension is not blocked out or, for MEWPs with three-point suspension, at least one of the three support points can turn freely and absorb the twist, or the MEWP (including the wheel sets) is flexible enough to absorb the track twist, and

   — there is no rigid connection between several connected MEWP parts that would obstruct the turning freedom or the free movement in vertical and cross-wise direction within the freedom of movement necessary for the threshold parameters between the parts.

b) For MEWPs having different axle or suspension configurations in stationary and running modes, proof against derailment is deemed to be shown by stationary tests, taking into account the work configurations according to 4.3.24.3. Neither when stationary nor when moving along the track shall it be possible to change from one configuration to the other if this would cause the load moment to reach or exceed 90 % of the rated load for the new configuration.

If one of these conditions is not observed, proof against derailment shall be achieved by stationary tests according to 4.3.24.3.

4.3.24.3 Load cases for prevention of derailment during moving

Wheel unloading shall be proven by stationary tests for rail-mounted MEWPs that could have their centre of gravity displaced when moving along the track. Using all possible unfavourable positions of the MEWP and load, and the worst combination of track cant, gradient and twist, no rail wheel shall leave the rail when 1,5 times the maximum load is applied.

In addition, at the most unfavourable track condition with a maximum load, no wheel shall unload by more than 60 % of its normal weight.

4.3.24.4 Limiting use of MEWPs due to derailment requirements

If the prevention of derailment is not guaranteed for all working configurations, the scope of the MEWP shall be limited and this shall be indicated in the technical documentation and the instruction handbook, and shall be displayed on notices on the MEWP.

4.3.24.5 Prevention of run-away — Placement and removal from rails

The documented system used to describe the placing of the vehicle on, or removal from the track, shall be assessed to ensure that there is no inadvertent movement of the vehicle at any time during operation. This would normally require that the MEWP have, at all times, whether on or off the track, at the very least one braked axle (with the brakes applied), sufficient to hold the vehicle on the most adverse gradient on which it can be on-tracked, in contact with either the rail or ground.

Where an emergency stop button is fitted, it shall apply the brakes by stopping rotation of the braked axle(s). Emergency stop buttons (normally red mushroom-headed switches) are fitted to MEWPs and on the outside of certain other vehicles. Where fitted, the button's operation should be tested to ensure that the brakes are applied in all possible vehicle configurations, including during both on- and off-tracking.

Verification shall be carried out by means of functional testing.

4.3.25 Vehicle-mounted MEWP chassis selection

For vehicle-mounted MEWPs, the chassis shall be selected to meet the responsible entity's specifications. Installation criteria shall meet the chassis manufacturer's specifications and the specifications for mounted sub-assemblies.

4.4 Extending structure

4.4.1 Methods to avoid overturning and exceeding permissible stresses

4.4.1.1 General

In addition to the provisions of 4.2.3.5, MEWPs shall be provided with devices, or the equivalent methods applied, to reduce the risk of overturning and of exceeding permissible stresses in accordance with Table 2.

NOTE Load or moment controls are not able to protect against an overload that grossly exceeds the rated load.

Table 2 — Control devices

Group	Load-sensing system and position control (4.4.1.2 and 4.4.1.3)	Load- and moment-sensing systems (4.4.1.2 and 4.4.1.4)	Enhanced overload criteria (4.4.1.4 and 4.4.1.6)	Enhanced overload and stability criteria (4.4.1.3, 4.4.1.5 and 4.4.1.6)
A	X	—	—	X
B	X	X	X	X

4.4.1.2 Load-sensing system

The load-sensing system shall operate as follows.

a) It shall trigger after the rated load is reached and before 120 % of the rated load is exceeded.

b) When the load-sensing system is triggered, a warning consisting of a flashing red light at each preselected control position, together with an acoustic signal audible at each control position, shall be activated. The light shall continue to flash for as long as the overload persists and the acoustic alarm shall sound for periods of at least 5 s, repeated every minute.

c) If the load-sensing system was triggered during movement of the work platform, the possibility of movement shall remain.

NOTE This movement can be used to release a trapped person.

d) If the load-sensing system is triggered while the work platform is stationary, it shall prevent all movement of the work platform. Movement shall only restart if the overload is removed.

For type 1, group A MEWPs, it is permitted for the load-control device to be effective only when raising the extending structure from the lowest position. In this case, for the overload test specified in 5.1.4.3, the test load shall be 150 % of the rated load.

For group A MEWPs, the load-sensing device need not be activated until the work platform is elevated more than 1 m or 10 % of lift height, whichever is the greater, above the lowest position. If an overload condition is sensed at or above this height, further elevation shall be prevented.

The load-sensing system shall be in accordance with 4.11.

The emergency override system shall remain active at all times, including those times when the load control is activated.

4.4.1.3 Position control

4.4.1.3.1 General

To avoid overturning of the MEWP, or the exceeding of the permissible stresses in the structure of the MEWP, the permissible positions of the extending structure shall be limited automatically by mechanical stops (see 4.4.1.3.2), non-mechanical limiting devices (see 4.4.1.3.3) or electrical safety devices (see 4.11.3).

4.4.1.3.2 Mechanical limiting devices

Where permissible positions are limited by mechanical stops, these shall be designed to resist without permanent deformation the maximum forces exerted. Hydraulic cylinders fulfil this requirement if designed for that purpose.

4.4.1.3.3 Non-mechanical limiting devices

Where non-mechanical limiting devices are used, permissible positions of the extending structure shall be limited by a device that measures positions of the extending structure and is operated through the control systems to limit movements to the working envelope. This device shall be backed up by a safety device in accordance with 4.11.

4.4.1.4 Moment-sensing system

The moment-sensing system shall operate as follows.

— When the permissible overturning moment (see 4.2.3.5) is reached, a visual warning shall be given and further movements shall be prevented, except those which reduce the overturning moment.

— The control system for the moment-sensing system shall comply with the requirements of 4.11.

4.4.1.5 Criteria for enhanced stability for limited work-platform dimensions

MEWPs for up to two persons may be excluded from the requirements for load- and moment-sensing systems if they meet the following criteria for *enhanced stability*.

a) The outside dimensions of the work platform — including any extension, but excluding steps that might be present on the outside surfaces of the work platform — at any horizontal section shall have

   — for one person, a sectional area not greater than 0,6 m^2, with no side greater than 0,85 m,

   — for two persons, a sectional area not greater than 1,0 m^2, with no side greater than 1,4 m.

b) For the static test specified in 5.1.4.3.1, the test loads shall be calculated using 150 % of the rated load as identified in 4.2.1. The other load and force combinations specified in 4.2.2 shall remain as specified.

4.4.1.6 Criteria for enhanced overload for limited work platform dimensions

MEWPs for up to two persons may be excluded from the requirements for load-sensing systems if they meet the following criteria for *enhanced overload.*

a) The outside dimensions of the work platform — excluding steps that might be present on the outside surfaces of the work platform — at any horizontal section shall have

— for one person, a sectional area not greater than 0,6 m^2, with no side greater than 0,85 m;

— for two persons, a sectional area not greater than 1,0 m^2, with no side greater than 1,4 m.

b) For the overload test specified in 5.1.4.4, the test load shall be 150 % of the rated load.

4.4.1.7 Variable working envelope with more than one rated load

MEWPs with more than one rated load and more than one working envelope shall have an indicator of the selected combination visible at the work platform.

EXAMPLE A physical change (such as a platform extension) to the configuration of the work platform that affects its rated load.

An indicator is not necessary for MEWPs on which the working envelope is limited by a moment-sensing system.

The MEWP shall be fitted with load- and moment-sensing systems or a load-sensing system and position control.

MEWPs with enhanced stability for two persons shall require activation of a load-sensing system when extended working envelope(s) are selected.

4.4.1.8 Variable working envelope with one rated load

For MEWPs with one rated load and a variable working envelope (e.g. those with variable positions of stabilizers), selection by manual means is acceptable. In such cases, the selection shall only be possible with the extending structure in the access position (see 4.4.1.3).

4.4.1.9 Verification

Verification of the requirements of 4.4.1 shall be carried out by means of a design check (see 5.1.2) and by testing in accordance with 5.1.4.

4.4.2 Sequencing of extending structure

When the extending structure needs to be extended or retracted in a specific sequence, this sequence shall be automatic during normal operation.

Verification shall be carried out by means of a design check and functional testing.

4.4.3 Trapping and shearing

Trapping and shearing points between moving parts within reach of persons on the work platform or standing adjacent to the MEWP at ground level shall primarily be avoided by providing safe clearances or guarding in accordance with ISO 13854.

Where the vertical distance between the outer ends of the scissor arms is not less than 50 mm, descent shall be automatically stopped by a safety device. Further downward movement shall only be possible after a time delay of 3 s. A further lowering command by the operator shall cause a distinctive audible alarm to sound and a distinctive visual warning to operate for at least 1,5 s before lowering of the extending structure commences. In all cases, the audible alarm and visual warning shall continue to operate throughout any further lowering.

If the average lowering speed above “the first descent limit” is not greater than 0,2 m/s, speed reduction is not necessary.

Verification shall be carried out by measurement and by visual examination.

4.4.4 Supporting extending structure for routine maintenance

When the work platform of a MEWP needs to be raised for routine servicing purposes, a means shall be provided to enable the extending structure to be held in the required position. This means shall be capable of supporting an unloaded work platform and of being operated from a safe position; it shall not cause damage to any part of the MEWP (see 6.3.14). It shall also be capable of supporting a work platform even when a failure occurs on the raising/lowering system.

Verification shall be carried out by visual examination and functional testing.

4.4.5 Speeds of extending structure

If accelerations or decelerations are less than or equal to 0,25 g, the MEWP shall not exceed the following speeds:

a) 0,8 m/s for raising and lowering of the work platform;

b) 0,8 m/s for telescoping of the boom;

c) 1,4 m/s for slewing or rotation (horizontal speed at the outer edge of the work platform, measured at maximum range).

However, if accelerations or decelerations are greater than 0,25 g, then the following speeds shall not be exceeded:

d) 0,4 m/s for raising and lowering of the work platform;

e) 0,4 m/s for telescoping of the boom;

f) 0,7 m/s for slewing or rotation (horizontal speed at the outer edge of the work platform, measured at maximum range).

Deceleration caused by an emergency stop shall not be considered during measurement of g forces. Accelerations and decelerations, including emergency stops, shall be taken into account in accordance with 4.2.

Verification shall be carried out by means of functional testing.

4.4.6 Support in transport position

The extending structure shall be supported in the transport position so as to limit vibrations during transport (see 4.2.4.2.3).

Verification shall be carried out by means of a design check and by visual examination.

4.5 Extending structure drive systems

4.5.1 General

4.5.1.1 Inadvertent movements

Drive systems shall be designed and constructed to prevent any inadvertent movements of the extending structure.

Verification shall be carried out by means of a design check and functional testing.

4.5.1.2 Protection of extending structure from power sources

If the power source is capable of producing greater power than the extending structure and/or work platform drive system requires, protection shall be provided to the extending structure and/or work platform drive system to prevent damage (e.g. by a pressure-limiting device).

The use of friction couplings does not fulfil this requirement.

Verification shall be carried out by means of a design check.

4.5.1.3 Failure of transmission chain or belt

Transmission chains or belts shall only be used in drive systems if inadvertent movements of the work platform are automatically prevented in the event of failure of a chain or belt. This can be achieved by using a self-sustaining gear box or by monitoring the chain/belt using a safety device in accordance with 4.11.

Flat belts shall not be used.

Verification shall be carried out by means of a design check and functional testing.

4.5.1.4 Kick-back of handles

Manual drive systems shall be designed and constructed to prevent kick-back of handles.

Verification shall be carried out by means of a design check and by visual examination.

4.5.1.5 Powered and manual drive systems for the same function

If both powered and manual drive systems are provided for the same function (e.g. to override an emergency system) and if there is a risk of injury from engaging both systems at the same time, this shall be prevented, using, for example, interlocks, shut-off valves or bypass valves.

Verification shall be carried out by means of a design check and functional testing.

4.5.1.6 Braking system for all drives

A braking system shall be provided on all drives. For raising movements, this system shall be an automatic lock or self-sustaining device. The braking system shall be automatically applied when the drive is no longer energized.

The braking system shall ensure that the work platform, loaded with 1,25 times the rated load for power-operated MEWPs or with 1,5 times the rated load for manually powered MEWPs, can be stopped and held at any position in all configurations of operation. The braking system shall be protected against inadvertent release.

Verification shall be carried out by means of a design check and functional testing.

4.5.2 Wire-rope drive systems

4.5.2.1 Wire-rope drive system safety

4.5.2.1.1 General

Wire rope, drum and pulley diameters shall be calculated in accordance with Annex C, assuming that all the load is taken on one wire rope system. Traction drive systems shall not be used.

Wire-rope drive systems shall have a device or system which, in the event of a wire-rope drive system failure, limits the vertical movement of the fully loaded work platform to 0,2 m. This requirement shall be met by either a mechanical safety device (see 4.5.2.1.2) or an additional wire-rope drive system (see 4.5.2.1.3).

4.5.2.1.2 Mechanical safety device

Mechanical safety devices shall be in accordance with 4.11, and shall operate by engaging with the extending structure. This safety device shall gradually bring the work platform plus the rated load to a stop and hold it in the event of the wire-rope drive system failure. The average deceleration shall not exceed 1,0 g_n. Any spring operating this device shall be a guided compression spring with secured ends, or shall have a wire diameter of more than half the pitch in the operating condition, to limit the shortening of the spring should it fail.

4.5.2.1.3 Additional wire-rope drive system

The additional wire-rope drive system shall be designed either

a) according to the first wire-rope system, with a device giving approximately equal tension in both systems, thus doubling the working coefficient, or

b) according to the first wire-rope system, with a device to ensure that the additional system takes less than half of the load in the operating condition, but is able to take the full load if the first system fails, or

c) according to a), but with larger drum and pulley diameters to increase the fatigue life of the additional wire-rope system to at least twice the calculated lifetime of the first system.

Failure of the first system shall be self-revealing.

Verification shall be carried out by means of a design check and by visual examination.

4.5.2.2 Load-carrying wire ropes

Load-carrying wire ropes (see ISO 2408) shall be made from galvanized steel wires or equivalent and shall have the following characteristics:

a) minimum diameter: 8 mm;

b) minimum number of wires: 114;

c) tensile grade of wires: minimum 1 570 N/mm^2, maximum 2 160 N/mm^2;

d) fatigue life suitable for the application (see Annex C);

d) corrosion resistance equivalent to galvanized steel;

e) required ratio of pulley diameter to wire diameter (see Annex C).

The minimum breaking load of the wire ropes shall be shown on a certificate.

Wire ropes used directly for lifting or supporting the work platform shall not include any splicing, except at their ends.

Wire rope with other characteristics may be used if they provide equivalent safety.

Verification shall be carried out by design and by visual examination.

4.5.2.3 System of multiple wire ropes

If more than one wire rope is attached at a single point, a device shall be provided for approximately equalizing the tension of the wire ropes.

Verification shall be carried out by means of a design check and by visual examination.

4.5.2.4 Re-tensioning wire ropes

It shall be possible to re-tension wire ropes.

Verification shall be carried out by means of a design check and by visual examination.

4.5.2.5 Terminations of wire ropes

For the terminations of wire ropes, only the following shall be used:

— splices;

— aluminium pressed ferrules;

— non-ageing steel pressed ferrules;

— wedge-socket anchorages.

U-bolt grips shall not be used as wire rope terminations for load-carrying wire ropes.

The junction between a wire rope and its termination shall be able to resist at least 80 % of the minimum breaking load of the wire rope.

Verification shall be carried out by means of a design check and by visual examination.

4.5.2.6 Visual examination of wire rope terminations

Visual examination of wire rope terminations shall be possible, preferably without the removal of the wire ropes or major disassembly of the structural components of the MEWP.

If it is not feasible to use inspection openings, the MEWP responsible entity shall provide detailed instructions for examination.

Verification shall be carried out by means of a design check and by visual examination.

4.5.2.7 Safety device for MEWP work platforms raised and lowered by wire ropes

MEWPs with work platforms raised and lowered by means of wire ropes shall be equipped with a safety device in accordance with 4.11 that interrupts movements causing slack rope conditions. Movements in the opposite direction shall be possible. This device is unnecessary if no slack rope condition can develop.

Verification shall be carried out by means of a design check and functional testing.

4.5.2.8 Rope drum grooves and prevention of rope leaving the ends of the drum

Rope drums shall be grooved and a means shall be provided to prevent the wire rope from leaving the ends of the drum, e.g. flanges extending to a height of at least twice the wire rope diameter above the highest layer.

Verification shall be carried out by visual examination.

4.5.2.9 Layers of rope

Only one layer of wire rope shall be wound on the drum unless a special spooling system is used.

Verification shall be carried out by visual examination.

4.5.2.10 Turns of rope

At least two turns of wire rope shall remain on the drum when the extending structure and/or the work platform is in its most extreme position.

Verification shall be carried out by means of functional testing and by visual examination.

4.5.2.11 Fastening rope to drum

Each wire rope shall be properly fastened to the drum. The fastening shall be able to take 80 % of the minimum breaking load of the wire rope.

Verification shall be carried out by means of a design check and by visual examination.

4.5.2.12 Unintentional displacement of rope

A means shall be provided to prevent unintentional displacement of wire ropes from pulleys, even under slack rope conditions.

Verification shall be carried out by means of a design check and by visual examination.

4.5.2.13 Drum and sheave grooves

The dimensions of the drum and sheave grooves shall be in accordance with the wire-rope manufacturer's recommendations.

Verification shall be carried out by means of a design check and by visual examination.

4.5.3 Chain drive systems

Round-link chains shall not be used. Leaf chains may be used.

The responsible entity shall have on record a chain certificate from the manufacturer of the chain, giving the minimum design breaking load of the chains.

4.5.3.1 Limit of vertical movement in case of failure

4.5.3.1.1 General

Chain drive systems shall have a device or system that, in the event of a chain drive system failure, limits the vertical movement of the fully loaded work platform to 0,2 m. This requirement shall be met by either of the drive systems specified in 4.5.3.1.2 and 4.5.3.1.3.

4.5.3.1.2 Single-chain drive systems

A single-chain drive system shall have a working coefficient of at least 5, plus a mechanical safety device in accordance with 4.11 that operates by engaging with the extending structure. This safety device shall gradually bring the work platform plus the rated load to a stop and hold it in the event of a drive system failure. The average deceleration shall not exceed 1,0 g_n. Any spring operating this device shall be a guided compression spring with secured ends, or shall have a wire diameter of more than half the pitch in the operating condition, to limit the shortening of the spring, should it fail.

4.5.3.1.3 Two-chain drive systems

Two-chain drive systems shall meet the requirements of either a) or b) below.

a) **Equal tension**

Each chain of a two-chain drive system shall have a working coefficient of at least 4 (a total minimum coefficient of 8) and shall be provided with a device giving approximately equal tension in the two-chain system, or else shall comply with b).

Failure in the first chain shall be self-revealing.

b) **Unequal tension**

The first component of a two-chain drive system shall have a working coefficient of at least 5 when carrying the full load, and the second component shall have a working coefficient of at least 4 (a total minimum coefficient of 9 when carrying the full load) and be provided with a device to ensure that the second component takes less than half the load in the operating condition, but is able to take the full load if the first component fails.

Failure in the first component shall be self-revealing.

Verification shall be carried out by means of a design check and by visual examination.

4.5.3.2 Multiple chains attached to a point

If more that one chain is attached at one point, a device shall be provided to approximately equalize the tension in the chains.

Verification shall be carried out by means of a design check and by visual examination.

4.5.3.3 Tensioning chains

It shall be possible to re-tension chains.

Verification shall be carried out by means of a design check and by visual examination.

4.5.3.4 Strength of junction between chain and termination

The junction between the chain and the chain termination shall be able to resist at least 100 % of the minimum breaking load of the chain.

Verification shall be carried out by means of a design check.

4.5.3.5 Visual examination of chains and terminations

Visual examination of chains and chain terminations shall be possible, preferably without the removal of the chains or major disassembly of structural components of the MEWP.

If it is not possible to provide inspection openings, the responsible entity shall provide detailed instructions for examination in accordance with Annex F.

Verification shall be carried out by means of a design check and by visual examination.

4.5.3.6 Safety device for MEWP work platforms raised and lowered by chains

MEWPs with work platforms raised and lowered by means of chains shall be equipped with a safety device in accordance with 4.11 that interrupts movements causing slack chain conditions. Movements in the opposite direction shall be possible. This device is unnecessary if no slack chain condition can develop.

Verification shall be carried out by means of a design check and functional testing.

4.5.3.7 Unintentional displacement of chain

A means shall be provided to prevent unintentional displacement of the chain from the sprockets or pulleys, even under slack conditions.

Verification shall be carried out by means of a design check and by visual examination.

4.5.4 Lead-screw drive systems

4.5.4.1 Lead-screw and nut design stress and material

The design stress of lead screws and nuts shall not be more than 1/6 of the ultimate tensile stress of the material used. The lead screw material shall have a higher abrasion resistance than the load-bearing nut.

Verification shall be carried out by means of a design check.

4.5.4.2 Separation of lead screw from work platform

The lead screw mechanism shall be designed to prevent separation of the work platform from the mechanism during normal use.

Verification shall be carried out by visual examination.

4.5.4.3 Load-bearing nut and safety nut

Each lead screw shall have a load-bearing nut and an unloaded safety nut. The safety nut shall only be loaded if the load-bearing nut fails. It shall not be possible to raise the work platform when the safety nut is under load.

Verification shall be carried out by means of a design check and by visual examination.

4.5.4.4 Detection of wear on nuts

It shall be possible to detect the wear of the load-bearing nuts without disassembly.

4.5.5 Rack and pinion drive systems

4.5.5.1 Design stress of racks and pinions

The design stress of racks and pinions shall not be more than 1/6 of the ultimate tensile stress of the material used.

Verification shall be carried out by means of a design check.

4.5.5.2 Safety device and over-speed governor

Rack and pinion drives shall have a safety device actuated by an over-speed governor. This safety device shall gradually bring the work platform plus the rated load to a stop and hold it in the event of the lifting mechanism failing. The average deceleration shall not exceed $1{,}0 g_{\mathrm{n}}$. Actuation of the safety device shall automatically interrupt the power supply.

Verification shall be carried out by means of a design check and functional testing.

4.5.5.3 Device to prevent pinion disengagement

In addition to the normal work platform guide rollers, positive and effective devices shall be provided to prevent any driving or safety-device pinion from becoming disengaged from the rack. These devices shall ensure that axial movement of the pinion is limited so that a minimum of 2/3 of the tooth width is always in engagement with the rack. They shall also restrain radial movement of the pinion from its normal meshing position to no more than 1/3 of the tooth depth.

Verification shall be carried out by visual examination.

4.5.5.4 Visual examination of pinions

Visual examination of the pinions shall be possible without the removal of the pinions or major disassembly of structural components of the MEWP.

Verification shall be carried out by visual examination.

4.6 Work platform

4.6.1 Level of work platform

4.6.1.1 Level control

The level of the work platform out of the transport position shall not vary by more than 5° from its original position when the extending structure is raised or lowered from the access position.

The levelling system, excepting hydraulic levelling systems, shall incorporate a safety device complying with 4.11 that, in the case of a failure within the system, will maintain the work platform level within a further 5°.

Verification shall be carried out by means of a design check and functional testing.

Mechanical levelling systems fulfil this requirement if designed to take at least twice the load imposed on them. If a single wire rope or chain is used, it shall be designed with a safety factor of five against breaking when subjected to twice the imposed loads.

Verification shall be carried out by means of a design check.

Hydraulic cylinders in hydraulic levelling systems shall comply with 4.10.2.

Verification shall be carried out by means of functional testing.

4.6.1.2 Platform level adjustment

Manually controlled adjustment of the level of the platform is permissible in all positions of the work platform. When the work platform is not in the lowered travel position or transport position, the rate of change of the platform angle shall not exceed the maximum that occurs during lowering or raising in operation.

4.6.2 Work platform materials

The work platform shall be made of at least non-flammable material(s), i.e. materials that will not sustain a flame after the ignition source has been removed.

4.6.3 Guardrail (protection) systems

Protection shall be provided on all sides of each work platform to prevent the fall of persons and materials. The protection shall be securely fastened to the work platform and shall, as a minimum, consist of guardrails at least 1,0 m high, toeguards at least 0,1 m high and intermediate guardrails not further than 0,55 m from either the guardrails or the toeguards.

Vertical posts may be used instead of an intermediate guardrail if the clear horizontal distance between those posts is no more than 180 mm maximum. Clear space between guardrail segments shall not exceed 120 mm.

Clear horizontal space between toeguard segments shall not exceed 15 mm.

The guardrails shall be constructed to withstand concentrated loads of 500 N per person, applied at the least favourable positions and in the least favourable direction at 0,5 m intervals, without causing permanent deformation of the guardrails.

For MEWPs operated in countries where national or other MEWP regulations allow, a minimum of 0,9 m may be applied instead of 1,0 m for the guardrail height (this recognizes national variations in physical stature of persons).

Folding guardrails satisfy this requirement provided that they remain securely fastened to the work platform and are equipped with locking pins secured against unintentional disengagement and loss, or an equally effective means of locking.

4.6.4 Anchorage(s)

Anchorage(s) for the connection of a fall protection device shall be provided for boom-supported lifts and may be provided for scissor-supported or mast-supported lifts.

— Each arrest anchorage used as part of a fall arrest system or fall restraint system shall be capable of withstanding a static force of 16 kN without reaching ultimate strength. For anchorages rated for more than one person, the strength requirement shall be increased by 20 % for each additional person. This strength requirement shall only apply to the anchorage and its attachment to the MEWP in all possible load directions.

— Each restraint anchorage used as part of a fall arrest system or fall restraint system shall be capable of withstanding a static force of 3 kN without reaching ultimate strength. For anchorages rated for more than one person, the strength requirement shall be multiplied by the number of persons. This strength requirement shall only apply to the anchorage and its attachment to the MEWP in all possible load directions.

When fitted, the number of anchorages shall equal or exceed the allowable number of persons. More than one occupant may attach to a single anchorage if the anchorage is rated for more than one person.

The responsible entity shall test any anchors defined as fall arrest anchorages according to the requirements of 5.1.4.2.

The anchorages shall be designed so as to accept personal protective equipment. Exposed edges or corners shall be relieved either with a radius of at least 0,5 mm or a 45° chamfer.

Verification shall be carried out by means of a design check and by visual examination.

4.6.5 Openings in guardrails for entrance and exit

4.6.5.1 General

Any part of the protection movable for the purpose of access to the work platform shall not fold or open outwards except as specified in 4.6.5.2. It shall be designed to fasten in the closed position. The gate shall either return automatically to the closed and fastened position, or be interlocked in accordance with 4.11 to prevent operation of the MEWP until it is closed. Inadvertent opening shall be prevented. Sliding or vertically hinged intermediate guardrails that return automatically to their protective position do not need fastening and interlocking. Consideration should be given to ease of entry and exit.

The minimum opening width for the purpose of access to the work platform shall be 420 mm.

On work platforms with fixed top guardrails, the opening shall not be less than 800 mm high and 420 mm wide.

Wherever possible, the opening should be at least 920 mm high and 645 mm wide.

Verification shall be carried out by visual examination.

4.6.5.2 Special-purpose work platforms

Special-purpose work platforms of 0,5 m^2 floor area or less, designed for single occupant use, may be equipped with an outward-opening door, provided they have a self-closing top guardrail in accordance with 4.6.3.

Verification shall be carried out by visual examination.

4.6.6 Floor of work platform

The floor of the work platform, including any trapdoor, shall be slip-resistant and self-draining. Any opening in the floor or between the floor and toeguards or access gates shall be dimensioned so as to prevent the passage of a sphere of 15 mm diameter.

Verification shall be carried out by visual examination.

The floor of the work platform and any trapdoor shall be able to take the rated load distributed according to 4.2.1.1.

Verification shall be carried out by means of a design check.

4.6.7 Chains or ropes

Chains or ropes shall not be used as guardrails or access gates.

Verification shall be carried out by visual examination.

4.6.8 Access ladder

When the distance between the access level and the upper edge of the toeguard in an access position exceeds 0,7 m, the MEWP shall be equipped with an access ladder. The steps or rungs shall be not more than 0,3 m apart and shall be spaced equally over the distance between the bottom step/rung and the floor of the work platform. The bottom step/rung shall be not more than 0,7 m above the access level. Each step or rung shall be at least 0,3 m wide, at least 25 mm deep, and shall be slip-resistant. The front of the steps or rungs shall be a horizontal distance of at least 0,15 m away from the supporting structure or any other components of the MEWP. The access ladder shall be symmetrical with the access gate.

Verification shall be carried out by means of a design check and by visual examination.

4.6.9 Handholds and handrails

Handholds, handrails or similar adequate devices shall be provided for both hands while climbing or descending the access ladder to the work platform. They shall be arranged to avoid the use of controls and piping as handholds or footsteps.

Verification shall be carried out by visual examination.

4.6.10 Trapdoors

Trapdoors in work platforms shall be securely fastened to the work platform so that no inadvertent opening is possible. It shall not be possible for trapdoors to open downward or to slide sideward.

Verification shall be carried out by visual examination.

4.6.11 Protecting controls and hands

The hand(s) operating the controls shall be protected.

Verification shall be carried out by visual examination.

4.6.12 Audible warning device

MEWPs of type 3 shall be equipped with an audible warning device (e.g. a horn) operated from the work platform.

Verification shall be carried out by means of functional testing.

4.6.13 Means of communication

MEWPs of type 2 shall be equipped with a means of communication (e.g. walkie-talkie) between the persons on the work platform and the driver.

Verification shall be carried out by visual examination and functional testing.

4.6.14 Mechanical stops

The movements of work platform(s) relative to the extending structure shall be limited by mechanical stops. Hydraulic cylinders fulfil this requirement if designed for that purpose.

Verification shall be carried out by means of a design check and functional testing.

4.6.15 Support in transport position

The work platform shall be supported in the transport position in such a way as to avoid harmful vibrations during transport (see 4.2.4.2.3).

Verification shall be carried out by means of a design check and by visual examination.

4.6.16 Work platforms constructed from non-conductive materials

Non-insulating work platforms may have drain holes and/or access openings. The work platform shall be made of at least non-flammable materials, i.e. materials that will not sustain a flame after the ignition source has been removed.

NOTE For work platforms constructed from non-conductive (insulating) materials, see ISO 16653-2.

4.6.17 Noise reduction

Noise reduction shall be an integral part of the design process for MEWPs, specifically taking into account technical progress and measures at source according to ISO/TR 11688-1.

NOTE ISO/TR 11688-2 gives further information on noise generation mechanisms in machinery.

Some major sound sources of MEWPs are power generation and transmission equipment such as combustion engines, the cooling system, electric drive systems and hydraulic systems.

Measures for noise reduction include enclosed power generation, transmission and hydraulic equipment, capsulated cooling system and exhaust silencers.

4.7 Controls

4.7.1 Activation and operation

MEWPs shall be provided with controls designed such that movements of the MEWP only take place while the controls are being actuated. The controls, when released, shall automatically return to the neutral position. The travel controls of vehicle-mounted MEWPs do not need to satisfy this requirement.

All controls shall be designed to protect against inadvertent operation, i.e. any operation other than that intentionally initiated by the operator. A separate control that has to be continuously activated by the operator in order for any motion to take place meets this requirement. Foot controls, if so equipped, shall have slip-resistant surfaces and be easy to clean.

Controls shall be positioned to avoid danger to the operator from the moving parts of the MEWP.

Verification shall be carried out by means of functional testing and by visual examination.

4.7.2 Direction of movement

The direction of all movements of the MEWP shall be clearly indicated on or near the controls by words or symbols in accordance with ISO 20381.

Verification shall be carried out by means of visual examination and functional testing.

4.7.3 Location, accessibility, protection and selection among duplicate controls

The control devices shall be situated on the work platform. Duplicate controls for all powered functions of the extending structure shall be provided at the base or ground level, except for drive or steering, and shall override control devices situated on the work platform. Control devices shall be readily accessible to the operator. Control boxes not permanently attached shall have their normal location and orientation clearly marked. All control devices shall automatically return to the “off” or “neutral” position when released, if used to control any movement of the MEWP.

The requirement for protection from inadvertent operation in 4.7.1 is applicable to all duplicated controls.

If movement can be controlled from additional control stations, a locking mechanism shall be provided such that movement is possible from only one pre-selected control station. The base or ground-level controls shall override all additional controls, including platform emergency stop control.

If cableless control systems are used, they shall comply with Annex G. Operation of extending structure and elevated drive functions shall only be possible when the cableless controls are located in the work platform in a position specifically designed by the manufacturer.

On MEWPs with non-conductive (insulating) components the lower controls shall be located such that an operator is not placed in the electrical path between the aerial device and the ground.

Verification shall be carried out by means of functional testing and by visual examination.

4.7.4 Emergency stops

MEWPs shall be provided with emergency stop controls in accordance with ISO 13850 at each control position.

Verification shall be carried out by means of a design check and functional testing.

4.7.5 Electrical switches

Electrical switches controlling safety functions shall be in accordance with 4.11.3.1.

Verification shall be carried out by means of a design check.

4.7.6 Pilot and solenoid valves

Pilot and solenoid-operated control valves shall be so designed and installed that they stop the corresponding movement in the event of power failure.

Verification shall be carried out by means of a design check and functional testing.

4.7.7 Restoration of power after failure

On starting, or on restoration of power after failure of the power supply, no movement shall occur without a deliberate action on the part of the operator.

Verification shall be carried out by means of functional testing.

4.7.8 Overriding emergency system

MEWPs shall be fitted with an overriding emergency system (e.g. hand pump, secondary power unit, gravity-lowering valves), in an easily accessible position, to ensure that in the event of failure of the main power supply or the operator becoming incapacitated, the work platform can be returned to a position from which it is possible to leave it without danger, taking into account the need to manoeuvre it clear of obstructions (see 6.3.4).

The controls of the emergency system shall be easily accessible from the ground (see 4.7.3). This is not necessary if the MEWP is equipped for safe access to (or exit from) the work platform by other means (e.g. fixed ladders).

Verification shall be carried out by means of a design check and functional testing.

4.7.9 Speed restriction

A device shall be provided to limit the speed of movement of the work platform to 1,4 times normal speed, even under emergency operations.

Verification shall be carried out by means of a functional check.

4.7.10 Automatic or programmed operation

Automatic or programmed operation performed with the joystick, lever or switch released is permissible if appropriate safety measures are employed, e.g. a warning device alerting the operator that the machine is “under operation”, and provided a separate control is activated and release interrupts the movement.

4.7.11 Winch control on vehicle-mounted MEWPs

If the MEWP is equipped with a material-handling winch, this shall have both upper controls and the lower controls. The lower controls shall be located in close proximity to the lower control station.

On MEWPs with non-conductive (insulating) components, the lower control shall be located such that an operator of the lower winch control is not placed in the electrical path between the aerial device and the ground.

4.8 Electrical equipment

4.8.1 Relevant norms and standards

The electrical equipment of MEWPs shall comply with the relevant standards, in particular with IEC 60204-1. If, owing to special conditions, MEWPs are used outside the ranges covered by IEC 60204-1 for d.c. supplies, ambient air temperature, altitude or connection to moving elements of the machine, then deviations will be necessary, and the responsible entity shall take the necessary safety measures and/or state any operating limitations in the instruction handbook (see 6.2 and Annex F).

Verification shall be carried out by means of a design check and by visual examination.

4.8.2 Main switch

A main switch shall be fitted in an easily accessible position. It shall be possible to secure it in a disconnected position by means of a locking device or equivalent, to prevent operation.

Verification shall be carried out by means of a design check and by visual examination.

4.8.3 Cables

Cables shall be multi-stranded when flexibility is necessary and, if necessary, shall be oil-resistant.

Verification shall be carried out by means of a design check and by visual examination.

4.8.4 Battery protection

Batteries shall be protected against damage due to short circuits and against mechanical damage. If batteries are the primary power source, the disconnection (isolation) of the battery, i.e. breaking of one pole of the electrical supply, shall be easily possible without the use of tools.

Verification shall be carried out by visual examination.

4.8.5 Ingress of water

When necessary to prevent ingress of water, the minimum degree of protection provided by enclosures shall be IP 54 according to IEC 60529. The responsible entity shall take into account any foreseeable conditions of use (e.g. fluids other than water necessitating higher degrees of protection).

Verification shall be carried out by means of a design check and by visual examination.

4.8.6 Electromagnetic compatibility (EMC)

The relevant EMC requirements shall be observed.

4.9 Hydraulic systems

4.9.1 Pressure-limiting device

The hydraulic system shall include the pressure-limiting device (e.g. pressure-relief valve) before the first control valve. If different maximum pressures are used in the hydraulic system, more than one pressure-limiting device shall be provided.

The adjustment of pressure-limiting devices shall require the use of tools and shall be capable of being sealed.

Verification shall be carried out by means of a design check and by visual examination.

4.9.2 Strength of pipes and connections

Pipes and those of their connections which can be subjected to the maximum pressure permitted by any pressure-limiting device shall be designed to withstand at least twice that pressure without permanent deformation (yield stress $R_{p0,2}$). If, under normal operation, components can be subjected to higher pressures than those permitted by the pressure-limiting device, they shall be designed to withstand at least twice the higher pressure without permanent deformation ($R_{p0,2}$); see 4.10.1.3 for failure conditions.

Verification shall be carried out by means of a design check.

4.9.3 Bursting strength of hoses and fittings

All fittings and hoses shall have a minimum bursting strength of three times the operating pressure for which the system is designed.

Verification shall be carried out by means of a design check.

4.9.4 Pressure rating of other components

All components of the hydraulic system, other than those specified in 4.9.2, 4.9.3 and 4.10, shall be rated for at least the maximum pressure to which they will be subjected, including any temporary increase in pressure setting necessary for carrying out the overload test (see 5.1.4.4).

Verification shall be carried out by means of a design check.

4.9.5 Gauge connections

Each hydraulic circuit shall be provided with sufficient connections for pressure gauges to allow checking for correct operation.

Verification shall be carried out by means of a design check and by visual examination.

4.9.6 Venting of air

The design of the hydraulic system shall enable entrapped air to be vented.

Verification shall be carried out by means of a design check.

4.9.7 Inlet filter

Any fluid reservoir open to the atmosphere shall be equipped with an air-inlet filter.

Verification shall be carried out by visual examination.

4.9.8 Fluid level indicators

Each fluid reservoir tank shall be equipped with easily accessible devices indicating both the permissible maximum fluid level and the necessary minimum level when the extending structure is fully lowered and retracted and the stabilizers fully retracted.

Verification shall be carried out by visual examination and by functional testing.

4.9.9 Fluid cleanliness

Each hydraulic system shall have means to ensure the fluid cleanliness level necessary for safe operation of the system and its components.

Verification shall be carried out by means of a design check.

4.9.10 Gas-loaded accumulators

In hydraulic systems incorporating gas-loaded accumulators, a means shall be provided to vent the liquid pressure automatically or to positively isolate the accumulator when the system is in the unpressurized state.

If the gas-loaded accumulator pressure is required by design to be retained when the system is shut off, complete information for safe servicing shall be given on or near the accumulator in a visible location. Duplicate information shall be provided in the instruction handbook (see 6.2 and Annex F) on the circuit diagram.

Verification shall be carried out by means of a design check and by visual examination.

4.10 Hydraulic cylinders

4.10.1 Structural design

4.10.1.1 General

The design of load supporting cylinders shall be based on an analysis of the pressures, imposed loads, and forces during normal operation, and failure conditions (see 4.10.1.3). Cylinders acting as mechanical stops shall be designed to withstand twice the imposed load and shall include the additive effects of both external and internal forces such as those resulting from hydraulic pressure.

4.10.1.2 Normal operating conditions

4.10.1.2.1 Buckling

The responsible entity shall identify the operating conditions which produce the combinations of extended length, pressure, deflections and externally applied loads and forces creating the maximum buckling conditions.

4.10.1.2.2 Constructional details

The design of welded joints shall conform to 4.2.4.2. Load-carrying threaded joints shall comply with relevant standards, and stress calculations shall take into account the reduced shear areas due to manufacturing tolerances and the elastic deformation caused by hydraulic pressures. The design of threaded joints subjected to varying tensile loads shall take into account the effects of fatigue and prevent inadvertent separation (unscrewing).

4.10.1.2.3 Conditions causing pressure above pressure-limiting device pressures (see Figures 6 to 10)

The following conditions cause pressures above those of the pressure-limiting devices:

a) the effect of devices that reduce the speed of the cylinders below the speed that could result from the full fluid supply to the cylinders, thereby causing an internal pressure loading additional to the normal pressure due to externally applied loads, with this additional pressure expressed by the ratio

$$\frac{D^2}{D^2 - d^2}$$

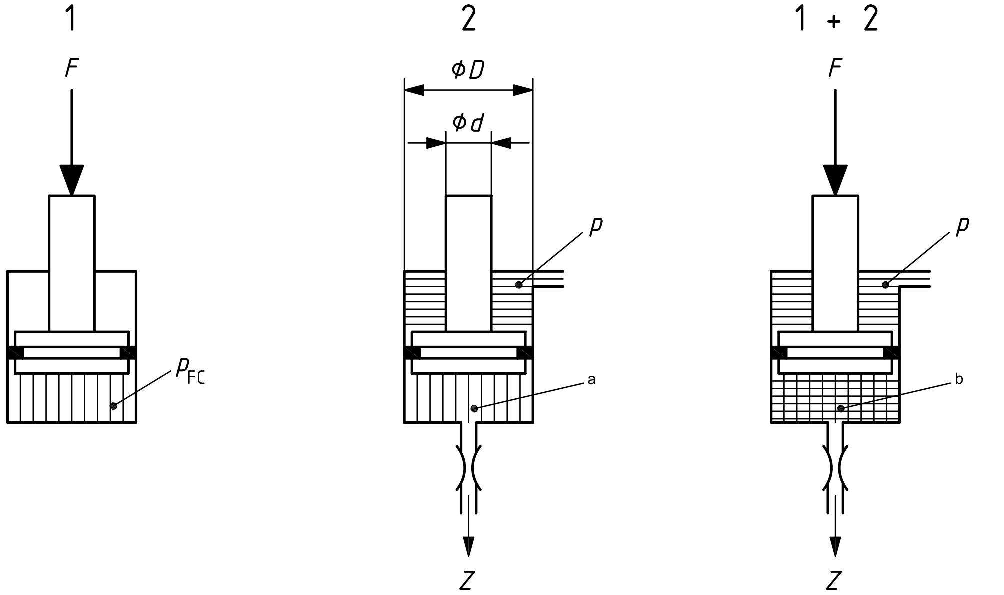
where

D is the diameter of the piston;

d is the diameter of the piston rod when a cylinder is in tension and the speed control device acts on the annulus;

b) the effect of thermal expansion of fluid confined in the cylinder when at rest.

NOTE The speed control devices described in a) above can take the form of the control valve being partially open or closed.



Key

D diameter of piston

d diameter of piston rod with cylinder in tension and speed control device acting on annulus

F load

p system pressure

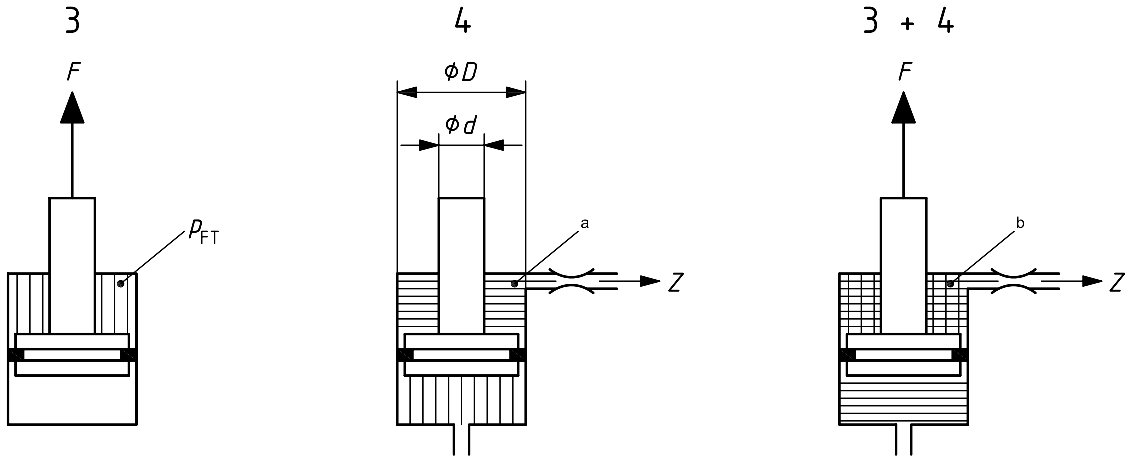
p_{FC} normal pressure

Z restricted flow

a $p \cdot \left(\dfrac{D^2 - d^2}{D^2} \right)$

b $p_{FC} + p \cdot \left(\dfrac{D^2 - d^2}{D^2} \right)$

Figure 6 — Cylinder pressures under normal operation — Cylinder in compression



Key

D diameter of piston

d diameter of piston rod with cylinder in tension and speed control device acting on annulus

F load

p system pressure

p_{FT} normal pressure

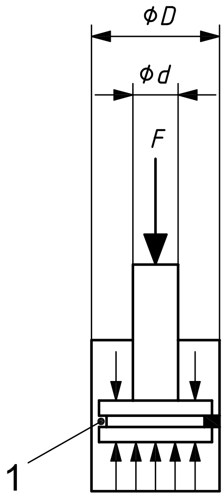
Z restricted flow

a $p \cdot \left(\dfrac{D^2}{D^2 - d^2} \right)$

b $p_{FT} + p \cdot \left(\dfrac{D^2}{D^2 - d^2} \right)$

Figure 7 — Cylinder pressures under normal operation — Cylinder in tension

The pressure at the top of the piston is equal to the pressure at the bottom. The load is supported by the area of the rod, $\pi d^2/4$, instead of the area of the piston, $\pi D^2/4$. The normal pressure, p_{FC}, increases by the ratio D^2/d^2.



Key

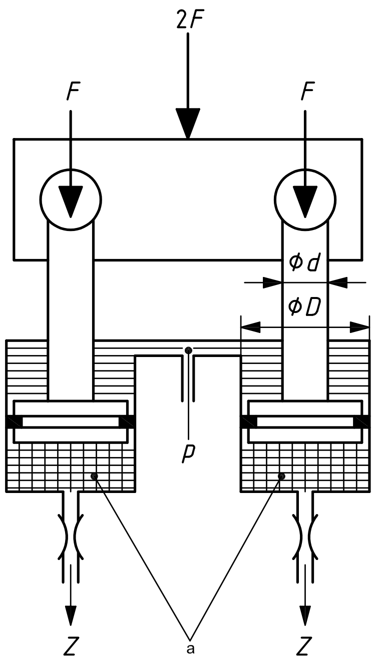
D diameter of piston

d diameter of piston rod with cylinder in tension and speed control device acting on annulus

F load

1 failed seal

Figure 8 — Cylinder pressures at seal failure



Key

D diameter of piston

d diameter of piston rod with cylinder in tension and speed control device acting on annulus

F load

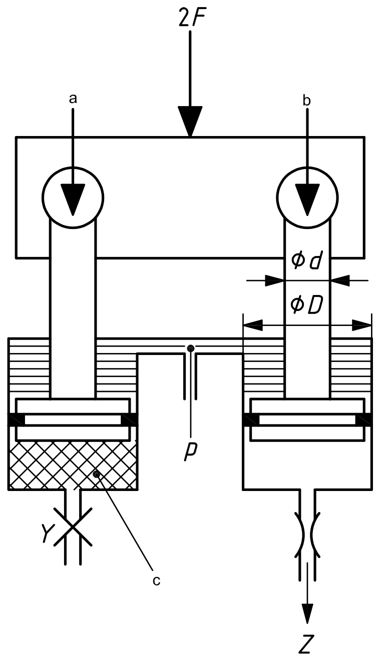
p system pressure

p_{FC} normal pressure

Z restricted flow

a $p_{FC} + p \cdot \left(\frac{D^2 - d^2}{D^2} \right)$

Figure 9 — Twin cylinders under compression in normal operation



Key

D diameter of piston

d diameter of piston rod with cylinder in tension and speed control device acting on annulus

F_B buckling load

F load

p system pressure

p_{FC} normal pressure due to load

Z restricted flow

a $F_B = 2F + p \cdot \left(\dfrac{\pi D^2 - \pi d^2}{4} \right)$

b $p \cdot \dfrac{\left(\pi D^2 - \pi d^2 \right)}{4}$

c $2\left[p_{FC} + p \cdot \left(\dfrac{D^2 - d^2}{D^2} \right) \right]$

Figure 10 — Twin cylinders under compression, one line blocked

4.10.1.3 Failure conditions

4.10.1.3.1 Oil leaking past piston seals

The pressure normally generated can increase by the ratio D^2/d^2 where oil leaks past piston seals in double-acting cylinders under compressive loads. This particularly affects the stresses in the cylinder tube and the head, and these shall not exceed the yield stress ($R_{p0,2}$). This ratio is the minimum safety factor for valves, hoses and pipes which are at the same pressure as the cylinder, unless the pressure increase is limited by other hydraulic components.

4.10.1.3.2 Several cylinders operating the same mechanism

When more than one cylinder operates the same mechanism, illustrated in Figures 9 and 10, consideration shall be given to the effect of one cylinder being blocked and taking or causing greater loads. In the case of double-acting cylinders, this includes the force(s) generated by the other cylinder(s) or the force required to move the other cylinder.

Under failure conditions, the calculated maximum stress shall not exceed the yield stress of the material ($R_{p0,2}$).

4.10.2 Prevention of unintended movement of load-holding cylinders

Load-holding cylinders shall be fitted with a device to prevent unintended movement caused by failure of an external pipe [excluding those indicated in c)] until it is released by an external force.

The effects of thermal expansion in load-holding cylinders shall be accounted for.

Such devices shall be either

a) integral with the cylinder,

b) directly and rigidly flange-mounted, or

c) placed close to the cylinder and connected to it by means of rigid pipes (as short as possible), having welded or flanged connections and whose characteristics are calculated in the same way as the cylinder.

Other types of fittings, such as compression fittings or flared pipe fittings, are not permitted between the cylinder and the lock valve.

NOTE These requirements, when met, also meet those of 4.5.1.6.

4.10.3 Verification

Verification of the requirements of 4.10 shall be carried out by means of a design check, functional testing and by visual examination.

4.11 Safety devices

4.11.1 General

Safety devices shall, in the prescribed situations, positively interrupt the relevant movements in an unsafe direction, unless otherwise specified.

Safety devices are composed of the following types of components:

a) components that provide information, e.g. switches, valves;

b) components that transmit information, e.g. wiring, rods, levers, piping;

c) components that respond to information, e.g. contacts, relays, valves.

Verification shall be carried out by means of a design check and functional testing.

4.11.2 Location of safety devices

Safety devices shall be located or protected so as to prevent damage. They shall only be adjustable by tools and shall be easily accessible for inspection.

Verification shall be carried out by visual examination.

4.11.3 Electrical safety devices

4.11.3.1 Safety switch systems

Safety switch systems acting as information-providing components shall be designed to fail in a safe mode.

Normally closed switches, if used, shall conform to IEC 60947-5-1.

Sensors or switches may be used, provided

a) they are duplicated, or

b) single sensors or switches have continuous monitoring of the plausibility of their signals.

NOTE Category 1 well-tried components meet this requirement.

Verification shall be carried out by means of a design check and functional testing.

4.11.3.2 Damage to wiring

Wiring used as a signal-transmitting component shall be installed and protected so as to avoid damage by external influences.

Verification shall be carried out by means of a design check and by visual examination.

4.11.3.3 Operating life of components

Components reacting to information (e.g. contacts and relays) shall have a reliable operating life, equivalent to at least twice the number of load cycles for which the MEWP is designed (see 4.2.4.2.3).

Verification shall be carried out by means of a design check.

4.11.4 Hydraulic/pneumatic safety devices

Hydraulic/pneumatic parts of devices/systems which act directly on full-flow valves of the hydraulic/pneumatic systems need to be duplicated if a failure of one component can cause a failure of the system. Pilot-operated control valves in these devices/systems shall be so designed and installed that they fail to safety (i.e. stop the corresponding movement) in the event of power failure.

This requirement shall be fulfilled either by

a) a full-flow valve acting directly on the relevant part of a hydraulic/pneumatic circuit, or

b) a valve which is positively mechanically operated, controlling a pilot-operated valve in accordance with 4.7.6.

Verification shall be carried out by means of a design check and functional testing.

4.11.5 Mechanical safety devices

Components of mechanical safety devices such as rods, levers, wire ropes and chains shall be designed to take at least twice the load normally imposed on them in operation (see 4.5.2.1 and 4.5.3.1 for wire ropes and chains).

Verification shall be carried out by means of a design check and functional testing.

4.11.6 Overriding of safety devices

The overriding of safety devices shall be prohibited, whether during normal operation or rescue, except in accordance with the responsible entity's prescribed safe override procedures. The overriding of safety devices during the testing, repair or maintenance of a MEWP shall be carried out in accordance with the responsible entity's recommendations and procedures. Procedures and equipment for overriding safety devices shall be designed to minimize the possibility that an unsafe condition could exist and to provide safety to personnel.

Verification shall be carried out by means of a design check and functional testing.

5 Verification of the safety requirements and/or measures

5.1 Examinations and tests

5.1.1 General

The MEWP shall comply with the safety requirements and/or protective measures of this International Standard.

Examinations and tests to ensure that the MEWP complies with this International Standard (see 5.2 and 5.3) shall consist of

a) design checks (see 5.1.2),

b) manufacturing checks (see 5.1.3), and

c) tests (see 5.1.4).

The results of examinations and tests, and the name(s) and address(es) of the person(s) carrying them out, shall be recorded in a signed report.

Examinations and tests applicable in a number of circumstances are given in 5.1.4, 5.3, 6.2.2 and Annex F.

5.1.2 Design check

The design check shall verify that the MEWP is designed in accordance with this International Standard. It shall include verification of the following:

a) drawings containing the main dimensions of the MEWP;

b) description of the MEWP, with necessary information about its capabilities;

c) information about the materials used;

d) diagrams of the electrical, hydraulic and pneumatic circuits;

e) the instruction handbook;

f) calculations.

All necessary information shall be provided to enable the calculations to be checked.

5.1.3 Manufacturing check

The manufacturing check shall verify that

a) the MEWP is manufactured in accordance with the design check documents,

b) the components are in accordance with the drawings,

c) test certificates are available for each type of rope, chain and hydraulic or pneumatic hose, and that these certificates indicate the minimum breaking force or bursting pressure, as appropriate,

d) the quality of welds, particularly in load-bearing components, is ensured by use of the appropriate standard(s), and

e) the construction and installation of parts (especially safety devices) are in accordance with this International Standard.

5.1.4 Tests

5.1.4.1 General

Tests shall be made to verify that

a) the MEWP is stable,

b) the MEWP is structurally sound using appropriate testing,

c) all functions work correctly and safely, and

d) markings are fitted.

Special aids may be required to allow these tests to be carried out safely on MEWPs without duplicate controls according to 4.7.3.

5.1.4.2 Dynamic fall arrest anchorage test

MEWPs designed for use with a fall arrest system (see 4.6.4) shall successfully complete the following test.

a) The MEWP shall, while positioned on a level surface, withstand the force of a free-falling 136 kg test mass

   — the origin of which has been placed so that its centre of gravity is 0,46 m outside of the top rail of the work platform in a direction that creates the most adverse stability condition,

   — which is attached by a non-shock-absorbing lanyard to a lanyard anchorage point nearest the test mass origin, the lanyard having been passed over the top rail of the work platform such that the overturning force is applied to the rail, and

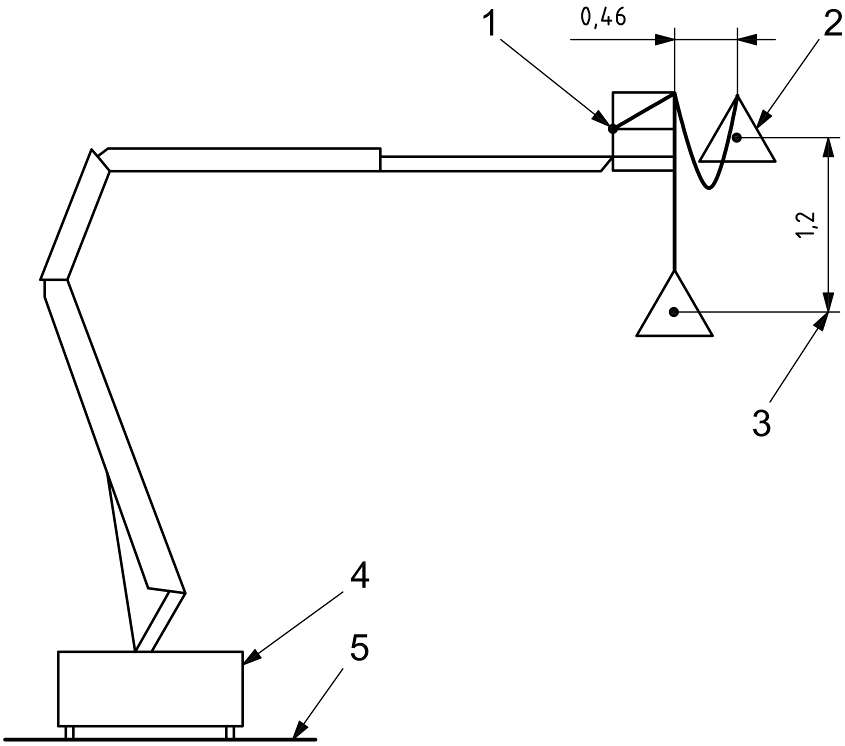
   — falling a minimum vertical distance of 1,2 m, without interference or obstruction and without hitting the floor/ground during the test.

b) The MEWP shall be loaded to the most adverse stability condition during the test. The test mass and the platform load shall equal the maximum platform rating. The test shall be conducted with no platform load if this is the condition of least stability. Any platform load shall be evenly distributed on the platform.

c) The MEWP shall not overturn as a result of this test. Permanent deformation of any part is acceptable, provided that the test mass is not released during the test.

See Figure 11.

Dimensions in metres



Key

1 anchorage (see 4.6.4)

2 136 kg test mass

3 free-fall distance

4 MEWP

5 level surface

The configuration of the boom, platform and chassis shall be the most adverse configuration.

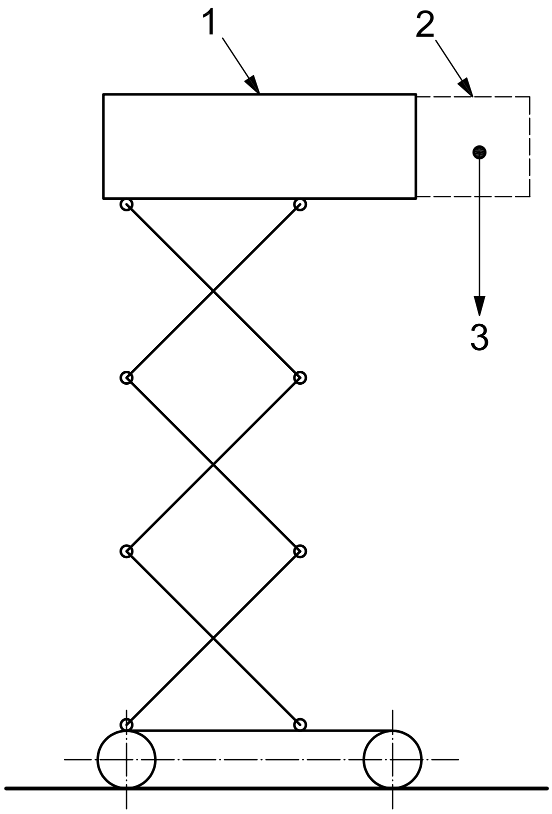
Figure 11 — Fall arrest anchorage test

5.1.4.3 Stability tests

5.1.4.3.1 Static tests

The MEWP shall be set up on the maximum allowable chassis inclination defined by the responsible entity plus 0,5°. Stabilizers, if provided, shall be used as specified by the responsible entity. If the MEWP is supported in the working position by pneumatic tyres and is not protected by a low-tyre-pressure operator warning system, the MEWP shall be set up with the inclination taking into account a deflated tyre. Test loads shall be applied to represent all the least favourable load and force combinations specified in 4.2.3.1, 4.2.3.2, 4.2.3.3 and 4.2.3.4.

For MEWPs in group A that have platform extension(s) with rated load(s) different from the main work platform rated load, and which do not have specific load control of the extension(s), the rated load (see 4.2.1.1) shall be in accordance with Figure 12.



Key

1 main work platform

2 extension platform (fully extended)

3 rated load, m

Rated load is expressed as (see also 4.2.1):

$$m = m_{\text{p,work}} + m_{\text{e,ext}}$$

where

$$m_{\text{p,work}} = n_{\text{p,work}} \times m_{\text{p}}$$

$n_{\text{p,work}}$ is the permitted number of persons on the main work platform;

m_{p} is equal to 80 kg (mass of a person);

$m_{\text{e,ext}}$ is the mass of tools and materials permitted on the extension platform.

Figure 12 — Static test

Persons and tools/material loads shall be distributed on the extension platform and, if necessary, on the main platform as specified in 4.2.2.2.2.

The test may be carried out on level ground if the test loads are re-calculated to include the effects of the maximum allowable chassis inclination defined by the responsible entity, plus 0,5°.

The test load(s) may be applied at any suitable strong point, if necessary, to avoid overstressing any part of the MEWP.

The test shall be repeated in all the least favourable extended and/or retracted positions. Examples are shown in Table 2 and Figure 3.

NOTE The MEWP is considered to be stable if it can attain a stationary condition without overturning while supporting the test load(s). During the stability test, the lifting of tyres or outriggers alone does not indicate a condition of instability.

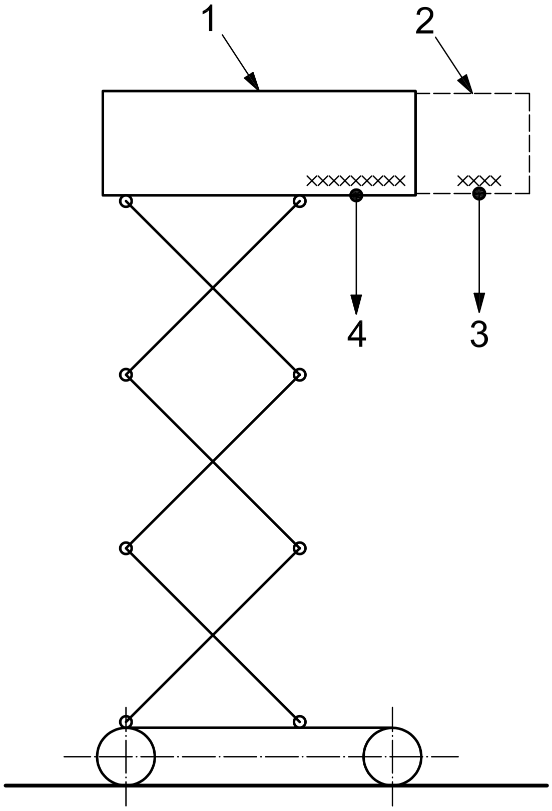
Additionally, it shall be demonstrated that following application of the manual forces in accordance with 4.2.2.4 in any position of the work platform, there is no permanent deformation of the work platform.

5.1.4.3.2 Dynamic tests on types 2 and 3 MEWPs

5.1.4.3.2.1 General

Types 2 and 3 MEWPs shall be subjected to kerb tests and braking tests with the rated load distributed evenly over the half of the work platform that will create the greatest overturning moment in the specific test case.

For types 2 and 3 MEWPs in group A that have platform extension(s) with rated loads different from the main work platform rated load and that do not have specific load control of the extension platform(s), the tests shall be carried out with the loads distributed in the same way and at the same time on both the main work platform and the extension platform. See Figure 13.



Key

1 main work platform

2 extension platform (fully extended)

3 rated load (extension platform), m_{ext}

4 rated load (main platform), m_{work}

Rated load m_{ext} is defined by (see also 4.2.1):

$$m_{ext} = \left(m_{p,ext} + m_{e,ext}\right) + m_p$$

Rated load m_{work} is defined by (see also 4.2.1):

$$m_{work} = \left(m_{p,work} - m_{p,ext} - m_p\right) + \left(m_{e,work} - m_{e,ext}\right)$$

where

$m_{p,work} = n_{p,work} \times m_p$

$m_{p,ext} = n_{p,ext} \times m_p$

$n_{p,work}$ is the permitted number of persons on the main work platform;

$n_{p,ext}$ is the permitted number of persons or rated number of occupants on the extension platform;

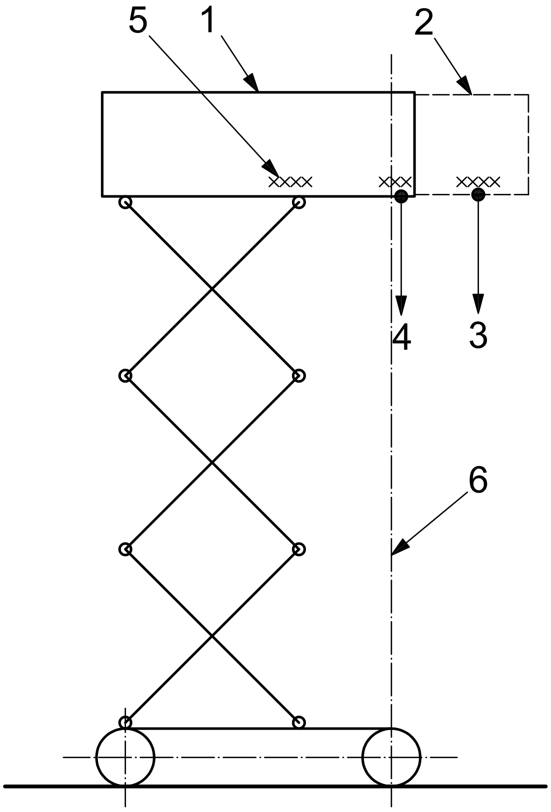
$m_{e,work}$ is the mass of tools and materials permitted on the main work platform;

$m_{e,ext}$ is the mass of tools and materials permitted on the extension platform;

m_p is equal to 80 kg (mass of a person).

Figure 13 — Dynamic tests on types 2 and 3 MEWPs

Tests shall also be carried out with only the extension load, distributed in the same way on the extension. In addition, the main platform loads that increase the overturning moments shall be taken into account in accordance with 4.2.3. An example of where these loads would need to be taken into account is given in Figure 14.



Key

1 main work platform
2 extension platform (fully extended)
3 rated load (extension platform), m_{ext}
4 rated load (main platform), m_{work}
5 removal of the stabilizing proportion of the main work platform load
6 tipping line

Rated load m_{ext} is defined by (see also 4.2.1):

$$m_{ext} = (m_{p,ext} + m_{e,ext}) + m_p$$

Rated load m_{work} is defined by (see also 4.2.1):

$$m_{work} = \left[(m_{p,work} - m_{p,ext} - m_p) + (m_{e,work} - m_{e,ext}) \right] f$$

where

$$m_{p,work} = n_{p,work} \times m_p$$

$$m_{p,ext} = n_{p,ext} \times m_p$$

$n_{p,work}$ is the permitted number of persons on the main work platform;

$n_{p,ext}$ is the permitted number of persons or rated number of occupants on the extension platform;

$m_{e,work}$ is the mass of tools and materials permitted on the main work platform;

$m_{e,ext}$ is the mass of tools and materials permitted on the extension platform;

m_p is equal to 80 kg (mass of a person);

f is the proportion of the main work platform load outside the tipping line.

NOTE f is calculated by distributing the persons and tools/materials on the work platform as specified in 4.2.2.1 and then representing the proportion of the load outside the tipping line by the factor f.

Figure 14 — Dynamic test on types 2 and 3 MEWPs with load locations

5.1.4.3.2.2 Kerb and depression tests

The tests shall be repeated, driving in both the forward and reverse directions, in each extended position of the MEWP and, if different travel speeds are allowed for different heights, at each of those heights, at the maximum permitted speed for each height. In all cases, the steering wheels shall be parallel to the length of the machine.

During the tests, it is not necessary to simulate the effect of the permissible wind speed.

The MEWP shall not overturn during the tests.

a) For tests performed on types 2 and 3 MEWPs, excluding rail-mounted MEWPs, where the MEWP is run into a kerb, the MEWP shall be driven on level ground so that

   1) each leading wheel/track in turn is driven into contact with a kerb of height 0,1 m at an angle of 30° from perpendicular to the kerb, and

   2) both leading wheels/tracks simultaneously are brought into contact with the same kerb.

   The drive control shall be maintained at maximum until the MEWP comes to a stop or both leading wheels/tracks climb the kerb.

b) For depression tests performed on types 2 and 3 MEWPs intended for off-slab use, excluding rail-mounted MEWPs, the MEWP shall be driven on level ground so that

   1) each leading wheel/track in turn is driven off the edge of a depression of 0,1 m, with the test machine approaching the depression at an angle of 30° from perpendicular to the depression and being driven until the leading wheel is in the depression, and

   2) both leading wheels/tracks are driven simultaneously into the same depression.

   The drive control shall be maintained at maximum until both leading wheels or tracks are driven into or over the depression.

c) For depression tests performed on types 2 and 3 MEWPs intended for paved/slab use only, excluding rail-mounted MEWPs, the MEWP shall be driven on level ground so that each leading wheel/track in turn is driven off the edge of a depression 600 mm square with a vertical drop of 100 mm, and with one front wheel/track aligned across (perpendicular to) the edge of the depression. The leading wheel/track shall enter at all points along the depression's edge, with only one leading wheel/track driven into the depression for each approach.

   Maximum speed shall be maintained until both leading wheels/tracks enter into, or are driven over, the depression.

5.1.4.3.2.3 Braking tests

Types 2 and 3 MEWPs shall be tested by being stopped as rapidly as their controls allow. This shall be done in both the forward and reverse directions, in each MEWP position, in each combination of chassis inclination, loads and forces that will together create conditions of minimum stability, and where different travel speeds are allowed for different heights, at each of those heights, at the maximum permitted speed for each height.

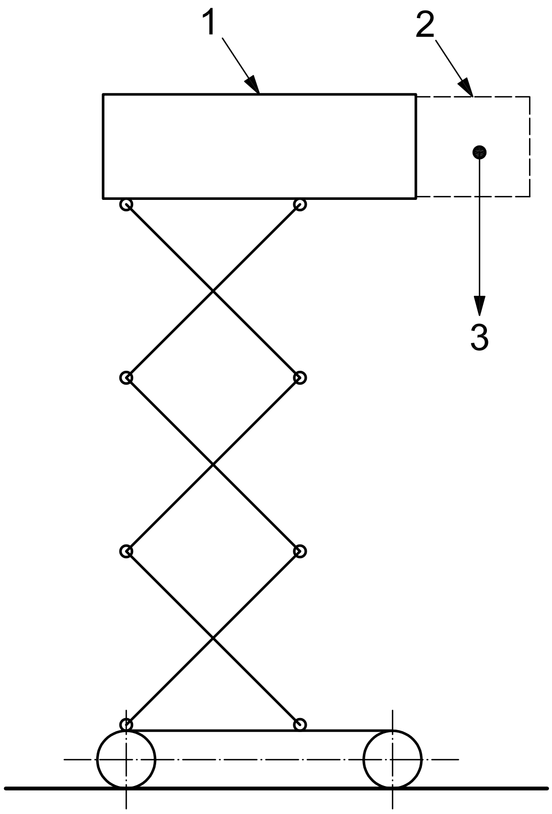
During the tests, it is not necessary to simulate the effect of the permissible wind speed.

The MEWP shall not overturn during the tests and the stopping distance shall comply with 4.3.17.

5.1.4.4 Overload test

The test load shall be 125 % of the rated load for power-operated MEWPs, and 150 % of the rated load for manually operated MEWPs.

For MEWPs in group A that have platform extension(s) with rated loads different from the main work platform rated load, and that do not have specific load control of the extension(s), the test load shall be as defined in Figure 15.



Key

1 main work platform

2 extension platform (fully extended)

3 rated load, m

Rated load, m, is defined by (see also 4.2.1):

$$m = \left(m_{\mathrm{p,ext}} + m_{\mathrm{e,ext}}\right) \times 1{,}25 + \left(m_{\mathrm{p,work}} - m_{\mathrm{p,ext}}\right)$$

where

$$m_{\mathrm{p,work}} = n_{\mathrm{p,work}} \times m_{\mathrm{p}}$$

$$m_{\mathrm{p,ext}} = n_{\mathrm{p,ext}} \times m_{\mathrm{p}}$$

$n_{\mathrm{p,work}}$ is the permitted number of persons on the main work platform;

$n_{\mathrm{p,ext}}$ is the permitted number of persons or rated number of occupants on the extension platform;

$m_{\mathrm{e,ext}}$ is the mass of tools and materials permitted on the extension platform;

m_{p} is equal to 80 kg (mass of a person).

Figure 15 — Overload test

The person and tools/material loads shall be distributed on the extension and, if necessary, on the main work platform, as specified in 4.2.2.2.2.

All movements with the test loads shall be carried out at accelerations and decelerations appropriate to safe control of the load. If several movements with the test load have to be carried out (i.e. lifting, lowering, slewing, travelling), the intended movements shall be carried out separately, when vibrations associated with preceding movements have subsided, and with care, taking into due account the least favourable positions.

If, due to the various combinations of loads or outreaches of a MEWP, tests with different test loads are necessary, all movements shall be carried out with all test loads, except where the least-favourable conditions can be sufficiently simulated by one performance test.

During the overload test, the MEWP shall be on level ground and the extending structure put into each position which creates maximum stress in any load-bearing part of the MEWP.

During this test, it is not necessary to simulate the effect of the permissible wind speed.

The braking systems shall be capable of stopping and sustaining the test load(s).

After removing the test load(s), the MEWP shall show no permanent deformation.

5.1.4.5 Vehicle-mounted overload and stability check tests

5.1.4.5.1 On level ground

Every vehicle-mounted MEWP shall sustain a static load 150 % of the platform rated load plus 150 % of lifting attachment capacity (when so equipped). The load shall be placed in the position of maximum overturning moment with the MEWP on a firm and level surface. The test shall be conducted without readily removable tools and material on the MEWP.

The platform load shall be applied at the centre of the work platform simultaneously with the lifting attachment load in the position of maximum overturning moment.

Simultaneous application of platform capacity and lifting attachment capacity shall be done only on vehicle-mounted MEWPs that are designed to be used in service with both types of load applied simultaneously.

If utilizing the stabilizing components is part of the configuration definition, these shall be so utilized according to the responsible entity's instructions, for purposes of determining whether the vehicle-mounted MEWP meets the stability requirements.

During this test, it is not necessary to simulate the effect of permissible wind speed.

The test shall not produce instability of the vehicle-mounted MEWP.

NOTE During the stability test, the lifting of one or more tyres or outriggers on the opposite side of the load does not necessarily indicate a condition of instability. The vehicle-mounted MEWP is considered to be stable if it can come to a stationary condition without turning over while supporting the test load(s).

5.1.4.5.2 On slopes

Every vehicle-mounted MEWP shall sustain a static load 133 % of the platform rated load plus 133 % of lifting attachment capacity (when so equipped). The load shall be placed in the position of maximum overturning moment with the MEWP on a slope of 5° in the direction of least stability. The test shall be conducted without readily removable tools and material on the MEWP.

The platform load shall be applied at the centre of the platform simultaneously with the lifting attachment load in the position of maximum overturning moment.

If there is a condition of greater instability without loads, the test shall be conducted under this condition (i.e. backward stability).

If having stabilizing components utilized is part of the definition of the configuration, they shall be utilized according to the responsible entity's instructions for the purposes of determining whether the vehicle-mounted MEWP meets the stability requirements.

Simultaneous application of platform capacity and lifting attachment capacity shall be done only on vehicle-mounted MEWPs that are designed to be used in service with both types of load applied simultaneously.

During this test it is not necessary to simulate the effect of permissible wind speed.

This test shall not produce instability of the vehicle-mounted MEWP.

NOTE The lifting of one or more tyres or outriggers on the opposite side of the load does not necessarily indicate a condition of instability. The vehicle-mounted MEWP is considered to be stable if it can come to a stationary condition without turning over while supporting the test load(s).

5.1.4.6 Functional tests

Functional tests shall demonstrate that

a) the MEWP can operate smoothly for all motions while carrying 110 % of the rated load at the rated speeds,

b) all safety devices work correctly, and

c) maximum permitted speeds are not exceeded.

5.2 Type tests

The first MEWP made to a new design or incorporating significant changes to an existing design shall be subjected to the following:

a) a design check — required for each vehicle-mounted MEWP (see 5.1.2);

b) a manufacturing check — required for each vehicle-mounted MEWP (see 5.1.3);

c) the appropriate testing (see 5.1.4).

5.3 Pre-market release tests

5.3.1 MEWPs not vehicle-mounted

MEWPs built in accordance with a type-tested model shall be subjected to the following tests before being placed on the market:

a) brake testing, where applicable (see 5.1.4.3.2.3);

b) overload testing (see 5.1.4.4);

c) functional testing (see 5.1.4.6).

5.3.2 Vehicle-mounted MEWPs

MEWPs built in accordance with a type-tested model shall be subjected to the following tests before being placed on the market:

a) brake testing, where applicable (see 5.1.4.3.2.3);

b) overload testing (see 5.1.4.4)

c) overload and stability checking (see 5.1.4.5)

d) functional testing (see 5.1.4.6).

6 Information for use

6.1 General

The responsible entity shall provide an instruction handbook in at least one of the languages of each country in which the MEWP is intended for market, sale or lease by the responsible entity.

6.2 Instruction handbook

6.2.1 Content

The instruction handbook shall include, but not be limited to, the following information:

a) operating instructions which give details for safe use;

b) transport handling and storage information;

c) commissioning information;

d) the responsible entity's recommended periodical examinations or tests;

e) maintenance information for use by trained personnel — instructions for maintenance operations to be carried out only by specialist maintenance personnel shall be separate from the other instructions;

f) parts that are detachable for functional reasons (see 6.3.8);

g) ambient temperature for which the MEWP has been designed.

Examples of elements of this type of information are given in Annex F.

6.2.2 Modification or repair

The instruction handbook shall state that modifications or additions to a MEWP are to be made only with the prior written permission of the responsible entity.

The instruction handbook shall include details for the performance of major alterations or major repairs to a MEWP. For the purposes of this International Standard, a “major alteration” or “major repair” is a modification of the whole or part of the MEWP which affects stability, strength or performance. As a minimum, the user shall be instructed to perform the design check (see 5.1.2), manufacturing check (see 5.1.3) and practical tests (5.1.4) to an extent corresponding to the type of major alteration or major repair.

6.2.3 Record-keeping

There shall be provisions in the instruction handbook to

— record the results of examinations and tests,

— record major alterations and repairs,

— keep certificates.

6.3 Marking

6.3.1 Responsible entity's plate

Symbols used for marking shall comply with ISO 20381.

One or more durable responsible entity's plates giving the following information indelibly shall be permanently attached to the MEWP in an easily visible place:

a) responsible entity's or supplier's name;

b) country of manufacture;

c) model designation;

d) serial or fabrication number;

e) year of manufacture;

f) unloaded mass, in kilograms;

g) rated load, in kilograms;

h) rated load, given as the allowable number of persons and mass of equipment, in kilograms;

i) for work platforms that have different specified rated loads, each rated load shall be given as the allowable number of persons and mass of equipment, in kilograms;

j) maximum allowable manual force, in newtons;

k) maximum allowable wind speed, in metres per second;

l) maximum allowable chassis inclination;

m) hydraulic supply information, if an external hydraulic power supply is used;

n) pneumatic supply information, if an external pneumatic power supply is used;

o) electrical supply information, if an external electric power supply is used;

p) name of the installer of the vehicle-mounted MEWP (if applicable);

q) the rated load capacity, including platform capacity and lifting attachment capacity (if applicable);

r) maximum work platform height.

The capacity rating in either case shall be designated with boom or booms and load-carrying attachments extended to the position of maximum overturning moment attainable throughout full rotation. Capacities of the

MEWP in other positions shall be specified separately. The responsible entity shall state all applicable ratings in the manual and on placards affixed to the MEWP.

If these capacity ratings are based on some fixed conditions of the load-carrying attachments, this shall be indicated.

Parts of this information may be repeated at other appropriate places on the MEWP (see 6.3.2 and 6.3.7).

6.3.2 Work platform

Symbols used for marking shall comply with ISO 20381.

The following information shall be permanently and clearly marked at or on each work platform in an easily visible place:

a) the rated load, in kilograms;

b) the rated load, given as the allowable number of persons and mass of equipment, in kilograms;

c) the maximum allowable manual force, in newtons;

d) maximum allowable wind speed, in metres per second;

e) allowable special loads and forces, if applicable (see 4.2.3.4);

f) the indication “non-insulated”; however, if equipped with a work platform constructed of non-conductive (insulating) materials, see ISO 16653-2;

g) information related to the use and load rating of the equipment for material handling;

h) information related to the use and load rating of the MEWP for multiple configurations;

i) the location of the lanyard anchorage point and the allowable number of occupants connected;

j) the type of anchorage (i.e. fall restraint or fall arrest);

k) where applicable, the responsible entity's fall protection equipment requirements;

l) the minimum approach distance requirements for energized electrical lines or apparatus, in accordance with ISO 18893 or by a governing authority if more stringent.

6.3.3 Multiple rated loads

If more that one rated load is designated, the loads shall be tabulated in relation to the configuration of the MEWP. MEWPs with a work platform which can be extended, enlarged or moved relative to the extending structure shall be marked with the rated load that can be carried in all positions and configurations of the work platform.

6.3.4 Emergency systems

The location and instructions for operating the emergency system(s) shall be marked on the MEWP near the relevant controls.

6.3.5 Work platform rated loads

MEWPs with main and secondary work platforms shall be marked with the total rated load as well as the rated loads of each work platform.

6.3.6 Indoor use

MEWPs designed for indoor use only — wind loads need not to be taken into consideration — shall be permanently and clearly marked to that effect in an easily visible place.

6.3.7 External power supply connections

Points for connection of external power supplies shall be permanently and clearly marked with the essential power supply information (see 6.3.1).

6.3.8 Detachable parts

Parts which may be detached for functional reasons (e.g. work platforms, stabilizers) shall be permanently and clearly marked in an easily visible place with

a) the responsible entity's or supplier's name and address,

b) the model designation of the MEWP,

c) the part number.

6.3.9 Abridged instructions

An abridged version of the instructions for using the MEWP shall be permanently and clearly affixed in a suitable position. This abridged version shall, as a minimum, refer the operator to the full instructions for use.

6.3.10 Projecting extremities

All projecting, movable extremities of MEWPs shall be marked with hazard colours in accordance with ISO 3864.

6.3.11 Wheel/stabilizer load

Each stabilizer/wheel shall be permanently and clearly marked in an easily visible place with the maximum load it could be required to support on the ground during operation of the MEWP.

6.3.12 Tyre pressure

The pressure for pneumatic tyres shall be indicated on the MEWP.

6.3.13 Clearances

Where safe clearances or adequate guarding are not possible, warning notices shall be fitted (see 4.4.3).

6.3.14 Maintenance

A notice shall be fitted to a MEWP warning persons not to enter the space beneath a raised work platform and an extending structure during maintenance unless a means of structure support is in place.

6.3.15 Stabilizer use

MEWPs requiring the use of stabilizers shall be provided with a warning notice at the operator's position to alert the operator of the need to position the stabilizers.

6.3.16 Pressurized vessel

Hydraulic systems with a gas-loaded accumulator shall have an appropriate warning label on the gas-loaded accumulator. Duplicate information shall be provided in the instruction handbook (see Annex F) on the circuit diagram.

Annex A
(informative)

Use of MEWPs in wind speeds greater than 12,5 m/s — Beaufort Scale 6

Beaufort Scale 6 was adopted for this International Standard after examination of a number of previously existing standards and the experience of users of MEWPs. A significant reaction from users was that Beaufort Scale 6 represented a natural limit at which operators became aware of the effects of wind speed and were reluctant to use the machines.

The occasional, or locally regular, occurrence of higher wind speeds was recognized, but it was considered unreasonable to expect all MEWPs to be designed for exceptional circumstances which were readily recognizable by operators. This took into account the fact that wind forces increase by the square of the wind speed.

It was agreed that higher wind speeds are in the category of *special loads and forces* (see 4.2.3.4) and could be dealt with

a) by the responsible entity's specification that higher wind speeds are acceptable [see 6.3.1 k)], or

b) by measures such as a reduction in the number of persons allowed on the work platform under such conditions.

Most responsible entities use procedure b), giving appropriate details in their operating instruction manuals.

Annex B
(informative)

Dynamic factors in stability and structural calculations

B.1 Stability calculations

Different methods of determining stability used in existing standards were considered during the development of this International Standard, including the following.

— Application of a factor to the rated load: it was eventually agreed that this was inadequate, particularly for large machines with large structural masses.

— Application of various factors to rated load, structural masses, etc., applied vertically: these factors varied from one standard to another and in no case were they substantiated by experiments or calculations.

— Residual load (i.e. the percentage of the total weight of the MEWP to remain on the ground on the unloaded side) when carrying the rated load on the work platform: this was shown to be impractical for machines with variable stabilizer widths and with several tipping lines at different distances from the slewing centre.

It was concluded that the method to be used must take into account not only structural masses, rated load, wind forces, manual forces, etc., but also their dynamic effects, where applicable, expressed as a percentage acting in the direction of movement. It was also agreed that the calculation method must be checked by a static stability type test representing the calculated overturning moment, something which is not required by other standards.

However, this still left open the percentage figure to be used for the dynamic effects, and it was agreed that this must be determined experimentally. The method chosen was to strain-gauge the stabilizers, during operation of the extending structure with the rated load in the work platform, on the basis that the load on the stabilizers determines the stability.

Taking the static stresses as unity, the stress fluctuations, when reversing the controls to obtain the most violent oscillations possible, varied between the minimum of 0,9 and the maximum of 1,2, over a curve similar to a sine wave. It was considered that the dynamic forces producing this result could be represented by a static test calculated using the mean value. The mean value 1,05 was rounded up to 1,10 to give a substantial margin of safety, and various calculations to compare the resulting test loads with their existing test methods were conducted.

Compared with existing test methods (which varied considerably), the new method showed slightly lower test loads for some smaller machines (under 10 m), similar figures for medium-sized machines (up to 20 m), and substantially higher figures for the largest machines (up to 70 m), due to their higher centres of gravity.

The oscillations produced during the tests were much more severe than those produced by even accidental misuse at normal maximum operating speeds, indicating that the results were related more to the energy-absorbing flexibility and natural frequency of the structure than to operating speeds.

B.2 Structural calculations

Clearly, under the same type of misuse, the stress fluctuations at the upper end of the extending structure would be much greater. Experience under known service conditions is the most valuable and reliable basis for design (see reference [30]), but responsible entities are advised to make similar strain-gauge tests to check that the peak stresses are within the maximum permissible stress limits for the particular design details. Being of a very intermittent nature, they would not normally need to be taken into account in fatigue calculations.

Annex C
(normative)

Calculation of wire-rope drive systems

C.1 General

A wire-rope drive system comprises the wire ropes running on rope drums and on or over rope pulleys as well as any associated rope drums, rope pulleys and compensating pulleys.

Compensating pulleys are rope pulleys over which the wire rope normally runs during operation over a segment not exceeding three times the diameter of the wire rope.

The categories of running time are given in Table C.1.

This annex does not address wire ropes which do not run on rope drums and/or over rope pulleys (carrying ropes and tensioning ropes) or sling ropes.

C.2 Calculation of wire-rope drive systems

When calculating the wire-rope drive systems, the following factors which influence the service life of a wire rope shall be taken into consideration:

a) mode of operation (drive group);

b) wire-rope diameter (coefficient c);

c) diameters of rope drums, rope pulleys and compensating pulleys [coefficient $(h_1 \cdot h_2)$];

d) rope grooves.

The mechanical components shall be graded according to their mode of operation into a “drive group” in accordance with Table C.1, in order to achieve an adequately long service life. The grading is made according to running-time categories, which take the average running time of the wire-rope drive system into account. As regards the grading into running-time categories, the mean running time per day, related to one year, is the determining factor.

Table C.1 — Drive groups according to running-time categories

Running-time category	Symbol			V_{006}	V_{012}	V_{025}	V_{05}	V_1	V_2	V_3	V_4	V_5
	Mean running time per day in hours related to one year			up to 0,125	> 0,125 up to 0,25	> 0,25 up to 0,5	> 0,5 up to 1	> 1 up to 2	> 2 up to 4	> 4 up to 8	> 8 up to 16	> 16
Load category	**No.**	**Duty term**	**Explanation**	**Drive group**								
	1	Light	Maximum load occurs only infrequently	1 E_m	1 E_m	1 D_m	1 C_m	1 B_m	1 A_m	2_m	3_m	4_m
	2	Medium	Low, average and maximum loads occur with roughly equal frequency	1 E_m	1 D_m	1 C_m	1 B_m	1 A_m	2_m	3_m	4_m	5_m
	3	Heavy	Maximum loads occur almost continuously	1 D_m	1 C_m	1 B_m	1 A_m	2_m	3_m	4_m	5_m	5_m
NOTE If the duration of a load cycle is 12 min or longer, the rope drive may be graded one drive group lower than the drive group grading determined from the running-time category and from the load category.												

C.3 Calculation of minimum rope diameters

The minimum rope diameter, d_{min}, in millimetres, is determined in accordance with the formula below, from the calculated traction force on the rope, S, in newtons:

$$d_{\text{min}} = c \cdot \sqrt{S} \qquad \text{(C.1)}$$

The values of the coefficient c [in millimetres divided by the square root of newtons (mm/$\sqrt{N}$)] are given in Table C.2 for the various drive groups. These values also apply to bright and to galvanized wire ropes.

The calculated rope traction force, S, is determined from the static traction force in the wire rope, taking into consideration the acceleration forces and the efficiency of the wire-rope drive system (see C.5).

Items which need not be taken into consideration include acceleration forces up to 10 % of the static traction forces.

Table C.2 — Coefficients c for wire ropes which are not non-twisting

Drive group	Coefficient c mm/$\sqrt{N}$			
	Nominal strength of individual wires N/mm^2			
	1 570	1 770	1 960	2 160
1 E_m	—	0,067 0	0,063 0	0,060 0
1 D_m	—	0,071 0	0,067 0	0,063 0
1 C_m	—	0,075 0	0,071 0	0,067 0
1 B_m	0,085 0	0,080 0	0,075 0	—
1 A_m	0,090 0	0,085 0		—
2_m	0,095			—
3_m	0,106			—
4_m	0,118			—
5_m	0,132			—

C.4 Calculation of diameters of rope drums, rope pulleys and compensating pulleys

The diameter, D, of rope drums, rope pulleys and compensating pulleys, related to the centre of the wire rope, is calculated from the minimum rope diameter, d_{min}, determined according to C.3, using the following equation:

$$D_{min} = h_1 \cdot h_2 \cdot d_{min} \tag{C.2}$$

In the above formula, h_1 and h_2 are dimensionless coefficients. Factor h_1 is dependent on the drive group and on the rope design, and is listed in Table C.3. Factor h_2 is dependent on the arrangement of the wire-rope drive system and is listed in Table C.4.

Thicker wires ropes (up to 1,25 times the calculated rope diameter) may be laid on rope drums, rope pulleys and compensating pulleys having the diameters calculated in accordance with Tables C.3 and C.4 for the same rope traction force, and without any impairment of the service life, provided that the groove radius is at least 0,525 times the diameter of the wire rope. Larger rope drum, rope pulley and compensating pulley diameters will increase the service life of the wire rope.

Table C.3 — Coefficients, h_1

Drive group	Rope drum and wire ropes that are *not* non-twisting	Rope pulley and wire ropes that are *not* non-twisting	Non-twisting compensating pulley and wire ropes
1 E_m	10	11,2	10
1 D_m	11,2	12,5	10
1 C_m	12,5	14	12,5
1 B_m	14	16	12,5
1 A_m	16	18	14
1_m	18	20	14
3_m	20	22,4	16
4_m	22,4	25	16
5_m	25	28	18

For the determination of h_2, wire-rope drive systems are classified according to the number, ω, of alternating bending stresses which the most unfavourable stressed portion of the rope has to run through during one load cycle (lifting and lowering of the load). The value of ω is entered as the sum of the following individual values for the elements of the wire-rope drive system:

rope drum $\omega = 1$

rope pulley for deflection in the same direction, $\alpha > 5°$ $\omega = 2$

rope pulley for deflection in the opposite direction, $\alpha > 5°$ $\omega = 4$

rope pulley, $\alpha \leqslant 5°$ (see Figure C.1) $\omega = 0$

compensating pulley $\omega = 0$

end attachment of rope $\omega = 0$

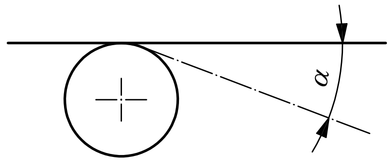
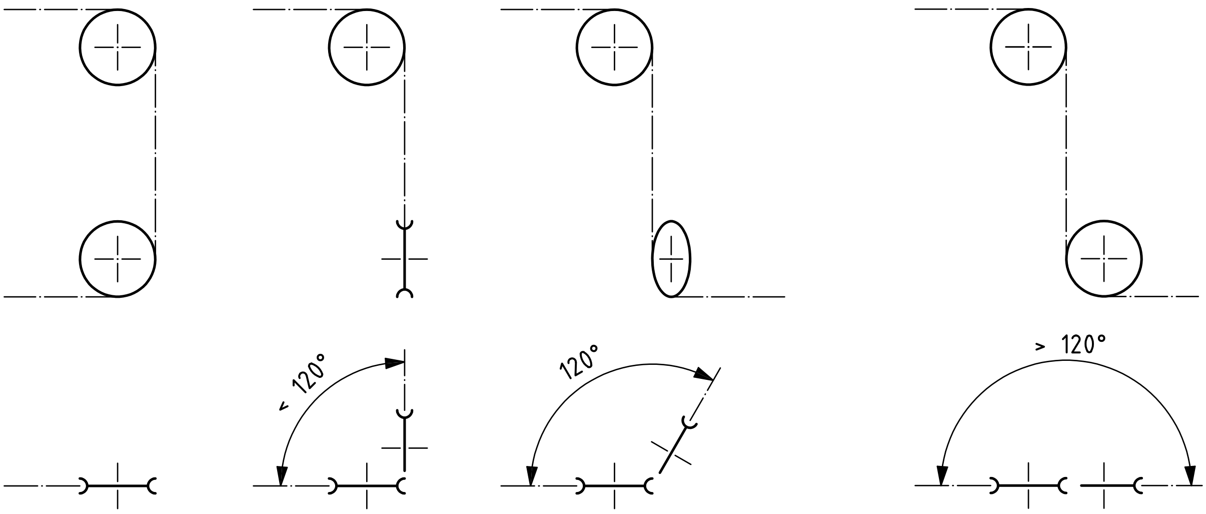


Figure C.1 — Angle of deflection

Deflection in the opposite direction shall be taken into consideration if the angle between the planes of two adjacent rope pulleys (traversed by the rope in succession) is greater than 120° (see Figure C.2).



a) Same direction **b) Opposite direction**

Figure C.2 — Deflection in same/opposite direction

Table C.4 — Coefficients, h_2

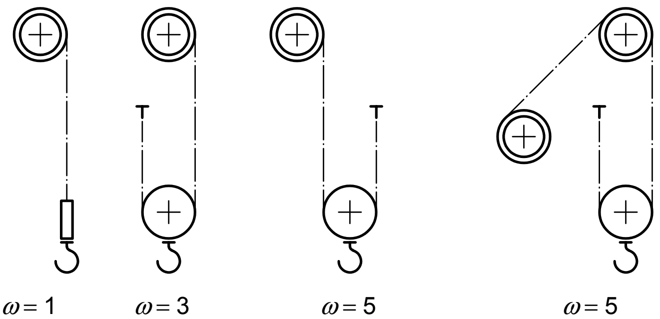
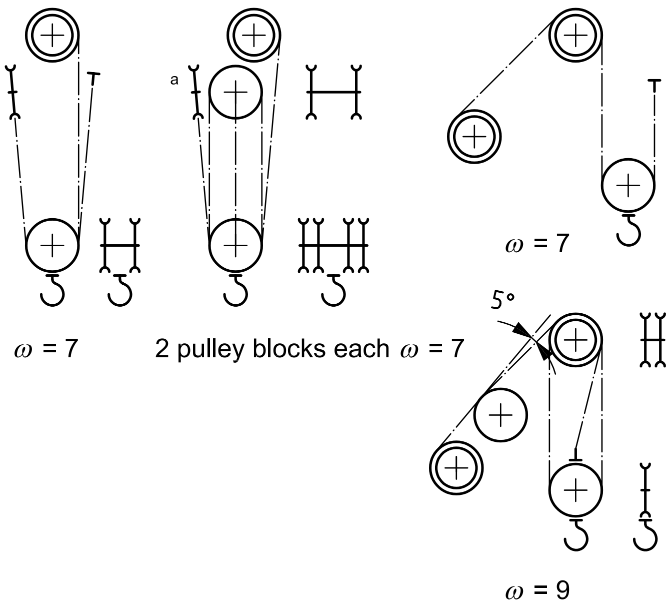
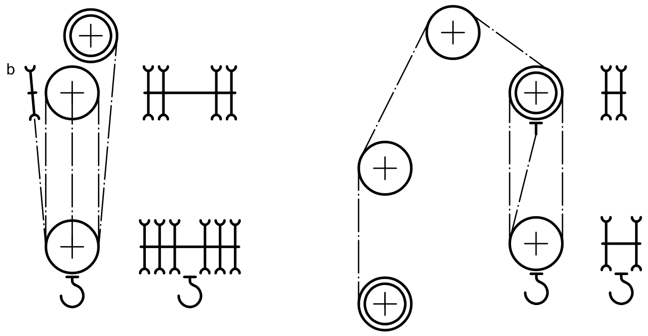
Description	Examples for arrangements of rope drives Examples of application (drums illustrated in double lines)	ω	h_2[a] for rope drums, compen-sating pulleys	h_2[a] for rope pulleys
Wire rope runs on rope drum and over no more than — 2 rope pulleys with deflection in the same direction, or — 1 rope pulley with deflection in opposite direction		⩽ 5	1	1
Wire rope runs on rope drum and over no more than — 4 rope pulleys with deflection in the same direction, or — 2 rope pulleys with deflection in the same direction and 1 rope pulley with deflection in the opposite direction, or — 2 rope pulleys with deflection in the opposite direction		6 to 9	1	1,12

Table C.4 (*continued*)

Description	Examples for arrangements of rope drives Examples of application (drums illustrated in double lines)	ω	h_2[a] for rope drums, compen-sating pulleys	 rope pulleys
Wire rope runs on rope drum and over at least — 5 rope pulleys with deflection in the same direction, or — 3 rope pulleys with deflection in the same direction plus 1 rope pulley with deflection in the opposite direction, or — 1 rope pulley with deflection in the same direction plus 2 rope pulleys with deflection in the opposite direction, or — 3 rope pulleys with deflection in the opposite direction	2 pulley blocks each $\omega = 11$ $\omega = 13$	$\geqslant 10$	1	1,25

[a] The correlation of ω and h_2 with respect to the description and the examples of application is only valid if one segment of rope runs through the entire arrangement of the rope drive during one working stroke. For the determination of h_2, only the values of ω which occur at the most unfavourable segment of the rope need be considered.

[b] Compensating pulley.

C.5 Efficiency of wire-rope drive systems

The efficiency of a rope drive, η_S, for calculation of the rope traction force using C.3, is determined as follows:

$$\eta_S = (\eta_R)^i \cdot \eta_F = (\eta_R)^i \cdot \frac{1}{n} \cdot \frac{1-(\eta_R)^n}{1-\eta_R} \quad \text{(C.3)}$$

where

η_S is the efficiency of the wire-rope drive system;

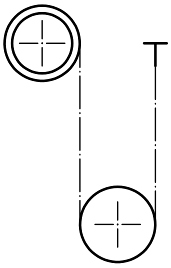
η_R is the efficiency of one rope pulley;

i is the number of fixed rope pulleys between the rope drum and the pulley block or load;

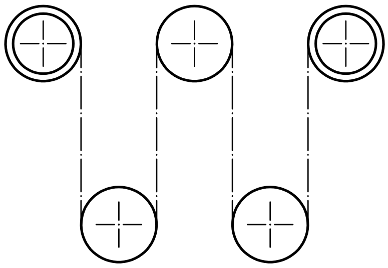
η_F is the efficiency of the pulley block:

$$\eta_F = \frac{1}{n} \cdot \frac{1-(\eta_R)^n}{1-\eta_R} \quad \text{(C.4)}$$

n is the number of rope plies in one pulley block [one pulley block consists of the sum total of all the rope plies and rope pulleys for one rope winding onto a rope drum (see Figure C.3)].



a) **Pulley block, two-ply** $n = 2$



b) **Twin pulley block, four-ply, consisting of two, two-ply, pulley blocks** $2 \times (n = 2)$

Figure C.3 — Pulley blocks

The efficiency of a rope pulley is dependent on the ratio of the rope pulley diameter to the rope diameter (D/d), on the rope design and on the rope lubrication, in addition to being dependent on the type of bearing arrangement of the pulley (plain bearings or anti-friction bearings). In so far as more accurate values have been proved by means of trials, the following shall be assumed for calculations:

— for plain bearings $\eta_R = 0,96$;

— for anti-friction bearings $\eta_R = 0,98$.

The efficiencies given in Table C.5 are calculated on the basis of the above values.

No efficiency need be taken into consideration in the case of compensating pulleys.

Table C.5 — Efficiency of pulley blocks

n	2	3	4	5	6	7	8	9	10	11	12	13	14
η_F **Plain bearings**	0,98	0,96	0,94	0,92	0,91	0,89	0,87	0,85	0,84	0,82	0,81	0,79	0,78
η_F **Anti-friction bearings**	0,99	0,98	0,97	0,96	0,95	0,94	0,93	0,92	0,91	0,91	0,90	0,89	0,88

Annex D
(informative)

Calculation example — Wire-rope drive systems

D.1 Method

D.1.1 General

The method given in Annex C is used to determine the coefficients and ratios used for 4.5.2 (wire-rope drive systems) using the load cycle figures in 4.2.4.2.3 and operating speeds in 4.4.5.

This method was preferred to the use of the group classification of mechanisms method given in ISO 4301-4, which posed problems of relating the state of loading and load spectrum factors to MEWPs, but gives results in line with International Standards concerning mobile cranes (see ISO 4308-2 and ISO 8087).

NOTE 1 According to 4.2.4.2.3, *light intermittent duty* is interpreted as large machines with large rated loads, often operating with less than the full rated load and used intermittently, while *heavy duty* is interpreted as smaller machines with low rated loads, regularly carrying the full rated load, and used regularly. Heavy duty only applies to levelling systems on machines with low rated loads (e.g. one person), carried during the whole of every load cycle, and does not apply to MEWPs, although it would still give the same drive group used in the example. *Medium duty* (see Table C.1) is considered the most severe working case for extending structures, as the load varies during the load cycle.

NOTE 2 The worst possible case has been taken (e.g. a single rigid boom moving through an arc to reach maximum height). In practice, as this movement is achieved by the use of more than one boom, the mean running time is divided by the number of booms and is further reduced by the higher operating speeds of telescopic movements.

NOTE 3 For the purpose of this analysis, a load cycle starts when the work platform is loaded in a position, and finishes when it is unloaded in the same position after being extended to a working position.

D.1.2 Summary of Annex C method

D.1.2.1 Use the number of load cycles and operating speeds from 4.4.5 to derive the mean running time per day in hours, related to one year, in Table C.1, to determine the drive group [see C.2 b)].

D.1.2.2 Calculate the minimum theoretical rope diameter, d_{min}, using, in Equation (C.1), coefficient c for this drive group from Table C.2:

$$d_{\text{min}} = c \cdot \sqrt{S}$$

where S is the calculated traction force in the rope.

This completes the process given in Annex C for calculating the wire rope diameter. However, the coefficient of utilization may be calculated by dividing the breaking force values from ISO 2408:2004, Table 5, corrected if necessary for different wire strengths, by the calculated traction force in the rope.

D.1.2.3 Calculate the diameters of drums and pulleys from Equation (C.2):

$$D_{\text{min}} = h_1 \cdot h_2 \cdot d_{\text{min}}$$

The coefficient h_1 for the drive group is taken from Table C.3. The coefficient h_2 is determined by the total number of alternating stresses in the most unfavourable stressed portion of the rope using Table C.4.

D.1.3 Calculation example

D.1.3.1 General

The following example illustrates the calculation process, but the load values have been chosen to give an exact 9 mm diameter for the wire rope, so the coefficients in Table C.2 are minimal.

D.1.3.2 Mode of operation (drive group) (see C.2 and Table C.1)

D.1.3.2.1 Case 1, light intermittent duty

$$\text{40 000 load cycles over 10 years} = \frac{40\,000}{365 \times 10} = 10{,}96 \text{ load cycles per day} \quad \text{(D.1)}$$

Worst case is considered to be a 25 m boom (radius r) moving through 180° (360° total) at 0,4 m/s (v) (see Figure D.1).

The running time for one load cycle, in seconds, is

$$\frac{\pi \times 2r}{v} = \frac{\pi \times 2 \times 25}{0{,}4} = 393 \quad \text{(D.2)}$$

Mean running time per day, in hours, relating to 1 year, results from Equations (D.1) and (D.2):

$\Rightarrow$ 10,96 × 393 s/day = 1,12 h/day $\Rightarrow$ category V_1 (see Table C.1)

Table C.1 gives $1A_m$ drive group for category V_1, medium duty.

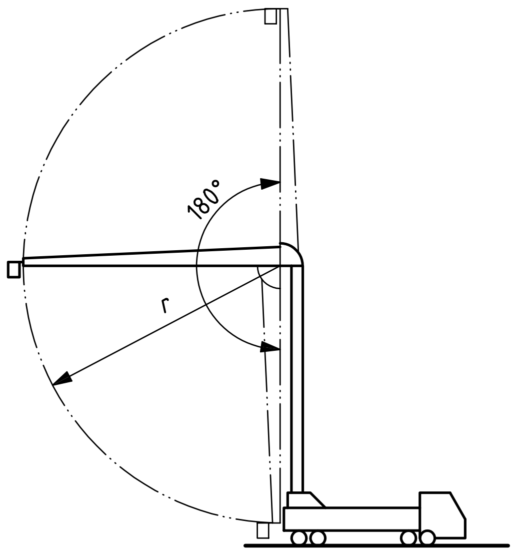


Figure D.1 — Case 1

D.1.3.2.2 Case 2, heavy duty

$$\text{100 000 load cycles over 10 years} = \frac{100\,000}{365 \times 10} = 27{,}4 \text{ load cycles per day} \quad \text{(D.3)}$$

Worst case is considered to be a 10 m boom (radius r) moving though 90° (180°) at 0,4 m/s (v) (see Figure D.2).

The running time for one load cycle, in seconds, is

$$\frac{\pi \times r}{v} = \frac{\pi \times 10}{0{,}4} = 78{,}5 \tag{D.4}$$

Mean running time per day, in hours, relating to one year results from Equations (D.3) and (D.4):

$\Rightarrow 78{,}5 \times 27{,}4$ s/day = 0,6 h/day $\Rightarrow$ category V_{05} (see Table C.1)

Table C.1 gives $1A_m$ drive group for category V_{05}, heavy duty.

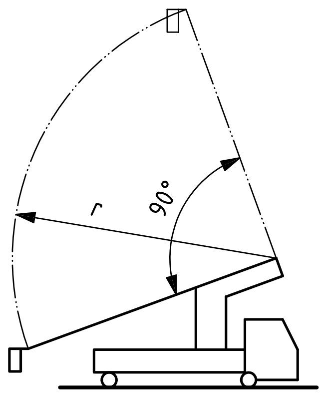


Figure D.2 — Case 2

The $1A_m$ drive group is thus adopted as appropriate for all MEWPs complying with this International Standard.

D.1.3.3 Calculation of minimum rope diameter (see C.3)

The minimum rope diameter is, using Equation (C.1):

$$d_{\text{min}} = c \cdot \sqrt{S}$$

where S is the calculated load on the rope, in newtons.

For drives of group $1A_m$, Table C.2 gives:

c = 0,090 for ropes of tensile grade 1 570 N/mm^2;

c = 0,085 0 for ropes of tensile grade 1 770 N/mm^2;

c = 0,085 0 for ropes of tensile grade 1 960 N/mm^2;

under not non-twisting conditions.

For S = 10 000 N and c = 0,09, and for S = 11 211 N and c = 0,085, the above calculation leads to a minimum rope diameter of 9 mm.

D.1.3.4 Working coefficients

From ISO 2408:2004, Table 5, the minimum breaking force for wire ropes of diameter 9 mm is

F_{01} = 47 300 N (fibre core),

F_{02} = 51 000 N (steel core).

Based on ISO 2408:2004, Table 5 (tensile grade 1 770 N/mm^2), the working coefficients given in Table D.1 result for 9 mm diameter ropes.

Table D.1 — Working coefficients

Tensile grade N/mm^2	Working coefficient		Formula
	Fibre core	Steel core	
1 770 (S = 11 211 N)	4,22	4,55	$\frac{F_{01,02}}{S}$
1 570 (S = 10 000 N)	4,20	4,52	$\frac{F_{01,02}}{S} \times \frac{1570}{1770}$
1 960 (S = 11 211 N)	4,67	5,04	$\frac{F_{01,02}}{S} \times \frac{1960}{1770}$

D.2 Calculation of diameters of rope drums, pulleys and static pulleys

Using Equation (C.2):

$$D_{min} = h_1 \cdot h_2 \cdot d_{min}$$

The coefficients of h_1 for drive group $1A_m$ are taken from Table C.3.

The coefficients of h_2 are determined by the total number of ω_t of alternating stresses, ω, in the most unfavourable stressed portion of the rope using Table C.4. Figure D.3 and Table D.3 show that the value h_2 for MEWPs is normally 1.

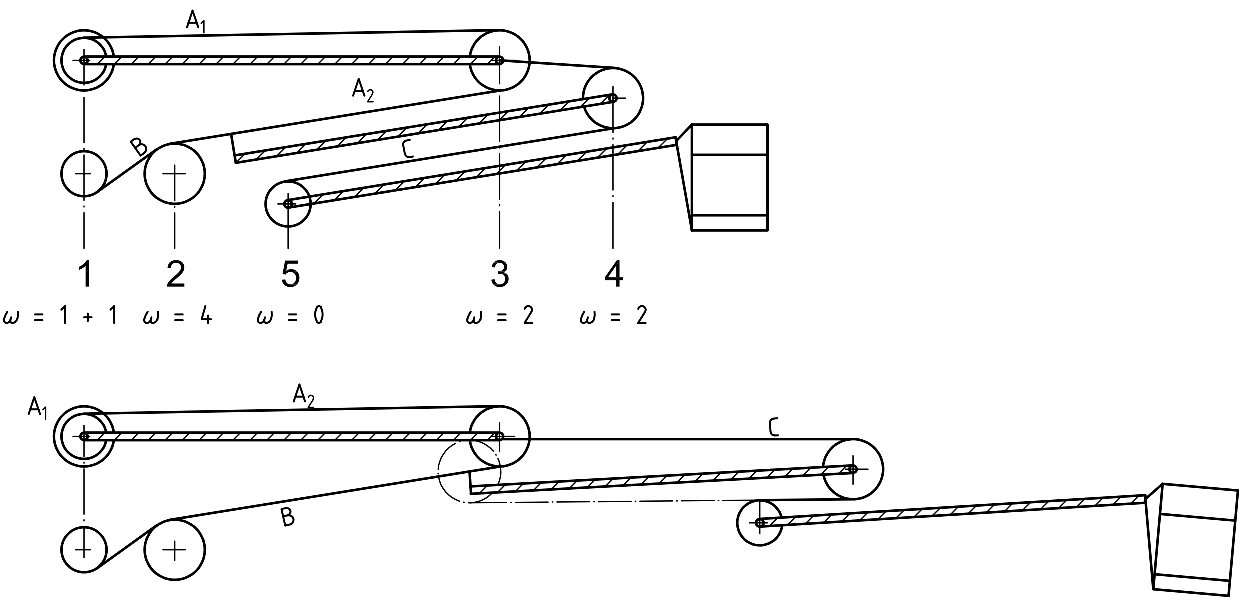
Under these circumstances

$$D_{min} / d_{min} = h_1 \cdot h_2$$

and the ratios given in Table D.2 result for MEWPs.

Table D.2 — Ratio D_{min} / d_{min}

Description	ω_t	h_2	h_1	D_{min}/d_{min}
Rope drum	⩽ 5	1	16	16
	6 to 9	1	16	16
	⩾ 10	1	16	16
Pulley deflecting $\alpha > 5°$ in the same direction	⩽ 5	1	18	18
	6 to 9	1,12	18	20,16
	⩾ 10	1,25	18	22,5
Pulley deflecting $\alpha > 5°$ in the opposite direction	⩽ 5	1	18	18
	6 to 9	1,12	18	20,16
	⩾ 10	1,25	18	22,5
Pulley deflecting $\alpha > 5°$ in any direction and compensating pulley (e.g. end attachment of rope)	⩽ 5	1	14	14
	6 to 9	1	14	14
	⩾ 10	1	14	14



Key

1 double rope drum

2 rope pulley (deflection in opposite direction)

3 rope pulley (deflection in same direction)

4 rope pulley (deflection in same direction)

5 end attachment of rope

Figure D.3 — Determination of number of alternating bending stresses, ω, in individual wire ropes for determination of pulley and drum diameters for extending structure retracted/extended (see Table D.3)

Table D.3 — Number ω

Rope	Number of alternating bending stresses, ω	h_2
A_1	1	1
A_2	2	1
B	$1 + 4 = 5$	1
C	2	1

Annex E
(informative)

Kerb test calculations

E.1 General

This annex gives an energy method for assessing the stability of a MEWP in dynamic impact situations such a as the following:

a) a MEWP with boom raised coming into contact with a step during a kerb and depression test (see 5.1.4.3.2.2) and failing to pass over it;

b) a boom-lift MEWP with boom in the lowered position, dropping into a depression as it comes off the step in a kerb and depression test (see 5.1.4.3.2.2);

c) a MEWP undertaking the braking test on a rated chassis inclination (see 5.1.4.3.2.3).

The example below is for the impact situation noted in a), above. See Figures E.1 to E.3.

Kinetic energy, E_{kin}, of the MEWP:

$$E_{\text{kin}} = \frac{m}{2} \times v^2 = \frac{m}{2} \times 0{,}7^2$$
$$= m \times 0{,}245$$

where

m is the mass of the MEWP, in kilograms;

v is the speed (0,7 m/s for this example).

Potential energy, E_{pot}, necessary for tipping:

$$E_{\text{pot}} = m \cdot g \cdot x = m \cdot g \cdot (y - s)$$

$$= m \cdot \left(\sqrt{s^2 + a^2 - s}\right) g$$

$$= m \times 0{,}6$$

where g is the acceleration due to gravity (9,81 m/s).

Conclusion:

$E_{\text{kin}} < E_{\text{pot}}$ i.e. no tipping will occur.

Dimensions in metres

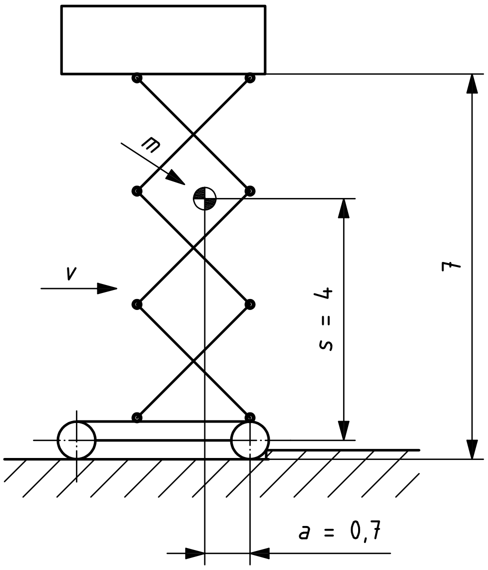
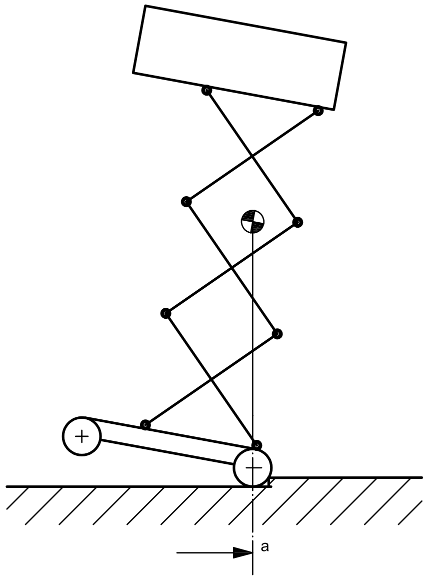


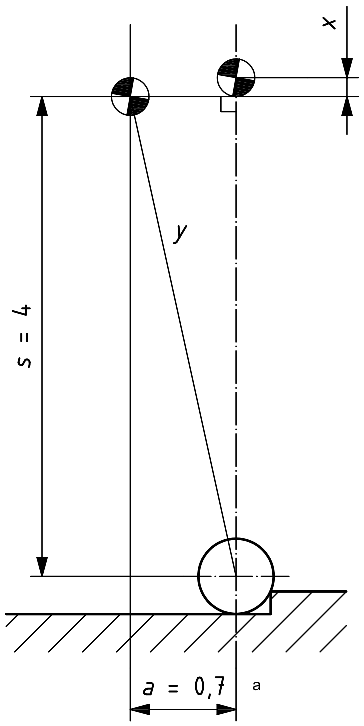
Figure E.1 — MEWP in front of obstacle



[a] Tipping line.

Figure E.2 — MEWP at obstacle

Dimensions in metres



[a] Tipping line.

Figure E.3 — Potential energy

E.2 Derivation of factor z

Factor z is described in 4.2.2.2.1 and denoted in Figure 3, b) and c). Factor z has units of acceleration and provides a linear solution to a non-linear impact event.

With reference to Figure E.4 and the previous calculations (E.1):

At the point of instability, kinetic energy equals the gravitational potential energy.

Taking moments about the tipping line:

$$m \cdot g \cdot a = m \cdot z \cdot s$$

$$z = g \cdot a / s$$

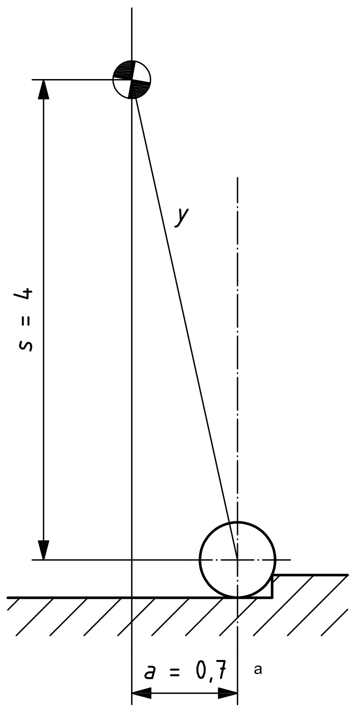
When $E_{\text{kin}} \leqslant E_{\text{pot}}, m \cdot g \cdot a = E_{\text{pot}} / E_{\text{kin}}$

$$z = a/s \; E_{\text{kin}} / E_{\text{pot}} \cdot g$$

$$z = 0{,}7/4{,}0 \times 0{,}245/0{,}6 \cdot g$$

$$z = 0{,}071 \cdot g$$

Dimensions in metres



a Tipping line.

Figure E.4 — Factor z

Annex F
(informative)

Instruction handbook

F.1 General

This annex presents the minimum content for each of the relevant topics. The instruction handbook (see 6.2) should include, but should not be limited to, the following information. See also ISO 18893 and ISO 18878.

F.2 Operating instructions

F.2.1 The operating instructions should give details for safe use, including the following:

a) information on the characteristics and description of the MEWP, as well as setting up the MEWP and its intended use;

b) the necessary bearing strength of the ground;

c) location, purpose and use of all normal controls, emergency lowering and any emergency stop equipment;

d) prohibition of overloading the work platform;

e) prohibition of use as a crane;

f) adherence to national traffic regulations;

g) keeping clear of live electric conductors;

h) avoidance of contact with fixed objects (buildings, etc.) or moving objects (vehicles, cranes, etc.);

i) prohibition of any increase in reach or working height of the MEWP by use of additional equipment (e.g. ladders);

j) prohibition of any addition that would increase the wind loading on the MEWP, e.g. notice boards (for exceptions, see 4.2.2.5);

k) environmental limitations;

l) information on vibration;

m) important daily checks on the safe condition of the machine (oil leaks, loose electrical fittings/connections, chafed hoses/cables, condition of tyres/brakes/batteries, collision damage, obscured instruction plates, special safety devices, etc.);

n) installation of removable guardrails;

o) prohibition of getting on and off the work platform when elevated;

p) precautions for travelling with the work platform elevated;

q) where applicable, the responsible entity's fall protection equipment requirements;

r) the minimum approach distance requirements for energized electrical lines or apparatus, as defined in ISO 18893 or by governing authority national or other regulations, if more stringent.

F.2.2 The operating instructions should provide transport, handling and storage information, including the following:

a) any special provision for securing parts of the MEWP for transport between places of use;

b) the method of loading onto other vehicles/vessels for transport between places of use, including lifting points, mass, centre of gravity, etc., for lifting purposes;

c) precautions to be taken before periods of storage indoors or outdoors;

d) checks to be made prior to use after periods of storage, exposure to extremes of ambient conditions such as heat, cold, moisture, dust, etc.

F.2.3 The operating instructions should provide commissioning information, including the following:

a) tests to be carried out before placing the MEWP on the market (see 5.3);

b) checks to be made on power supply, hydraulic oils, lubricants, etc., on first use, after long periods of storage or changes in environmental conditions (winter, summer, changed geographical location, etc.).

F.2.4 The operating instructions should provide the responsible entity's recommended periodic examinations or tests, including the following:

a) periodic examinations and tests to be carried out according to the operating conditions and frequency of use;

b) the content of periodic examinations and testing, i.e.

— a visual examination of the structure with special attention to corrosion and other damage of load-bearing parts and welds,

— an examination of the mechanical, hydraulic, pneumatic and electrical systems with special attention to safety devices,

— a test to prove the effectiveness of brakes and/or overload devices, and

— functional tests (see 5.1.4.6);

c) information to the effect that the frequency and extent of periodic examinations and tests can also depend on national regulations.

NOTE It is normally not necessary to dismantle parts at periodic examinations, unless there are any doubts in relation to reliability and safety. The removal of covers, the exposure of observation apertures, and bringing the MEWP to the transport position are not considered to be dismantling.

F.2.5 The operating instructions should provide maintenance information for use by trained personnel, including the following:

a) technical information on the MEWP, including electric/hydraulic/pneumatic circuit diagrams;

b) consumable items requiring regular/frequent checks for attention (lubricants, hydraulic oil level and condition, batteries, etc.);

c) safety features to be checked at specified intervals, including safety devices, load-holding actuators, overriding emergency device, any emergency stop equipment;

d) measures to be taken to ensure safety during maintenance;

e) checking for any dangerous deterioration (corrosion, cracking, abrasion, etc.);

f) criteria for method and frequency of examination and repair/replacement of parts, including

— for wire-rope drive systems, single wire ropes according to 4.5.2.1.2 or first and second ropes in systems according to 4.5.2.1.3 a), b) or c) should be replaced when the limits of wear indicated in ISO 4309 are detected in any one of those ropes,

— for chain drive systems, single chains according to 4.5.3.1.2, or pairs of chains according to 4.5.3.1.3 a) or b) should be replaced when the limits of wear indicated by the chain manufacturer are detected in any one of these chains, and

— other components, if applicable (e.g. expected lifetime);

g) the importance of using only responsible entity-approved replacement parts, particularly for load-supporting and safety-related components;

h) the necessity of obtaining the responsible entity's approval of any alteration which might affect stability, strength or performance;

i) parts requiring adjustment, including setting details;

j) any necessary tests/checks after maintenance to ensure safe operating conditions.

Annex G
(normative)

Additional requirements for cableless controls and control systems

G.1 General

Cableless controls shall be designed according to IEC 60204-32:2008, 9.2.7, with the additions given in this annex.

The transmitter shall not transmit while the means to prevent unauthorized use is activated.

G.2 Control limitation

G.2.1 Activation of the transmitter shall be indicated on the transmitter and shall not initiate any movement of a MEWP.

G.2.2 The receiver shall provide output operating commands to the control system only when it is receiving frames containing the right address and correct command.

G.2.3 The MEWP contactor shall only be energized (i.e. controlled to the "on" state) by at least one correctly received frame without any operating commands but containing a start command.

G.2.4 To avoid inadvertent movements after any situation having caused the MEWP to stop (e.g. power supply fault, battery replacement or lost signal condition), the system shall only output operating commands resulting in any MEWP movement after the MEWP driver has returned the controls to the "off" position for a suitable period of time, i.e. it has received at least one frame without any operating commands.

G.2.5 Whenever the MEWP switch is de-energized, all operating command outputs for MEWP movements from the receiver shall cease.

G.3 Stop

G.3.1 The part of the cableless control system to perform the stop function is a safety-related part of the MEWP's control system.

G.3.2 The control system shall initiate a stop of all MEWP movements when no valid frame has been correctly received within 0,5 s.

G.3.3 Unless the receiver monitors that the state of the control system corresponds with the state of the receiver outputs, the stop specified in G.3.2 shall also de-energize the MEWP switch. If the receiver monitors that the state of the control system corresponds with the state of the receiver outputs, the de-energizing of the MEWP switch may be delayed by up to a maximum of 5 min.

G.3.4 If emergency stop functions of category 0, as required by IEC 60204-32:2008, 9.2.5.4.2, create any additional risk, the stop function may be of category 1.

G.4 Serial data communication

G.4.1 The frame shall be sent repeatedly during operation.

G.4.2 The system shall provide a transmission reliability to a hamming distance of the total number of bits in a frame divided by 20 and at least 4, or other means which ensure an equal level of reliability such that the probability of an erroneous frame getting through is less than 10^{-8}.

G.5 Use of more than one operator control station

G.5.1 Transferral of control from one transmitter to another shall not be possible until the first transmitter has been de-activated by a deliberate action, specifically designed for this purpose.

G.5.2 A means shall be provided to enable several transmitter/receiver pairs to operate in the transmission range without unwanted interference with each other.

G.5.3 The means provided in G.5.2 shall be protected from accidental or unintentional change.

G.6 Battery-powered operator control stations

After the warning and the period required in 9.2.7.6 of IEC 60204-32:2008 (when the transmitter battery voltage becomes so low that a reliable transmission cannot be guaranteed) the transmitter shall go automatically to the locked-off condition (i.e. the receiver stops all MEWP motions and de-energizes the MEWP switch).

G.7 Receiver

The receiver shall withstand the vibration, random wide band test, Test Fh, in accordance with IEC 60068-2-64.

G.8 Warnings

Where persons can be expected to be in the vicinity of the MEWP or a part of the MEWP (e.g. in the case of a travelling MEWP or slewing MEWP) and the risk exists of persons being trapped, run over, etc., then warnings in addition to those specified in 6.3 shall be provided.

The MEWP shall be provided with a marking at the access onto the MEWP stating that the MEWP is provided with a cableless control system, and either a continuous visual warning while a cableless control system is engaged or an automatic acoustic and/or visual warning prior to movements of the MEWP.

G.9 Information for use

G.9.1 The manufacturer's instructions shall include installation information to ensure that when a cableless control system is in use, it shall not interfere with, or be interfered by, other systems in use at that location.

G.9.2 The manufacturer shall state the actual delay for the stop function specified in G.3.2.

Annex H
(informative)

List of significant hazards

Hazards have been identified by the risk assessment procedure and are listed in Table H.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 H.1 — List of significant hazards

Hazards		Relevant clauses/subclauses in this International Standard
1	**Mechanical hazards**	
1.1	Crushing hazard	4.2.4, 4.3.4, 4.3.5, 4.3.22, 4.4.3, 4.6.10, 4.7.1, 6.3.13, 6.3.14
1.2	Shearing hazard	4.4.3, 4.7.1, 6.3.13
1.3	Cutting or severing hazard	NS
1.4	Entanglement hazard	4.3.19, 6.3.13
1.5	Drawing-in or trapping hazard	4.3.19, 6.3.13
1.6	Impact hazard	4.3.5, 4.3.22, 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	4.9.1, 4.9.2, 4.9.3, 4.9.4, 4.9.5, 4.9.10
1.10	Ejection of parts	NS
1.11	Loss of stability (of machinery and machine parts)	4.2, 4.3.2, 4.3.6, 4.3.7, 4.3.8, 4.3.9
1.12	Slip, trip and fall hazards	4.6.2, 4.6.4, 4.6.5, 4.6.6, 4.6.7, 4.6.8, 6.3.13
2	**Electrical hazards caused, for example, by**	
2.1	Electrical contact (direct or indirect)	4.8, F.2.1 g)
2.2	Electrostatic phenomena	NS
2.3	Thermal radiation	NS
2.4	External influences on electrical equipment	4.8.1, 4.8.6
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	4.3.20
3.2	Health-damaging effects from hot or cold work environment	4.3.20
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.)	4.6.17
4.2	Interference with speech communication, acoustic signals, etc.	4.6.17

Table H.1 (*continued*)

Hazards		Relevant clauses/subclauses in this International Standard
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	4.8.1, 4.8.6
7	**Hazards generated by materials and substances processed, used or exhausted by machinery**	
7.1	Hazards resulting from contact with or inhalation of harmful fluids, gases, mists, dusts and fumes	4.3.20
7.2	Fire or explosion hazard	4.3.21
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	4.6.7, 4.6.8
8.2	Inadequate consideration of human hand-arm or foot-leg anatomy	NS
8.3	Neglected use of personal protective equipment	NS
8.4	Inadequate area lighting	NS
8.5	Mental overload or underload, stress, etc.	NS
8.6	Human error	4.7.1, 4.7.2
9	**Hazard combinations**	
10	**Hazards caused by failure of energy supply, breakdown of machinery parts, and other functional disorders**	
10.1	Failure of energy supply (of energy and/or control circuits)	4.3.15, 4.7.6, 4.7.7, 4.7.8, 4.7.9
10.2	Unexpected ejection of machine parts or fluids	NS
10.3	Failure/malfunction of control system	4.7.4, 4.7.7
10.4	Errors of fitting	4.8.1
10.5	Overturn, unexpected loss of machine stability	4.2, 4.3.2, 4.3.6, 4.3.7, 6.3.1 k)
11	**Hazards caused by (temporary) missing and/or incorrectly positioned safety-related measures/means**	
11.1	All kinds of guards	4.3.19
11.2	All kinds of safety-related (protection) devices	4.3.8
11.3	Starting and stopping devices	4.3.1, 4.4.5, 4.5.2.7, 4.5.3.6, 4.5.5.2, 4.6.4, 4.7.1, 4.7.2, 4.7.3, 4.7.4, 4.7.5, 4.7.6, 4.7.7, 4.7.8, 4.11.3
11.4	Safety signs and signals	4.3.2, 4.6.11, 4.7.2, 4.9.10
11.5	All kinds of information or warning devices	4.3.2, 4.6.12, 6.2, F.2.1 c), F.2.2
11.6	Energy supply disconnecting devices	4.8.2
11.7	Emergency devices	4.7.4
11.8	Feeding/removal means of work pieces	NS

Table H.1 (*continued*)

Hazards		Relevant clauses/subclauses in this International Standard
11.9	Essential equipment and accessories for safe adjusting and/or maintaining	4.4.4, 4.9.1, F.2.5 a), F.2.5 i)
11.10	Equipment evacuating gases, etc.	4.3.20
12	**Inadequate lighting of moving/working area**	NS
13	**Hazards due to sudden movement/instability during handling**	4.2, 4.3.2, 4.3.3, 4.3.6, 4.3.7, 4.3.8, 4.3.9, 4.3.10, 4.3.11, 4.3.13, 4.6.1, 4.6.15, 4.7.3, 4.7.4, 4.7.5, 4.7.9
14	**Inadequate/non-ergonomic design of driving/operating position**	4.6.10
14.1	Hazards due to dangerous environments (contact with moving parts exhaust gases, etc.)	4.3.20, 4.3.21
14.2	Inadequate visibility from driver's/operator's position	4.3.2, 4.3.22
14.3	Inadequate seat/seating (seat index point)	NA
14.4	Inadequate/inergonomic design/positioning of controls	4.6.10, 4.7.1, 4.7.2, 4.7.3
14.5	Starting/moving of self-propelled machinery	4.3.16, 4.3.17, 4.3.18, 4.3.19, 4.3.22, 4.7.1, 4.7.3
14.6	Road traffic of self-propelled machinery	4.3.15, 4.3.17, 4.3.18
14.7	Movement of pedestrian-controlled machinery	4.3.18
15	**Mechanical hazards**	
15.1	Hazards to exposed persons due to uncontrolled movement	4.2.3, 4.4.4, 4.7.1
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	4.6.7, 4.6.8
15.6	Hazards caused due to towing, coupling, connecting, transmission	NS
15.7	Hazards due to batteries, fire, emissions, etc.	4.3.20, 4.3.21, 4.3.23
16	**Hazards due to lifting operation**	
16.1	Lack of stability	4.2, 4.3.2, 4.3.6, 4.3.7, 4.3.8, 4.3.9, 4.4.1
16.2	Derailment of machinery	4.3.24
16.3	Loss of mechanical strength of machinery and lifting accessories	4.2.5, 4.4.1, 4.6.14, 6.2.1 b), F.2.2 a), F.2.2 b)
16.4	Uncontrolled movements	4.3.3, 4.3.4, 4.3.5, 4.4, 4.5, 4.6.1
17	**Inadequate view of trajectories of the moving parts**	4.3.22
18	**Hazards caused by lightning**	NS
19	**Hazards due to loading/overloading**	4.4.1
20	**Hazards due to lifting persons**	
20.1	Mechanical strength	4.2, 4.5.2, 4.5.3
20.2	Loading control	4.4.1
21	**Controls**	

Table H.1 (*continued*)

Hazards		Relevant clauses/subclauses in this International Standard
21.1	Movement of work platform	4.4, 4.6.1, 4.7.1, 4.7.2, 4.7.3, 4.7.4 4.7.9
21.2	Safe travel control	4.7.1, 4.7.2, 4.7.3, 4.7.4
21.3	Safe speed control	4.3.1, 4.3.18, 4.3.19, 4.4.5
22	**Falling of persons**	
22.1	Personal protective equipment	4.6.2, 4.6.3
22.2	Trapdoors	4.6.9
22.3	Work platform tilt control	4.6.1
23	**Work platform falling/overturning**	
23.1	Falling/overturning	4.2, 4.3.2, 4.3.3, 4.3.6, 4.3.7, 4.3.8, 4.3.9, 4.3.10, 4.4.1, 4.4.2, 4.6.13, 4.10
23.2	Acceleration/braking	4.3.18, 4.4.5, 4.5.1.6
24	**Markings**	6.3

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