BG ETEM
Energie Textil Elektro
Medienerzeugnisse

Basics

Safety in Construction and Design of Printing and Paper Converting Machines

Mechanics

Your statutory accident insurance

Contents

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Preliminary remarks

The present brochure describes the actual state of the art of safety technology in printing and paper converting. It refers primarily to the following standards:

- **EN 1010-1:** Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 1: General requirements
- **EN 1010-2:** Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 2: Printing and varnishing machines including pre-press machinery
- **EN 1010-3:** Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 3: Cutting machines
- **EN 1010-4:** Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 4: Bookbinding, paper converting and paper finishing machines
- **EN 1010-5:** Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 5: Machines for the production of corrugated board and machines for the conversion of flat and corrugated board

All standards of the EN 1010 series are so-called C standards applicable for specific machines, in this case printing and paper converting machines. For machine safety, a number of other standards can also be used as reference such as the A- and B-type standards, which are valid for all machines.

The continuation of the EN 1010 series of standards is being implemented in the drafts of the EN ISO 12643, parts 1–5. This means that in future there will be European and internationally harmonized standards on safety technology for printing and paper converting machines.

It should be noted that the stipulations of C-type standards take priority over the respective A and B standards. The standards listed in the annex can be ordered from

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A-Z Definitions[1]

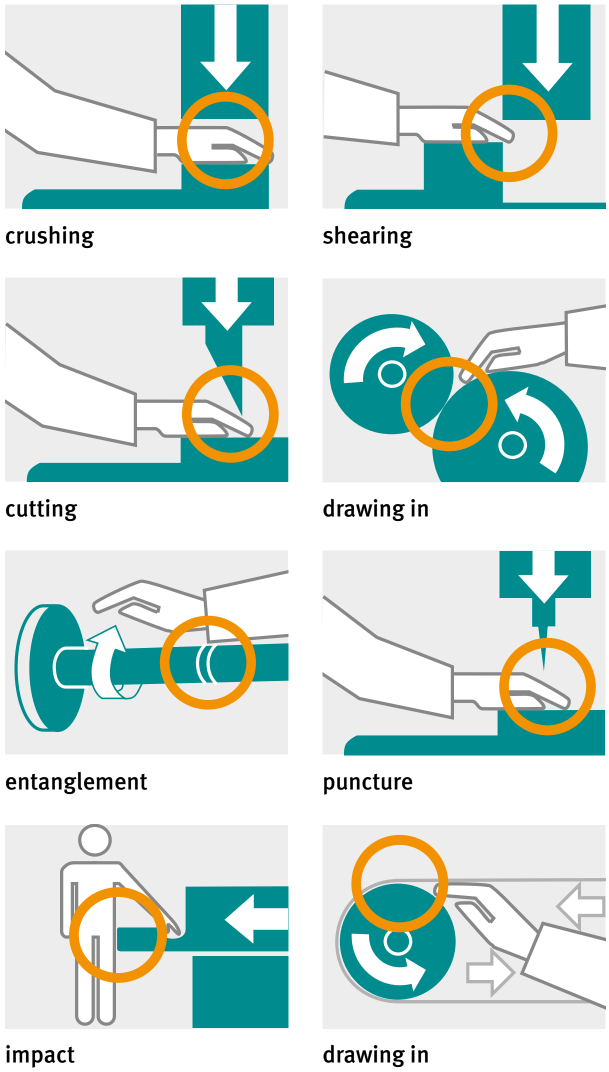
Danger[2] is the condition or situation characterised by a material or energetic potential which, when set free, makes persons or property susceptible to acute harm or injury.

Hazard is defined as dangers which have a potential to cause harm or injury coinciding with the presence of persons at the same time and place. Hazards are potential danger sources which either exist permanently under the conditions of intended use of the machinery (for example movement of hazardous movable parts, noise emission, high temperatures) or which occur unexpectedly, for example explosions, crushing hazards resulting from an unexpected start-up.

Hazardous movements are movements of machines, machine elements, drive elements, tools, work pieces etc. which may cause danger points or are the source of danger and potential harm.

Danger points are defined locations of moving parts of machines where there is the risk of harm. Depending on the danger mechanism, the type of movement and the countermeasures taken, mechanical danger points can be classified as

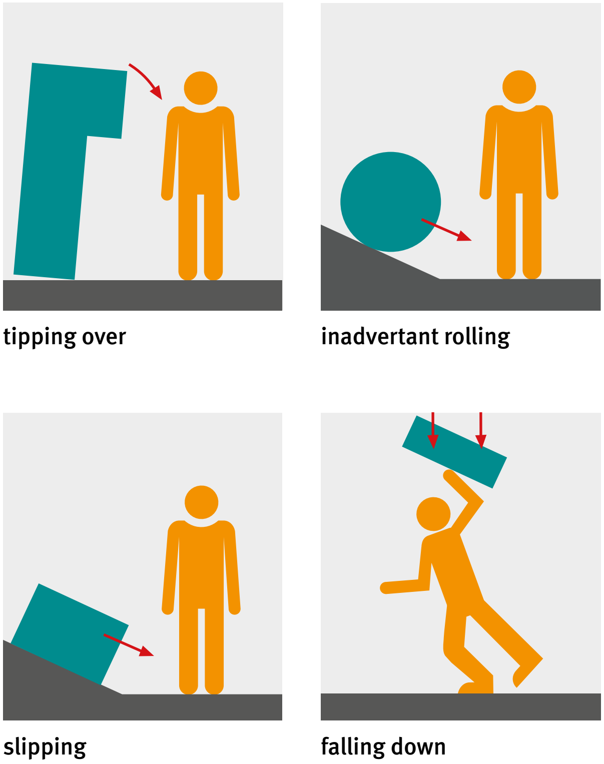
- Danger points created by the **controlled movement** of work equipment, machines and parts thereof



Mechanical danger points created by the controlled movement of parts

[1] A detailed explanation of safety-related terms is given in EN ISO 12100
[2] Neudörfer, A.: Konstruieren sicherheitsgerechter Produkte (Safety-oriented product design), Springer-Verlag Berlin Heidelberg 2014

- Danger points created by the **uncontrolled movement** of work equipment, machines and parts thereof



Mechanical danger points created by the uncontrolled movement of parts

Danger zone is an area within and/or around the machine formed by one or more danger points where the risk of harm exists for persons present in this area.

Hazard identification is a method to identify and describe dangers and hazards for persons in a work system. Determinations can only be made for defined situations or operating conditions. According to the Machinery Directive, hazard identification is an essential part of the design process and must be documented.

Machinery is an assembly of linked parts or components, at least one of which moves. This includes respective drive systems and control and power circuits joined together for a specific application, in particular for the processing, handling, movement or packaging of certain material. The term “machinery” also applies to assemblies of linked parts or components which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole (see EN ISO 12100).

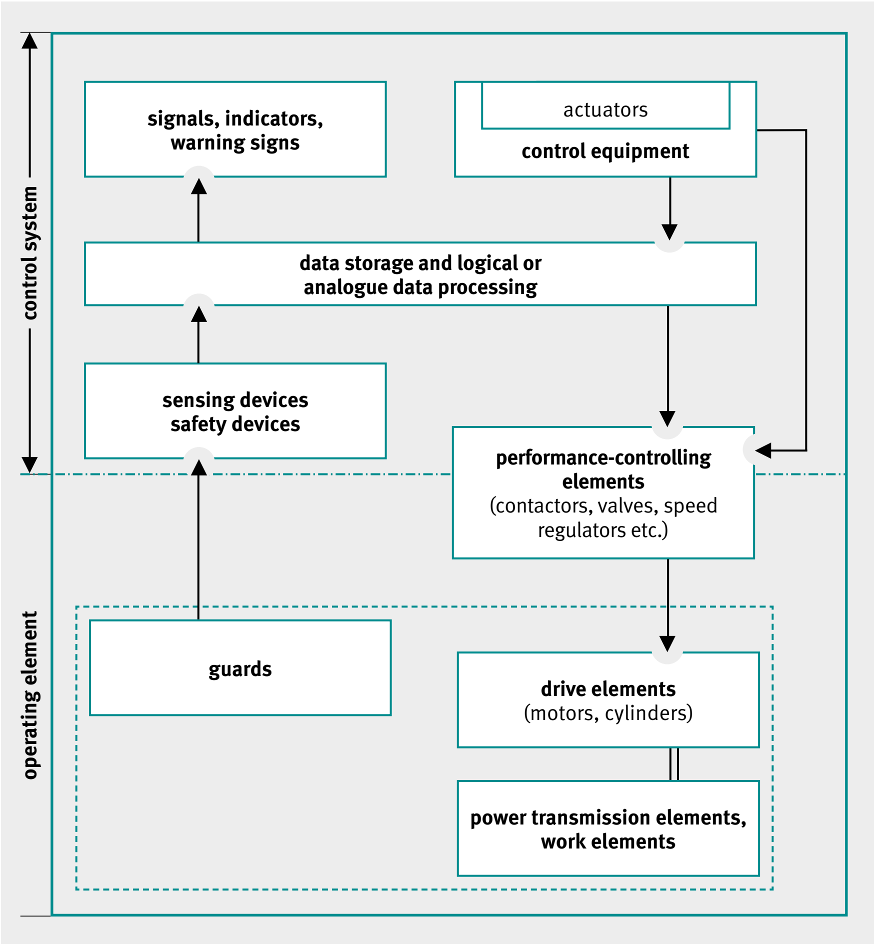
Risk in the context of technical safety is the probability of occurrence of harm and severity of harm (adverse health effects) to be expected. In the context of hazard identification, the evaluation of risk is a prognosis of the likelihood of frequency and severity of possible injuries or damage to health resulting from a hazard under the conditions of applicable safeguarding measures.

Residual risk is the risk remaining after safety measures, for example guarding, have been adopted.

Risk assessment denotes the overall process of risk analysis and risk estimation.

Risk analysis combines the results of identification of machine limits, hazard identification and of risk estimation.

Risk estimation is a method to evaluate, on the basis of risk analysis, whether the envisaged objectives of risk reduction have been achieved.



— Man–machine interface
Scheme of a machine setup in accordance with EN ISO 12100

Safeguarding (guards and protective devices) is required to protect persons from hazards which cannot be avoided by design measures.

Guards are designed to put a distance between the danger point or danger zone and the work area so that persons have no access to the danger points. Guarding systems can be enclosures, covers, fences, protection strips and the like.

Protective devices provide protection without a physical distance between the danger points and the person at risk. They eliminate or reduce risks, either on their own or in addition to a guard. Examples are protective devices with continued actuation such as two-hand controls, pressure-sensitive mats and devices with approach reaction such as photo-electric beams and light grids.

Inherently safe design of machines is one that either avoids hazards or reduces the risk related to that hazard simply by modifying machine design or performance, i.e. without the use of guards or protective devices.

Guard interlocking describes guards which are associated with an electrical, mechanical or other type of interlocking device preventing movement of machine elements until the guard is closed.

Guard interlocking with guard locking functions as follows:

- The hazardous movements safeguarded by the guard cannot operate unless the guard is closed, interlocked and locked.
- The guard remains closed, interlocked and locked until the hazardous movement is stopped. Only then can the guard be opened.
- The hazardous movements safeguarded by the guard can operate if the guard is closed, interlocked and locked. However, the action of closing, interlocking and guard locking does not principally trigger the start of the hazardous movement.

Guard interlocking without guard locking functions as follows:

- The hazardous movements safeguarded by an interlocking guard cannot operate unless the guard is closed.
- Opening of the interlocking guard during a hazardous movement will initiate a stop command, causing the hazardous movement to stop.
- Hazardous movements can be started if the interlocking guard safeguarding this movement is closed. The action of closing does not principally trigger the start of the hazardous movement.

Hold-to-run controls are devices to initiate the operation of machine parts and maintain operation as long as the actuator is hold depressed. The operation is stopped instantly upon release of the actuator.

Enabling devices are additional hand-operated control elements which allow machine operation to continue as long as they are hold depressed. They are mainly used where interlocking guards have to be opened.

The **intended use** defines the use for which the machine is suited according to the manufacturer specification or which is regarded as common use from a view of design, construction and function of the machine. The intended use also implies compliance with the instructions provided in the instruction handbook and should envisage any reasonably foreseeable misuse.

The **foreseeable misuse** should anticipate the following aspects of human behaviour:

- Foreseeable malpractice resulting from carelessness, but not from deliberate misuse of the machine.
- Inadvertent behaviour as a result of a malfunction, incident or breakdown etc. during machine operation.
- Behaviour to be expected where operators choose to handle a certain task according to “the line of least resistance”.

1 Integration of Safety – Basic Concepts

1 Integration of Safety – Basic Concepts

1.1 Hazards

1.1.1 Mechanical hazards

Mechanical hazards relate to all injury resulting from the movement of machine parts, tools, work pieces and ejection of solid or fluid substances. Thus, mechanical energy in all its variations is the cause of mechanical hazards.

Mechanical hazards are, for example:

- Crushing
- Shearing or severing
- Entanglement
- Drawing-in
- Impact
- Puncture
- Friction or abrasion
- Ejection of fluids under high pressure.

The factors influencing mechanical hazards include:

- Shape (cutting elements, sharp edges, pointed tips)
- Mass and stability (potential energy of parts that can be moved under the influence of gravity)
- Mass and speed (potential energy of parts, with controlled and uncontrolled movement)
- Inadequate mechanical strength.

1.1.2 Other hazards

In addition to mechanical hazards which are still the main cause of accidents on machines, a number of other hazards exist, resulting from:

- Electrical energy
- Static energy
- Hydraulic, pneumatic and thermal energy
- Fire and explosion
- Noise and vibration
- Non-ionising and ionising radiation
- Emission of dusts, gases, vapours, liquids etc.
- Errors in fitting
- High temperatures
- Neglect of ergonomic principles in machine design
- Neglect of adequate surface properties (hazards from slipping, tripping and falling)

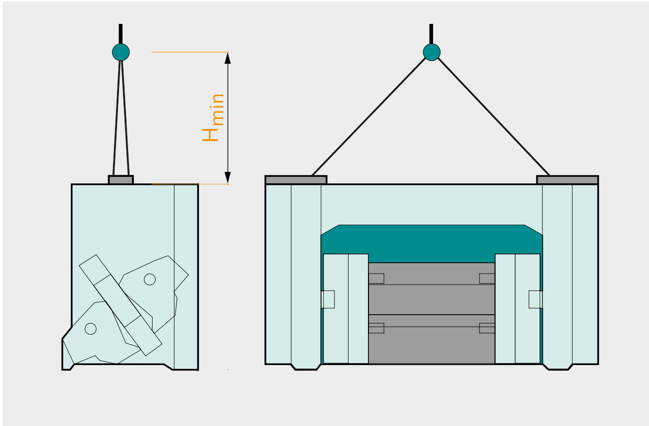
Even individual hazards which are assessed as minor may become significant when combined with others.

1.2 Transport of machines

Machines and machine components which cannot be moved or transported by hand, must be designed to allow transport by means of cranes or lifting trucks, for example by providing

- standardized transport appliances with slings, hooks and eyebolts, appliances to allow automatic grabbing with a lifting hook where attachment is not possible from the ground,

- facilities for taking up prongs where machines are to be transported by fork truck, indicating the mass of the machine and of some of its removable parts on the machine in kilograms (kg) as well as on the removable parts and in the instruction handbook.
- in special cases, indication of the centre of gravity if this is not identical with the centre of the machine.



The instruction handbook must contain information about suitable means of transport

1.3 Emergency measures

1.3.1 Emergency stop devices

Machines must be equipped with one or more emergency stop devices in order to avert imminent or pending hazardous situations. Emergency stop devices are not required for

- machines where the risk would not be reduced by the provision of an emergency stop device, for example where the time required until actual standstill would not be reduced
- machines which can only be started under hold-to-run control or two-hand control
- portable hand-held machines and hand-operated machines.

Emergency stop devices must, for example, be

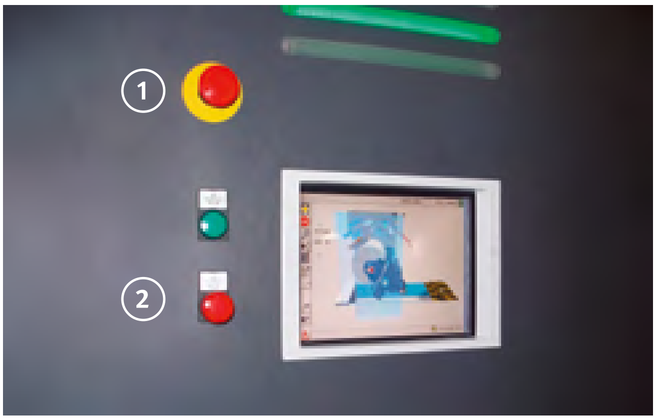
- provided with actuators which are clearly visible and identifiable and can be easily accessed,
- designed to achieve stopping of the hazardous situation as quickly as possible without giving rise to additional risks
- designed, where required, to trigger or permit the triggering of specific movements for safety purposes, for example reversing.

Emergency stop devices must satisfy the following requirements:

- The emergency stop button must remain engaged after actuation.
- Releasing the actuator must not induce the machine to restart, but shall merely enable the machine to restart (see EN ISO 13850).
- The emergency stop signal must override all other control commands.
- The emergency stop function must not impair the effectiveness of safety devices and/or devices with safety function.
- The emergency stop function must not impair the function of any facilities designed to release trapped persons.
- Emergency stop buttons must be designed for easy actuation.

The following operating elements are allowed, for example:

- mushroom-type buttons
- wires, ropes, bars
- handles
- foot-operated switches without shrouding.



Emergency stop (1) and hold safe pushbuttons (2)

Main switch with emergency stop function

Panel with operating and indicator elements and emergency stop button combined

1.3.2 Provisions for releasing trapped persons

Where trapped persons cannot be freed easily, for example out of a safeguarded danger zone, adequate measures for releasing and evacuation are required.

Such measures are, for example,

- provisions after an emergency stop allowing certain elements to be moved manually (for example by means of a hand wheel)
- provisions for reversing the movement of certain elements
- provisions allowing doors in guards to be opened from out of the guarded zone.

1.4 Hazard identification and risk assessment

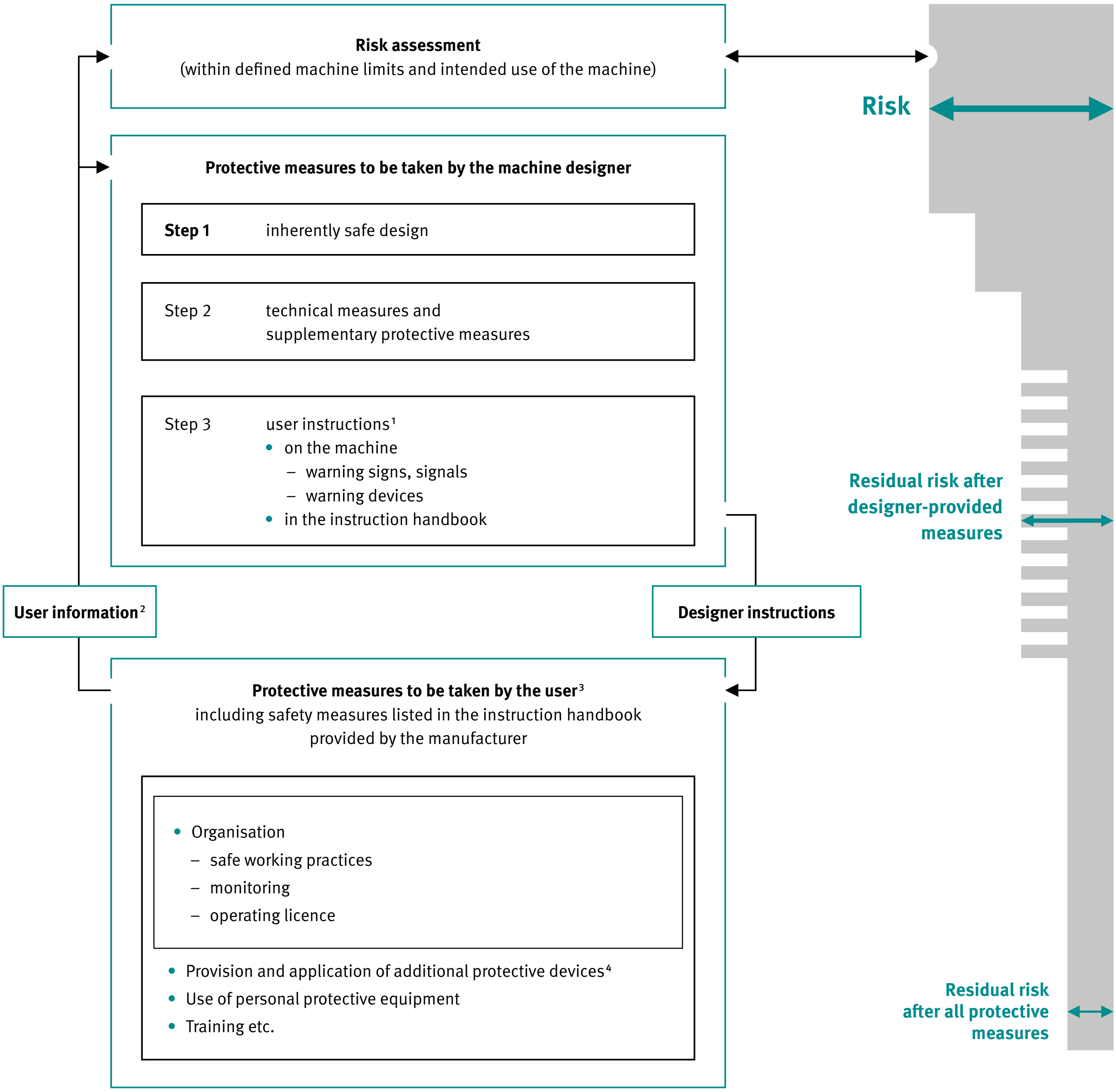
Legal basis
The Machinery Directive 2006/42/EC requires machine designers to carry out hazard identification and risk assessment for their machinery. They oblige manufacturers to assess and document all risks induced by the hazards existing on their machinery. Standard EN ISO 12100 may be used for reference.

Aim of hazard identification/risk assessment
Absolute safety does not exist. The aim of risk assessment therefore is to ensure the highest level of safety for the user, taking into account any constraints existing at the time of manufacture. Such constraints are:

- state of the art (standards, technical rules)
- technical requirements
- economic aspects.

Hazard identification consists of a series of logical steps enabling the machine designer to systematically identify and analyze hazards and evaluate the related risks, thus providing a useful basis for the selection of appropriate protective measures.

Process of risk reduction to be applied by machine designers in accordance with EN ISO 12100



[1] Part of the designer's task is to provide adequate user information for the purpose of risk reduction: Protective measures are effective only when implemented by the user.
[2] User information is information on the intended use of the machines in general or the use of a specific machine provided to the designer by users.
[3] There is no hierarchy for the protective measures to be taken by the user. Such measures are not within the scope of this standard.
[4] Protective measures required by special processes not covered by the intended use of the machine or for special operating conditions which are not within the designer's responsibility.

Methods

1. Identification

Define the machine as an entity

Determine the scope of delivery
- machine (year of manufacture, type, designation)
- auxiliary equipment (standard, optional)
- instruction handbook
- where applicable, training material determining, for example, the manufacturer's responsibility for the scope of supply and the user's responsibility for the surrounding conditions (supply connections).

Define the use of the machine
a. Intended use
- definition of intended use
- definition of reasonably foreseeable misuse
- technical parameters (space requirements, electric and pneumatic energy supply)
- specification of the materials to be processed, qualification of personnel
- possible applications
- peripheral interface

b. Specify the machine
In addition to the essential health and safety requirements, the Machinery Directive requires, for example, specific requirements to be stipulated for

- machinery equipped for specific applications such as machines for working wood and analogous material
- machinery implying specific hazards:
  - hazards induced by lifting operations (feeders)
  - hazards resulting from the machine's mobility.

Identify the life phase of the machine
All life phases of the machine must be considered:

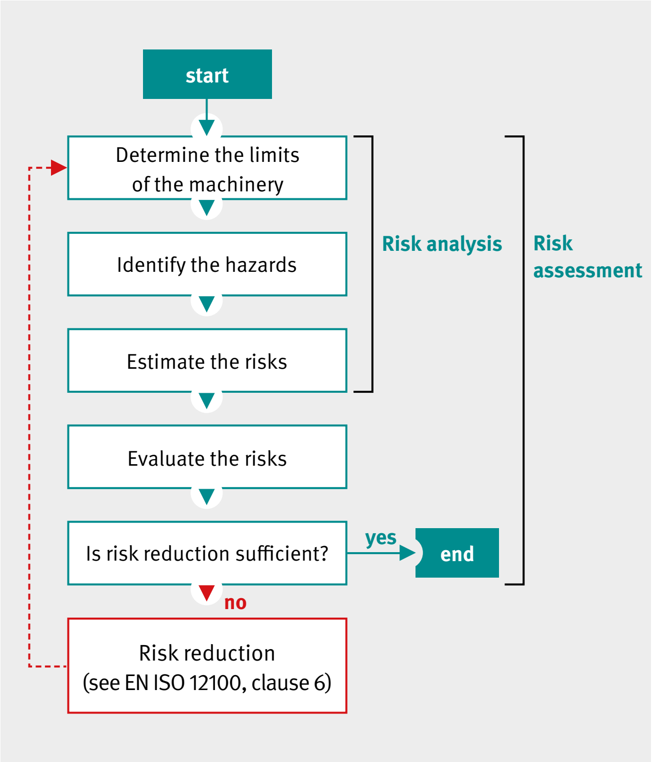
- construction (erection at user's site)
- transport and commissioning (assembly, mounting, commissioning)
- use/application (make-ready, setting-up and adjustment, operation, cleaning, fault finding, maintenance and repair)
- decommissioning, dismantling, removal (as far as safety is concerned), disposal.

Identify danger points/danger zones
Identify and describe their exact location (possibly by illustration).

Identify hazards
Identify all possible hazards (EN ISO 12100, EN 1010-1):

- mechanical hazards
- hazards caused by electric contact (short circuits, electrostatic phenomena)
- pneumatic and hydraulic hazards
- hazards caused by neglect of safety principles in the design (malfunction of the control system, energy supply.)
- hazards caused by radiation
- thermal hazards
- hazards caused by noise
- hazards caused by chemical substances
- hazards caused by neglect of ergonomic principles.

Analyse/describe hazards
Give a precise description of the type of hazard, the time and type of occurrence (in which phase of machine life) and describe the persons who may be exposed to the hazard (operators, assembly personnel, forwarding agents, cleaning personnel) and the possible causes of the hazard (operational mistakes, design faults, material defects, environmental conditions).



Iterative process of risk reduction according to EN ISO 12100

2. Risk assessment

Risks must be evaluated for each individual hazard identified in the first step. The following factors can be taken as a basis for the assessment of risks:

- Probability of occurrence of an event causing harm (probability of occurrence)
- Frequency and duration of exposure of persons to the hazard
- Severity (degree) of possible damage (after-effects)
- Technical and human possibilities to minimize or avoid harm.

The systematic analysis of risk factors can principally be based on two approaches: the “deductive” and the “inductive” method.

Deductive method
A final event is assumed and the incidents giving rise to this final event are subsequently scanned.

Inductive method
A machine component is assumed to fail and the effects of such failure are then analysed (what will happen if ... fails?).

The assessment of risk following this procedure enables the manufacturer to determine whether adequate safety has been achieved for his particular machine.

The following approaches can be applied:

- following a preset list of questions,
- comparison of risks with similar machines,
- FMEA (Failure Mode and Effects Analysis, risk priority number)
- or application of the respective machine-specific standard, for example EN 1010.

3. Determination of protective measures under consideration of respective standards

For each hazard identified, appropriate protective measures need to be determined:

- definition of safety objective
- specification of protective measures

In selecting the most appropriate methods, designers must apply the following principles, in the order given:

1 eliminate the danger
2 reduce the danger to a minimum
3 provide protective measures where dangers cannot be eliminated (taking into account respective standards, the intended use of the machine as well as any reasonably foreseeable misuse)
4 inform about residual risks where protective measures do not meet the required safety effect.

It should also be checked if

5 additional measures are required for emergency cases (for example evacuation of trapped persons)
6 there are other possibilities of increasing safety (for example by easing maintenance interventions)
7 personal protective equipment is required.

4. Residual risks

The general objective of the Machinery Directive and all related standards is to design machinery providing a maximum level of safety for the user. The task of risk assessment is, amongst others, to identify and indicate any residual risks associated with the machine. Where risks remain despite the protective measures implemented, the user must be warned (pictograms on the machine, warning in the instruction handbook).

The following table lists a number of steps which must be seen as an iterative process to be repeated several times, depending on the results of risk assessment.

Company Name
Machine: Type: Drawing No.:

Intended use:
Inadmissable use:

AREA/UNIT:

Hazard (type)	Location (danger point)	Life phase	Hazard (description)	Risk assessment by				Safety measure	Safety measure
				Standard	own risk assessment				
					PO	SH	RPN		

PO = Probability of Occurence of the hazardous event (taking into account frequency and duration of exposure)
SH = Severity of Harm
RPN = Risk Priority Number
RPN = PO x SH; Acceptable RPN = 8

PO:
1 = Occurrence impossible (does not occur)
2 = Occurrence improbable (not to be expected)
3 = Occurrence seldom (may be expected, but no cases known) once per ½ year
4 = Occurrence occasional (may occur), once per week
5 = Occurrence frequent (may occur more often), more than once per week

SH:
1 = Minor injuries (crushing, abrasion)
2 = No remaining injuries (healing)
3 = Serious remaining injury/invalidity
4 = Fatality

Table for risk assessment

Practical approach
Analysis of failures and influences:

PO: Possibility of occurrence of an injury or harm to health
SH: Severity of harm
RPN: Risk priority number

RPN = PO x SH

For orientation purposes, it can be assumed that where a risk priority code of 8 is exceeded, protective measures must be taken.

In cases where requirements for the specific hazard have already been specified in the respective standard and been considered in machine design, an additional risk assessment is not necessarily required.

1.5 Safety objectives

In order to make man/machine interaction as safe as possible, safety objectives have been developed for the technical safety of machinery.

The “3-level priority approach” for the integration of safety allows machine designers to integrate the hierarchy of safety objectives into their design task.

Level 1 safety is achieved where, for example, the minimum gaps between moving parts of the machine as in EN ISO 13854 “Safety of machinery. Minimum gaps to avoid crushing of parts of the human body” have been adhered to, or where gaps between the moving parts of the machine have been reduced to such an extent that it is impossible for any part of the body to reach into the gap (4mm maximum). This type of design is also described as “inherently safe design”.

Where danger points cannot be avoided, the indirect safety technology must be used, i.e. protective measures must be applied to safeguard the danger point (**Level 2** safety). This includes the provision of specific safety devices.

Level 3 safety is used where the first two levels cannot be implemented. Warning of residual risks is provided on the machine and in the instruction handbook. Warning technology is allowed only where the residual risk is sufficiently low and serious injury is not to be expected.

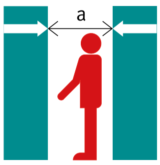
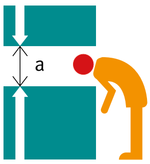
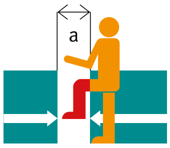
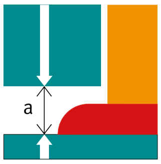
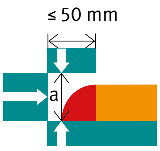
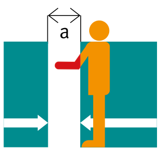
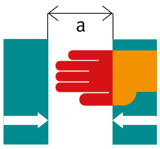
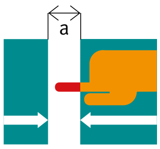
PRIORITY LEVELS OF SAFETY OBJECTIVES AND RELATED SAFETY MEASURES

Level	Safety objectives	Safety measures	Effectiveness
1	Avoid danger points (direct safety technology)	By designing safety into machinery, harm to the life and health of persons is not to be expected under the intended use of the machine and under operating conditions that can be reasonably foreseen	No danger points, no hazards (for example by using flange-mounted motors instead of V-belts)
2	Safeguard danger points (indirect safety technology)	Danger points are provided with protective devices, allowing for the machine to be operated safely without subjecting the operator to undue constraints	Hazards cannot be excluded for example in case of damage or failure of the safety device
3	Warn of danger points (warning safety technology)	Permissible only if levels 1 and 2 cannot be applied. Indicates the conditions under which equipment can be used safely or where residual risks exist	Hazards remain since safety is dependent on behaviour (for example warning of hot parts on the machine)

1.6 Minimum gaps

The table below gives an extract from EN ISO 13854 „Safety of machinery – Minimum gaps to avoid crushing of parts of the human body".

MINIMUM GAPS TO AVOID CRUSHING OF PARTS OF THE HUMAN BODY

Part of the body	Minimum gap a (mm)	Illustration
Body	500	
Head (most unfavourable posture)	300	
Leg	180	
Foot	120	
Toes	50	
Arm	120	
Hand, wrist, fist	100	
Finger	25	

1.7 Safety distances

The most essential safety distances can be taken from the tables below (extract from EN ISO 13857).

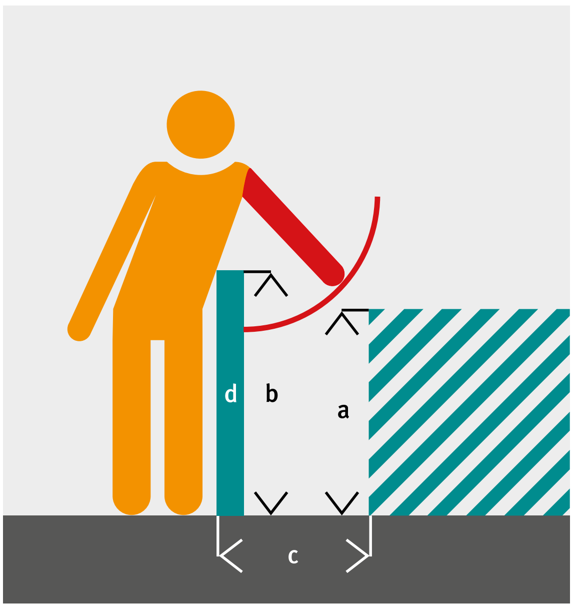
REACHING OVER

Distance of danger point from floor a (mm)	Height of edge of safety device b[1] (mm)							
	2,400	2,200	2,000	1,800	1,600	1,400	1,200	1,000
	Horizontal distance c from danger point (mm)							
2,400	100	100	100	100	100	100	100	100
2,200	–	250	350	400	500	500	600	600
2,000	–	–	350	500	600	700	900	1,100
1,800	–	–	–	600	900	900	1,000	1,100
1,600	–	–	–	500	900	900	1,000	1,300
1,400	–	–	–	100	800	900	1,000	1,300
1,200	–	–	–	–	500	900	1,000	1,400
1,000	–	–	–	–	300	900	1,000	1,400
800	–	–	–	–	–	600	900	1,300
600	–	–	–	–	–	–	500	1,200
400	–	–	–	–	–	–	300	1,200
200	–	–	–	–	–	–	200	1,100
0	–	–	–	–	–	–	200	1,100

[1] Edges below 1,000 mm have not been included because reach distances cannot be increased and in addition there is the risk of falling into the danger zone

Safety distances for low-risk danger points (e.g. friction or abrasion) when reaching over

Reaching over guarding structures
When reaching over edges, for example edges of machine frames or guards, the safety distance is a result of
a = distance of danger point from floor
b = height of edge of guard
c = horizontal distance of edge from danger point
d = guarding structure



REACHING OVER

Distance of danger point from floor a (mm)	Height of edge of guard b[1] (mm)								
	2,500	2,400	2,200	2,000	1,800	1,600	1,400	1,200[2]	1,000[2]
	Horizontal distance c from danger point (mm)								
2,600	100	300	400	500	600	600	700	800	900
2,400	100	300	400	600	700	800	900	1,000	1,100
2,200	–	300	400	600	800	900	1,000	1,200	1,300
2,000	–	–	400	600	800	900	1,100	1,300	1,400
1,800	–	–	–	600	800	900	1,100	1,400	1,500
1,600	–	–	–	500	800	900	1,100	1,400	1,500
1,400	–	–	–	–	800	900	1,100	1,400	1,500
1,200	–	–	–	–	700	900	1,100	1,400	1,500
1,000	–	–	–	–	–	800	1,000	1,400	1,500
800	–	–	–	–	–	600	900	1,300	1,500
600	–	–	–	–	–	–	800	1,300	1,400
400	–	–	–	–	–	–	400	1,200	1,400
200	–	–	–	–	–	–	–	900	1,200
0	–	–	–	–	–	–	–	500	1,100

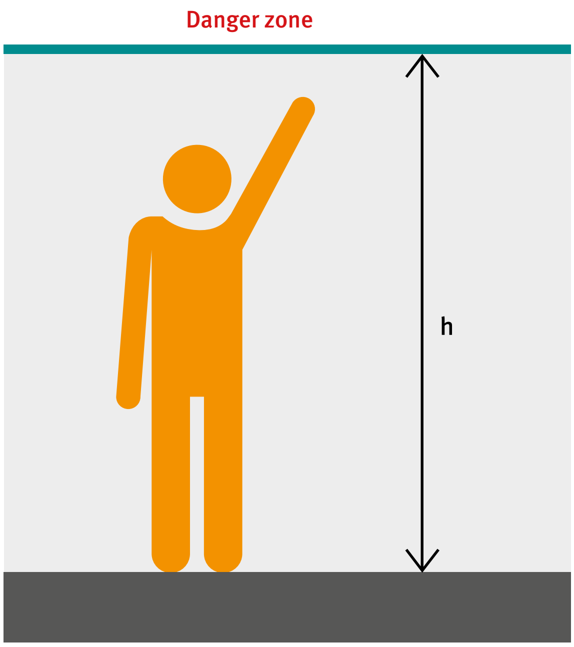
[1] Edges below 1,000 mm have not been included because the reach distances cannot be increased and in addition there is the risk of falling into the danger zone

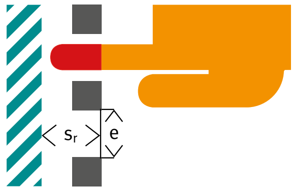
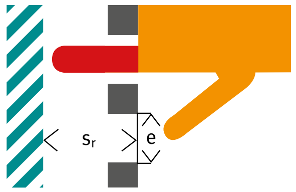
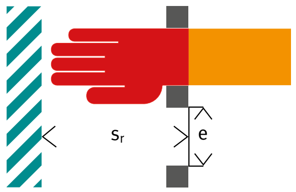
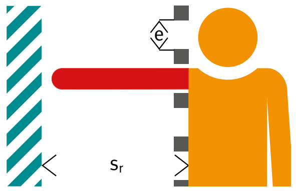
[2] Guarding structures with a height of less than 1,400 mm should not be used without additional preventive measures.

Safety distances for high-risk danger points (for example entanglement or drawing-in) when reaching over

With the body standing upright at full height, the safety distance upwards when reaching up is:

- for low-risk danger points (friction or abrasion) h = 2,500 mm
- for high-risk danger points (entanglement or drawing-in) h = 2,700 mm



Part of the body	Illustration	Opening (mm)	Safety distance s_r (mm)		
			Slot	Square	Circle
Finger tip		e ≤ 4	≥ 2	≥ 2	≥ 2
		4 ‹ e ≤ 6	≥ 10	≥ 5	≥ 5
Finger up to knuckle joint		6 ‹ e ≤ 8	≥ 20	≥ 15	≥ 5
		8 ‹ e ≤ 10	≥ 80	≥ 25	≥ 20
Hand		10 ‹ e ≤ 12	≥ 100	≥ 80	≥ 80
		12 ‹ e ≤ 20	≥ 120	≥ 120	≥ 120
		20 ‹ e ≤ 30	≥ 850[1)]	≥ 120	≥ 120
Arm up to shoulder joint		30 ‹ e ≤ 40	≥ 850	≥ 200	≥ 120
		40 ‹ e ≤ 120	≥ 850	≥ 850	≥ 850

1) For slots with a length of equal or less than 65 mm, reach is limited by the thumb and the safety distance can be reduced to 200 mm. The red lines in the table indicate those parts of the body where access is limited due to the size of the opening.

Safety distances for danger points (reaching through regular openings)

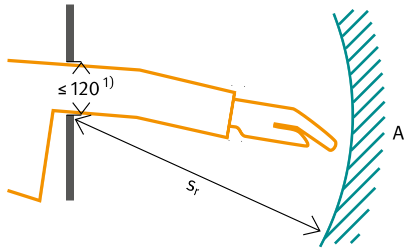
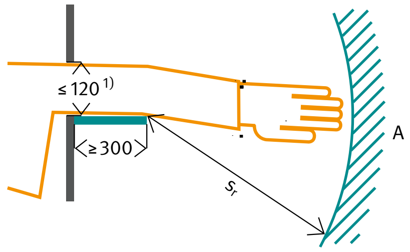
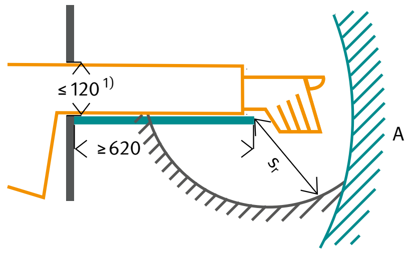
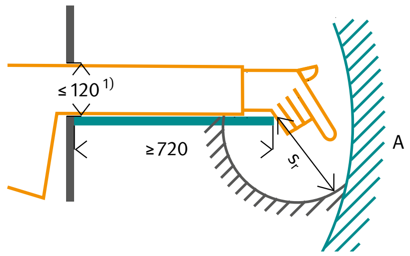
Body sizes are an important aspect when designing technical safety of machinery.

The basis for the determination of safety distances are the findings and data derived from the scientific study of the ratio of measurements of the human body and their exact determination (anthropometry).

Safety distances are calculated on the basis of reach distances or body measurements plus an extra distance for safety.

The opening width e relates to one side in case of square openings, to the diameter in case of circular openings and to the smallest measurement in case of slot openings.

For openings › 120 mm, the safety distances stipulated in table 3 of EN ISO 13857 must be applied.

Limitation of movement	**Safety distance s_r (mm)**	**Illustration**
Movement limited only at the shoulder or armpit	≥ 850	
Arm supported up to the elbow	≥ 550	
Arm supported up to the wrist	≥ 230	
Arm and hand supported up to the knuckle joint	≥ 130	

A = Range of movement of upper limbs

1) Diameter for circular openings, side length for square openings, width for slots

Safety distances for reaching around with limitation of movement (table 3 of EN ISO 13857)

1.8 Safety devices

1.8.1 Classification and examples of application

Safety devices for safeguarding danger points

Guards

- fixed guards
  - enclosures
  - perimeter fencing
  - tunnel-type guards
  - covers
- movable guards
- adjustable guards
- interlocking guards
- interlocking guards with guard locking

Safety devices with continued actuation

- two-hand controls
- hold-to-run controls
- pressure-sensitive mats

Deflector-type devices

- hand deflectors
- finger deflectors

Safety devices with approach reaction

Non-contact

- light barriers
- photoelectric grids
- laser scanners

With contact

- Pendulum-type flaps
- trip bars
- pressure-sensitive mats

Safety objective	Safety device	Example of application
Prevent access to a danger point from all sides	Guard: enclosure	Chain drive completely enclosed
Prevent access to a danger point from a greater distance	Guard: perimeter fencing	Danger zones on pallet strapping machines, in-line machines, reel stands with automatic reel loading system
Keep persons or parts of their body out-side the danger zone during a hazardous movement	Safety device with continued actuation	Two-hand control on cutting machines
Switch off, stop or reverse the hazardous movement when persons or parts of their bodies approach	Safety device with approach reaction: non-contact type, contact type	Photo-electric barrier on cutting machi-nes, pressure-sensitive mats on platen machines, trip bars in front of inrunning nips of cylinders

Application of safety devices depending on their mode of action

1.8.2 Guards

The requirements for guards are laid down in the following standards:

- EN ISO 12100
- EN ISO 14120
- EN ISO 14119

1.8.2.1 General requirements

- In order for guards to withstand the stresses to be expected during normal operation and environmental conditions (resistance to corrosion, deformation and excesses of temperature), they must be of adequately solid and robust construction, i.e. they must be constructed from suitable materials and be adequately dimensioned.
- They must not give rise to additional hazards.
- They must not be easy to bypass or made ineffective.
- They must have sufficient distance to the danger zone (EN ISO 13857).
- They must not unduly restrict operators' view of the working process where such observation is required.
- They must be securely held in place.
- They must be fastened by systems which can only be opened by means of tools or they must be interlocked with the hazardous movement.
- As far as possible, they must not remain in their guarding position after unfastening.
- Fasteners must remain attached to the guard after removal.

The Guide to the Application of the Machinery Directive 2006/42/EC Edition 2.1 - July 2017 sets out the following details in §218:

"The second indent of section 1.4.2.1 requires the fixing systems for fixed guards to remain attached to the guards or to the machinery when the guards are removed. This requirement aims to reduce risks due to loss of one or more of the fixings when guards are removed, for example, for maintenance purposes. This can lead to the guards not being replaced, being only partially fixed or fixed with replacement fixings that do not have adequate strength, so that the guard cannot adequately perform its protective function, for example, where containment of ejected parts is necessary. Application of this requirement depends on the manufacturer's assessment of the risk concerned. The requirement applies to any fixed guards that are liable to be removed by the user with a risk of loss of the fixings, for example, to fixed guards that are liable to be removed during routine cleaning, setting or maintenance operations carried out at the place of use. The requirement does not necessarily apply to fixed guards that are only liable to be removed, for example, when the machinery is completely overhauled, is subject to major repairs or is dismantled for transfer to another site. For the same reason, it may not be necessary to apply the requirement to the casings of machinery intended for use by consumers, where the manufacturer's instructions specify that the repairs requiring removal of these casings are only to be carried out in a specialist repair workshop. In that case, fixing systems should be used that are not easy to remove."

Ergonomic considerations are of great importance when designing guarding systems. Guards will be accepted by operating personnel only if they do not unduly impede operator intervention required for make-ready and maintenance and similar operations.

The following aspects will contribute to the effective use of guards:

- Ease of opening and closing, lifting and shifting (supported by weights or springs, gas pressure springs or counterweights)
- It must be possible for guards to be opened, closed, lifted and shifted manually.
- Functional grips and handles (in all guard positions)
- Easy access must be possible when guards are in open position
- Open guards must be secured against falling shut where there is a risk of injury from gravity falling. Such measures can be, for example:
  - counterweights on guards
  - gas pressure springs or spring screws
  - locking devices which positively secure the guard in the open position.

1.8.2.2 Fixed and interlocking guards

Guards which are removed or opened **infrequently** or for maintenance purposes only must, unless interlocked with the hazardous movement, always be fixed to the machine frame in such a way that fasteners can only be loosened by means of tools. Removal of such guards must count as an operator intervention requiring the use of tools.

Guards which are opened **frequently or for setting-up** must be interlocked with the hazardous movement in such a way that hazardous movements are stopped in time after opening or removal of the guard.

Guard opening is considered **frequent**, for example, if it is required at least once per working shift.

Guard locking is required where hazards are to be expected after opening of the guards (for example longer stopping time of rotary knives on rotary cutters and sheeters).

On printing and paper converting machines, protective hoods and gates (guards) are often used for risk reduction. When such interlocking guards are opened, the opening movement initiates stopping of the hazardous movement. On such types of interlocking guards it must be ensured that the hazardous movement has come to a standstill before the danger zone can be reached.

The minimum distance S is calculated according to the following equation:

$$S = K \times (T - t_3) + C$$

K = 1,600 mm/s

S minimum distance in mm, measured from that edge of the hood/gate opening which is closest to the danger zone up to the danger zone

T **stopping of the entire system in s**

t_3 time in s required to open the guard to such an extent that the opening allows access

C safety factor specified in table 4 of EN ISO 13857.

The safety factor C depends on the design of the interlocking device. The stop command is initiated by the opening of the guard. There may be cases where the stop command is given only after the protective hood/gate is already slightly ajar. This may be due to for example production tolerances to be applied when mounting the safety interlock switches. The width of the opening slot thus generated is the decisive factor for determining the value of the safety factor C. For slots smaller than 4 mm C = 2 mm.

SAFETY FACTOR C ACCORDING TO EN ISO 13857, TABLE 4

Width of opening slot	Safety factor C acc. to EN ISO 13857
≤ 4 mm	2 mm
4 mm up to ≤ 6 mm	5 mm
6 mm up to ≤ 8 mm	20 mm
8 mm up to ≤ 10 mm	80 mm
10 mm up to ≤ 12 mm	100 mm
12 mm up to ≤ 20 mm	120 mm
› 20 mm	850 mm

EN 1010-2 requires guard locking for interlocking guards on rotary printing and varnishing machines if the stopping time exceeds 10 s.

1.8.2.3 Requirements for safeguarding danger zones

1 Danger zones must be safeguarded by perimeter fencing and/or light barriers located at a height of 400 mm and 900 mm (EN 1010-1 “Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 1: General requirements”).

2 Access to the danger zone must be safeguarded, for example by:
- an access gate which is interlocked with the hazardous movement,
- a photo-electric sensitive device (for example light barriers at a height of 400 and 900 mm)
- a pressure-sensitive mat.

3 Where the danger zone cannot be observed from positions from where the hazardous movement can be restarted, additional measures must be taken, for example: The mechanical locking mechanism of the interlocking gate must be designed such that the gate cannot be closed from inside the danger zone or an additional control device (enabling device) must be provided outside the danger zone in such a way that it cannot be actuated from inside the danger zone. The position of the enabling device must allow the operator to observe the danger zone when actuating the device. Machine start must be possible only after the enabling device has been actuated.

1.8.2.4 Interlock switches with safety function

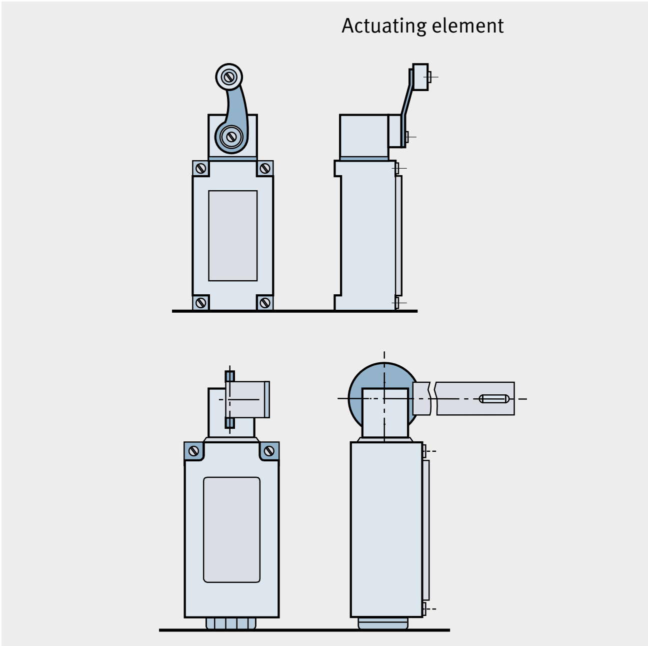
Interlock switches serve to monitor the position of interlocking guards. Interlock switches with safety function (safety limit switches) must satisfy special requirements when used in the interlocking system of guards (EN 60204-1 “Safety of machinery – Electrical equipment of machines – Part 1: General requirements”, EN ISO 14119 “Safety of machinery – Interlocking devices associated with guards – Principles for design and selection” and EN 60947-5-1 “Control circuit devices and switching elements; Electromechanical control circuit devices”).

- They must be arranged and designed so as to prevent inadvertent actuation, change of position and damage: Switches and cam actuators can be secured by using positively-locking (not friction-locking) fastening elements such as round fixtures, fastening bolts or mechanical stops.
- Interlock switches must be actuated and incorporated into the control system in such a way that they cannot be easily bypassed and must, therefore, always be NC contacts.
- They must allow to be tested for their proper function and be easily accessible for this purpose.
- They must not be used as mechanical stops.
- Interlock switches must be arranged so as to protect them against damage from foreseeable outer sources.
- The operating stroke must be tuned to accord to the positive opening travel specified by the manufacturer. The minimum plunger travel must be adhered to in order to ensure the contact travel required for the positive opening operation.
- Where **proximity switches** (Type 4) are used as interlock switches with safety function, they must have the same level of safety as the mechanical interlock switches, i.e. they must be fail-safe (EN 61496-1 “Safety of machinery – Electrosensitive protective equipment – Part 1: General requirements and tests”).

There are basically two types of mechanical interlock switches: [1]

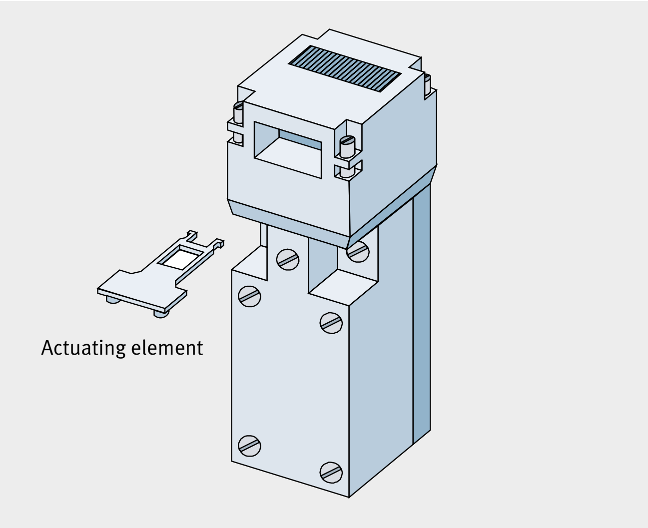
Interlock switches Type 1:
Switches where switching element and actuating element are a composite unit from the aspects of design and function.

Interlock switches Type 2:
Switches where switching element and actuating element are not a composite unit but are, by actuation, joined for a common function or separated.

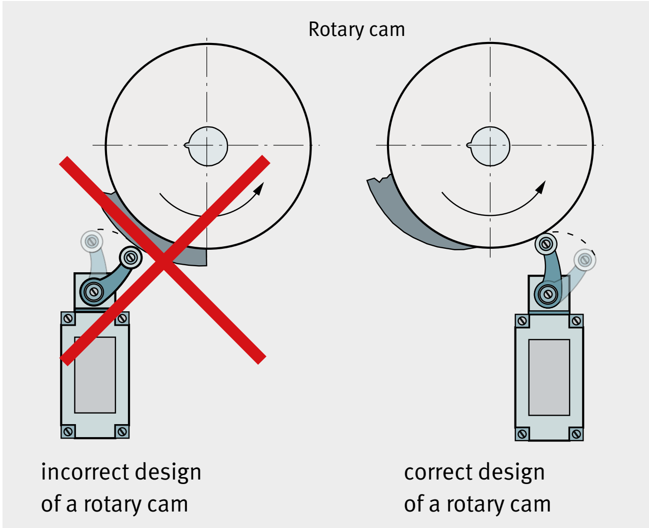


Interlock switch Type 1

[1] Further details are provided in the DGUV information sheet 203-003 “Selection and fitting of interlocking devices”



Interlock switch Type 2



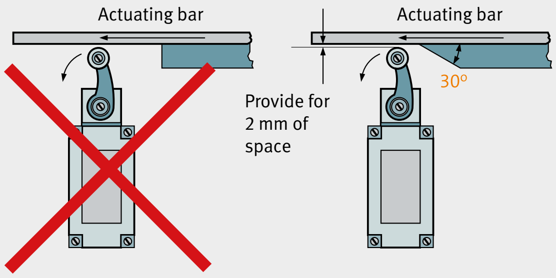
When arranging limit switches, special attention must be given to the design of actuating bars and rotary actuating cams.

In order to prevent approach rollers being damaged, rotary cams must have adequate approach angles. Manufacturer specifications must be satisfied.

Example of an interlock switch Type 1 with rotary cam

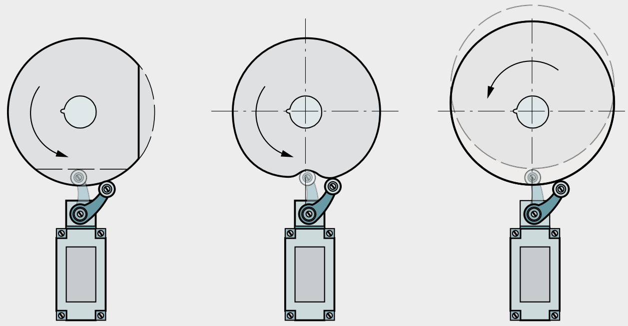
There are different types of rotary cams:

Where actuating bars are used, excessive approach angles must be avoided. Manufacturer instructions must be satisfied.



Excessive approach angle, non-observance of manufacturer specification

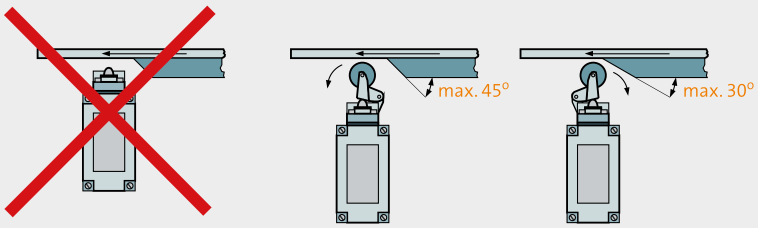
Approach angle according to manufacturer's specification



Rotary cam with segment cutout

Rotary cam with "negative" lobe (cutout)

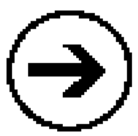
Eccentric rotary cam



Interlock switches with plain or linkage-type plunger are not suitable for lateral approach

Interlock switches which comply with the requirements of EN 60947-5-1 "Switching elements – Electromechanical control circuit devices" are identified by the picture symbol on the switch.

For machines used in the industrial sector, IP 54 is required.



Symbol: Interlock switch with safety function in accordance with EN 60947-5-1

1.8.2.5 Design of guards

Functional reliability
Guards are intended to protect persons against hazards associated with the access to danger points. Moreover they also protect against hazards generated by noise, radiation and projectile parts. Guards must be reliable and must not give rise to new danger points.

Interlocking with and without guard locking
Interlocking establishes a positive interdependency between the effect of a movable guard and the hazardous movement. Guards which need to be removed or opened frequently or for setting-up must be interlocked with the hazardous movement.

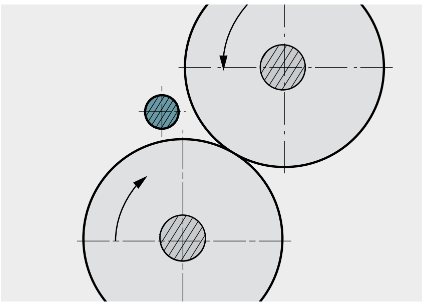
Easy defeat by simple means must not be possible. Simple means would, for example, be screws, needles, pieces of metal, coins, wire.

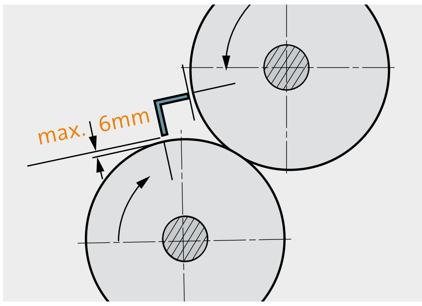
Prevention of reaching through
Guard dimensions must take account of the size of the danger point and human body measurements. Permissible mesh sizes depend on the distance of the mesh guard to the danger point. The wider the mesh, the greater must be the distance from the danger point.

Applying safety distances
When designing guard sizes (opening e and safety distance s_r), the safety distances specified in EN ISO 13857 must be applied.

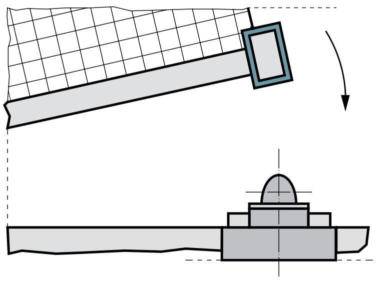
Guards must be designed and arranged in such a way that safety distances cannot be undercut. Safety distances also apply for gaps, for example openings in guards and between guards and machine frames, for example for feeding, removal and observance of work pieces.

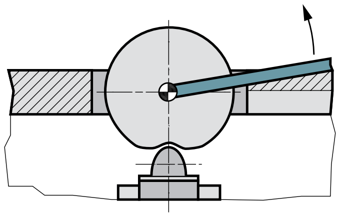
Examples of design:

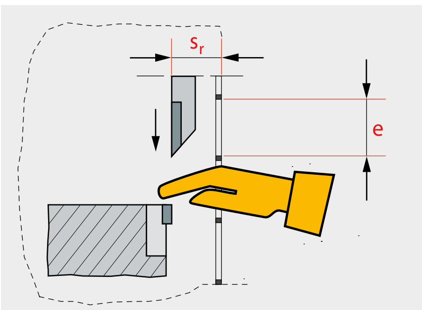

incorrect



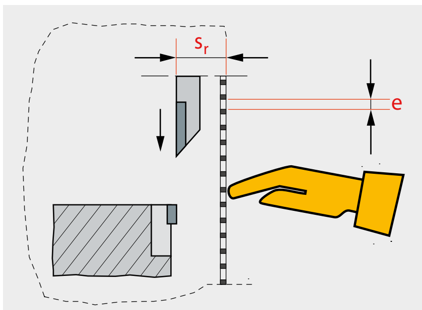
correct


defeatable

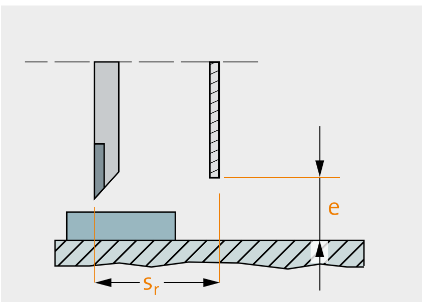

safe

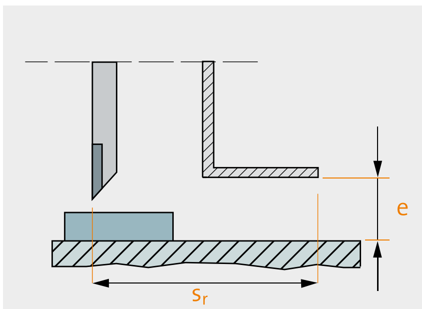


EN ISO 13857 not adhered to



EN ISO 13857 adhered to



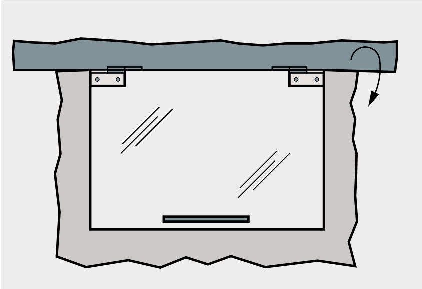


Opening width and safety distance must comply with EN ISO 13857

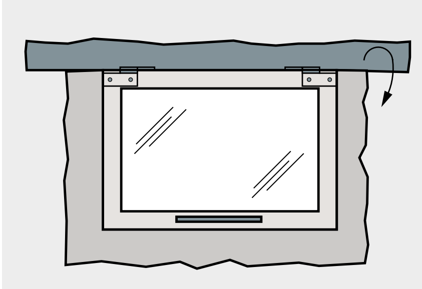
Adequate strength
Guards must be made of solid and resistant materials and be so dimensioned that they withstand the environmental and operational stresses to be expected. These characteristics must be guaranteed for the entire useful life of the machine.

Where this is not possible, provisions must be made for the replacement of worn parts. Materials used must be suitable for the respective application with a view to strength and resistance to corrosion, deformation and excessive temperatures.

A specification of the materials used must be supplied with the guards. The dimensional stability of acrylic glass and wire mesh can be improved by setting the guard in a metal frame.

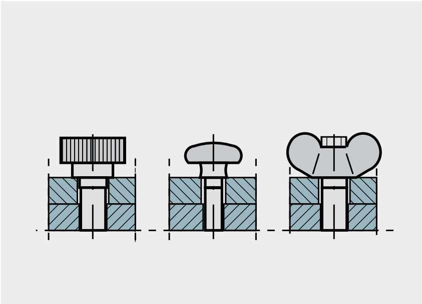


unfavourable (without frame)

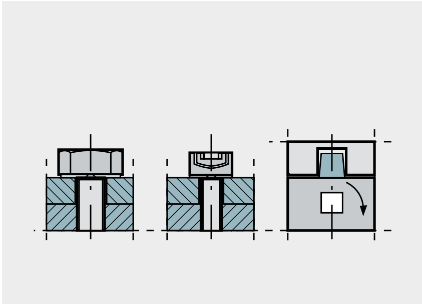


favourable (with frame)

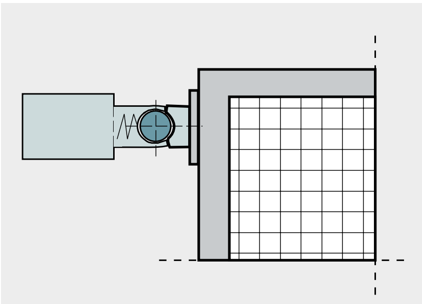
Correct fastening
Guards which are opened for maintenance purposes only must be fastened in such away that they can be opened only by means of tools (for example wrenches, screw drivers, bit keys). Fastening elements must be retained so that they cannot get lost. Quick-release fasteners, screw-on handles, knurled-head screws and wing-type screws are not permitted. After being unfastened, guards should not remain in their guarding position. Fastening elements must remain attached to the guard or to the machine after guards have been removed.



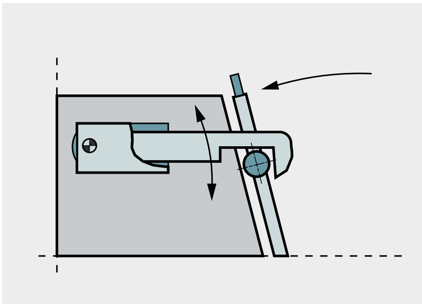
non-admissible



admissible



possible

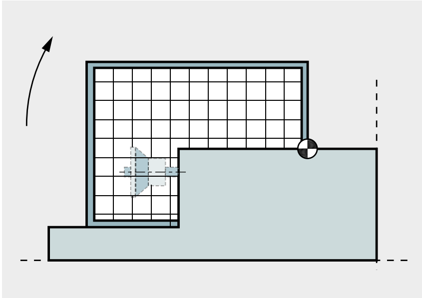


better

Arresting in final position
As far as possible, movable guards must be attached to the machine in such a way that they are safely secured in the open position by means of hinge-joints, tracks etc. Positive locking fixtures should be preferred. Friction-type locking mechanisms (for example universal ball points) are not recommended because their effect (wear) can weaken.

Friction-type elements are acceptable for fixing guards in a stable position from which they cannot move without intervention.

Avoid interference with control elements
Control elements required for interventions during machine runs should not be positioned behind guards which have to be opened for actuation of such controls. They should be located outside guards or be accessible via apertures in the guard. Such apertures must be adequately dimensioned to ensure easy operation of the actuator. Reaching into danger points must, however, be prevented. The safety distances laid down in EN ISO 13857 must be complied with.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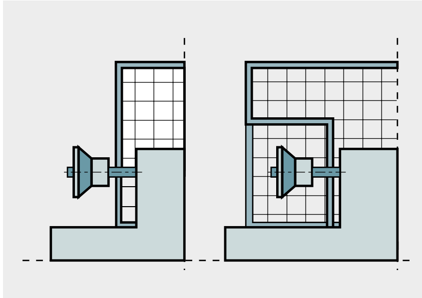
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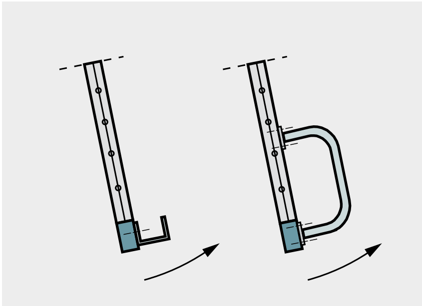
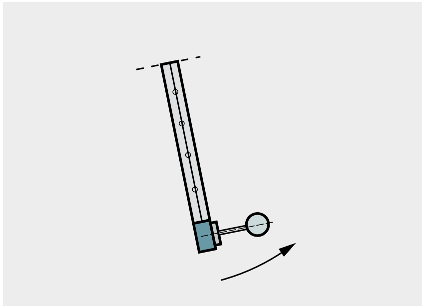
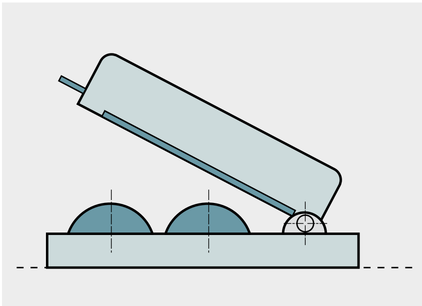
Adequate grips and handles
Functional grips and handles are required for handling of guards. Grip bars or frames with a longitudinal axis running parallel to the swivelling axis are easy to handle in all positions. Angle profiles are not suitable as grip bars. Machine parts should also not be used as handles. On screwed-on guards, handles increase the probability of guards being returned into their safeguarding position.


unfavourable


favourable

Easy handling
Guards should be user-friendly and easy to handle. Movable guards should be capable of being moved with one hand using only minimal force. They must therefore be of light construction without impairing static and dynamic strength (risk of deformation). Ideally, guards should be designed so that they can be opened horizontally (by sliding). If this is not possible and they have to be swung upwards, then the upper end position should be above the tipping point. Guard opening should be assisted by springs, gas-pressure springs, counterweights etc.

Gas-pressure springs are an approved constructional element. However, the risk assessment must take into account the failure of the gas-pressure springs. Very large guards should be provided with at least two gas-pressure springs. It is also important to state in the instruction handbook the necessity to replace the springs in case of fading gas pressure.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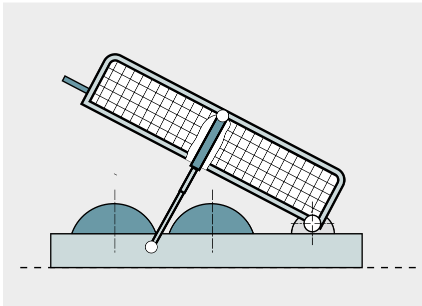
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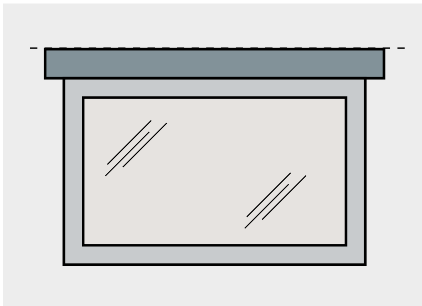
Good visibility
Guards must provide adequate visibility where operations going on behind them are to be observed. Reflections and optical distortions impair the vision and tire the eyes. Wire mesh is to be preferred to other transparent materials (for example acrylic glass) which tends to yellow and go blind with time and is easily scratched or even breaks.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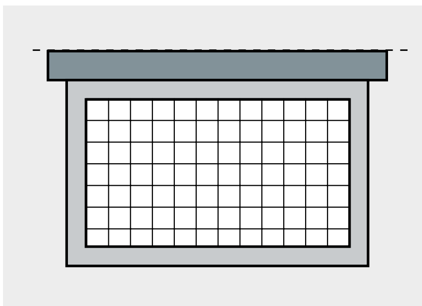
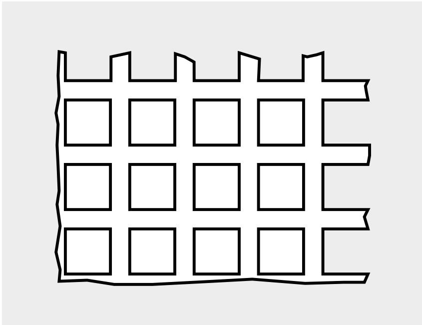

to be preferred

Taking advantage of the effects of contrast
Perforated plate with a high percentage of perforations provides better visibility, especially if the guard is darkcoloured and the background is bright. Dark wire mesh only has a minimal adverse effect on visibility.

Foreseeable misuse
Guards must, as far as possible, be designed to take account of all kinds of application, foreseeable misuse included. Adequate design and selection of material prevents, as far as possible, guards from being climbed on.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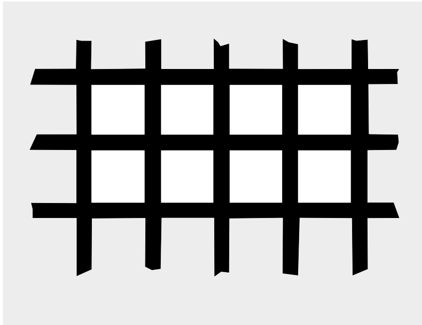
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MATERIALS SUITABLE FOR GUARDS

Material	Semi-finished product	Protection[1]	Protection against projectile and/or loose parts		
			Fluids, Dusts, Vapours	Swarf	Work pieces Tools
Metal	sheet metal	X	X	X	X
	bar, rod	X	–	–	/
	wire, mesh	X	–	–	/
	moulding	X	X	X	X
	plate	X	/	X	X
Wood and Derivates	rod	X	–	–	–
	mesh	X	–	–	/
Plastic	plate	X	X	X	X
	bar, rod	X	–	–	/
	wire, mesh	X	–	–	/
	moulding	X	X	X	X
Safety glass	plate	X	X	X	X
	moulding	X	X	X	X

X = admissible / = conditionally admissible – = unacceptable
[1] EN ISO 13857 must be applied for reaching through

ADVANTAGES AND DISADVANTAGES OF GUARD MATERIALS

Material	Advantages	Disadvantages
Sheet metal	– solid – complete protection against contact (from mechanical point of view)	– no visibility – sound transmission
Expanded metal	– good visibility – inexpensive – easy to manufacture	– sharp edges – not solid – no protection against fluids and dusts
Perforated metal	– solid – easy to manufacture – no heat accumulation	– limited visibility – no protection against fluids and dusts – limited protection against reaching through
Corrugated wire grid	– solid – good visibility – easy to manufacture – no heat accumulation	– no protection against fluids and dusts – limited protection against reaching through
Safety glass	– good visibility – non-shatter – non-scratch – complete protection against contact	– spoils easily – heavy – expensive
Transparent plastic	– impact-proof – good visibility – complete protection against contact	– spoils easily – scratches – not solid (without metal frame)* – risk of breaking when hit by projectiles
Fibre-glass reinforced plastic	– solid – complete protection against contact – sound-insulating	– no visibility – little resistance against projectiles

* Transparent plastic panels must be of sufficient mechanical strength (for example reinforced by metal frame)

1.8.3 Safety devices with approach reaction

1.8.3.1 Light barriers and other vision based protective devices

Electro-sensitive protective devices (ESPDs) with safety function are intended to prevent access or detect the presence of persons. They consist of at least one sensing device (for example an optoelectronic transmitter and receiver), one control and monitoring device and one switchoff element. Electro-sensitive protective equipment is often designed using active optoelectronic protective devices (for example light barriers, light grids or laser scanners). When selecting a suitable optoelectronic protective device, the following criteria should be considered:

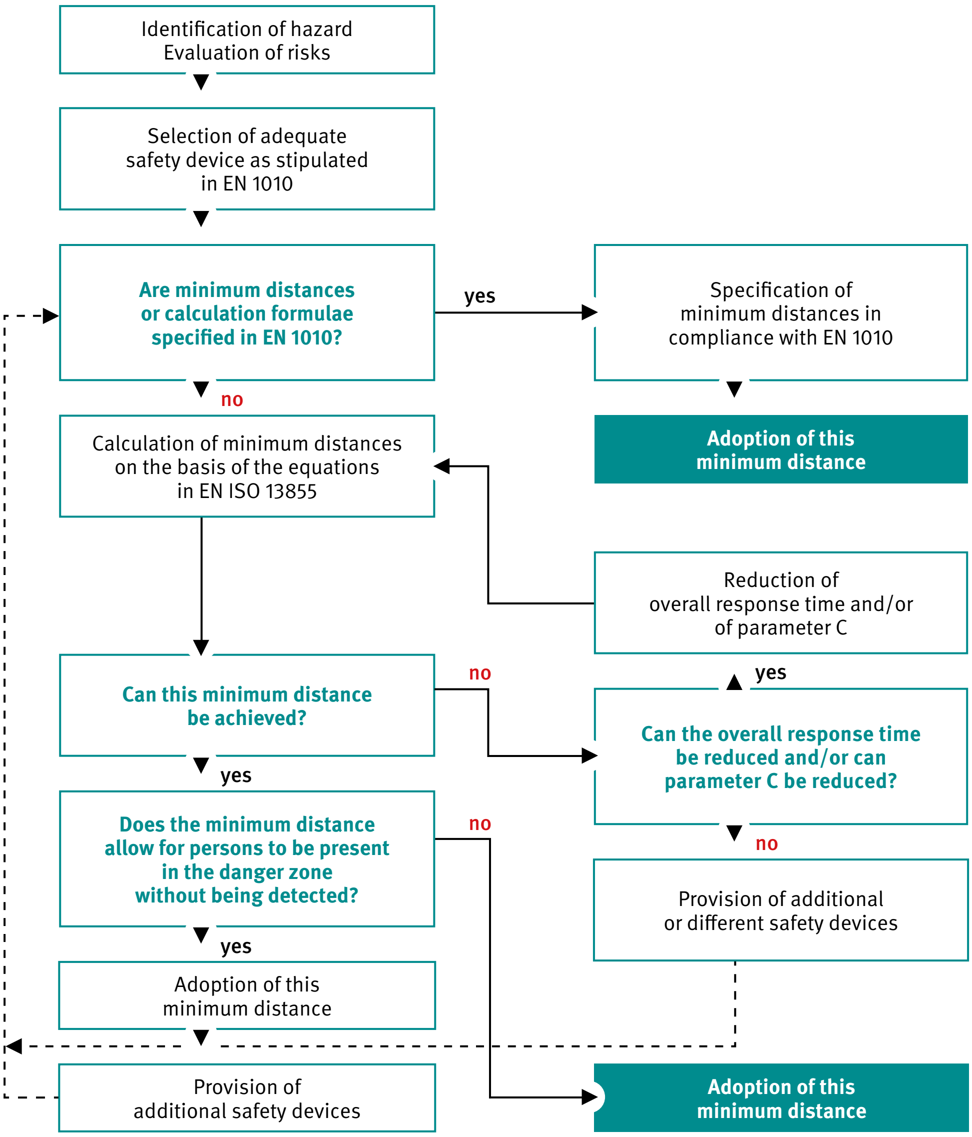
- Stipulations in standards (for example EN ISO 13855, Clause 6, or the standard series EN 1010),
- the clearance available in front of danger points,
- ergonomic influences (e.g. regular access to danger point under normal operating conditions).

Optoelectronic protective devices cannot be used where there is a risk of injury from ejected material, or where the time needed to access the danger point is shorter than the run-down time (to standstill) of the hazardous movement. The effectiveness of optoelectronic protective devices significantly depends on the arrangement of the sensor.

Minimum distances

The minimum distance S on electro-sensitive protective devices (ESPDs) depends on

- the stopping time of the machine (e.g. through slowing down accelerated masses),
- the response time of the machine control system,
- the response time of the ESPD,
- the safety margins added to the safety distance.



The formula below takes account of all factors influencing the general calculation of minimum distances:

$$S = (K \times T) + C$$

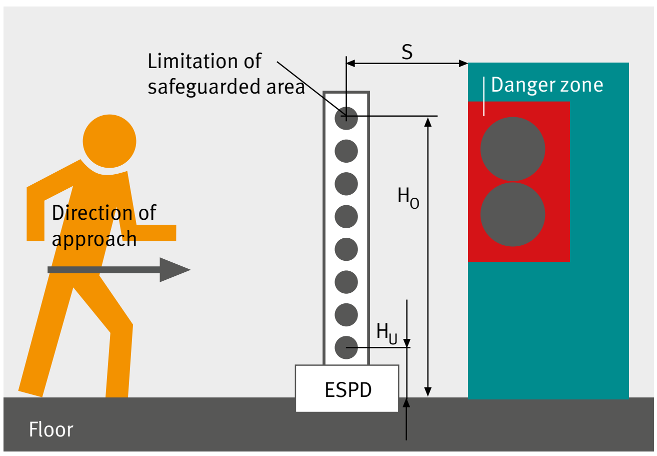
S is the minimum distance in mm, measured from the danger point to the sensing point;

K denotes a parameter in mm/s, derived from data on the approaching speed of the body or parts of the body;

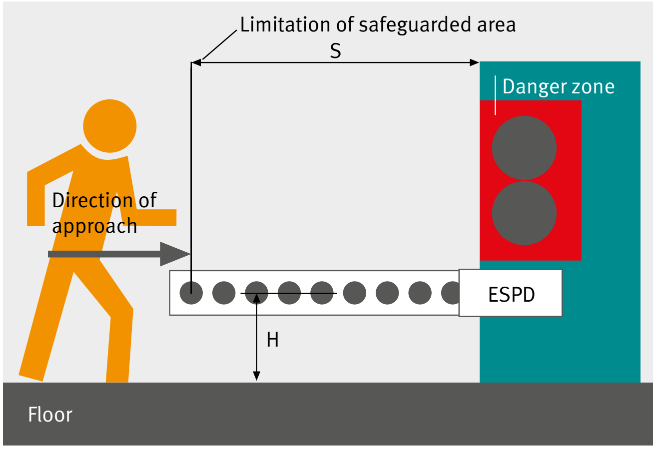
T the overall stopping time in seconds;

C is an extra distance in mm relating to access to the danger zone before the safety device has been activated.

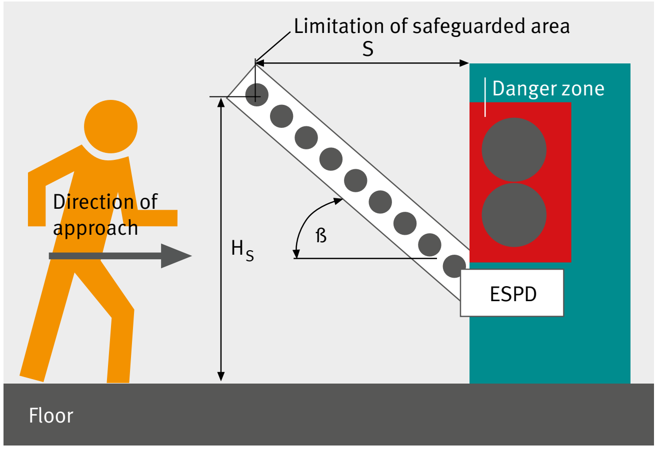
For calculating the minimum distance S, three different ways of approach must be considered:



1. Perpendicular approach to sensing plane



2. Parallel approach to sensing plane



3. Angular approach to sensing plane

CALCULATION OF THE REQUIRED MINIMUM DISTANCES DEPENDING ON THE APPROACH DIRECTION (IN ACCORDANCE WITH EN ISO 13855)

Approach direction	**Equation**	**Explanatory notes / Conditions**	
Please also take into account EN ISO 13857 – Safety distances to prevent hazard zones being reached by upper and lower limbs			
1. Perpendicular approach and		ß = 90° (± 5°) Full body access H_u ≤ 300 mm H_o ≥ 900 mm	
14 mm ≤ d ≤ 40 mm	S = 2,000 x T + 8 x (d – 14)	100 mm ≤ S ≤ 500 mm (d – 14) > 0	
	S = 1,600 x T + 8 x (d – 14)	S > 500 mm (d – 14) > 0	
d ≤ 30	S = 2,000 x T + 8 x (d – 14)	S > 150 mm	machine cycle start-up possible on leaving the detection zone
d ≤ 14		S > 100 mm	
40 mm < d ≤ 70 mm	S = 1,600 x T + 850	H_u ≤ 300 mm H_o ≥ 900 mm Penetration of hands is not detected	
d > 70 mm		Penetration of body parts is not detected	
		Multiple individual beams	
		Number of beams	Heights [mm]
		2	400 and 900
	S = 1,600 x T + 850	3	300; 700; 1,100
		4	300; 600; 900; 1,200
		Single-beam devices (only permitted in combination with other protective devices)	
	S = 1,600 x T + 1,200	1	750

CALCULATION OF THE REQUIRED MINIMUM DISTANCES DEPENDING ON THE APPROACH DIRECTION (IN ACCORDANCE WITH EN ISO 13855)

Approach direction	Equation	Explanatory notes / Conditions
Perpendicular approach (perpendicular protective field) with respect to **reaching over**	Values for C_{RO} see table	ß = 90° (± 5°) $H_U \leq 300$ mm $H_O \geq 900$ mm H must already be known
	$S = 2{,}000 \times T + C_{RO}$	100 mm ≤ S ≤ 500 mm
	$S = 1{,}600 \times T + C_{RO}$	S > 500 mm
Parallel approach		ß = 0° (± 5°) H_{max} = 1,000 mm (only permitted in combination with other protective devices) H ≥ 300 mm (Access beneath the protective field possible)
d ≤ (H/15) + 50	$S = 1{,}600 \times T + (1{,}200 - 0.4 \times H)$	(1,200 – 0.4 x H) ≥ 850 mm, therefore: H ≤ 875 mm and $H_{min} = 15 \times (d - 50)$ mm
Angular approach to Protective Field Plane	See "Perpendicular Approach" and/or "Parallel Approach"	ß > $\lvert \pm 30° \rvert$ (± 5°) see "Perpendicular Approach"
		ß < $\lvert \pm 30° \rvert$ (± 5°) see "Parallel Approach" with $d \leq (H_S/15) + 50$ and $S = 1{,}600 \times T + (1{,}200 - 0.4 \times H_S)$ $H_S \leq 1{,}000$ mm (Parts of the protective field with H > 1,000 mm are not taken into account)

S = minimum distance (mm)
d = detection capability or resolution (mm)
T = total stopping time (s)
H = height (mm)
ß = angle between protective field plane and approach direction

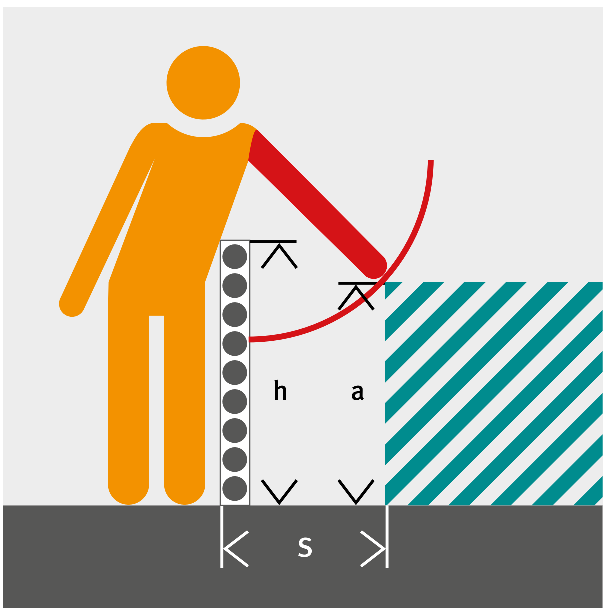
If there are any **barriers or obstacles on the route from the protective field to the beginning of the hazard area**, the length of the available safety distance is equal to the length of the shortest distance between these two points. In practice, this distance can be determined by joining these two points with a length of cord. The length of the tautened cord is equal to the available safety distance. This distance must not be shorter than the calculated minimum distance S.

If **laser scanners (AOPDDR) or vision based protective devices (VBPD)** with a two-dimensional protective field are used, the calculations of the necessary minimum distances S are carried out in the same way as for light grids.

RELATIONSHIP BETWEEN THE HEIGHT OF THE PERPENDICULAR SAFEGUARDED AREA OF AN ESPD, THE HEIGHT OF THE HAZARD AREA AND THE DISTANCE BETWEEN THEM

Height of the hazard area a in mm	Height of the upper edge of the protective field of the electro-sensitive protective device H in mm											
	900	1,000	1,100	1,200	1,300	1,400	1,600	1,800	2,000	2,200	2,400	2,600
	Additional safety distance C_{RO} to the hazard area in mm in accordance with EN ISO 13855											
2,600	0	0	0	0	0	0	0	0	0	0	0	0
2,500	400	400	350	300	300	300	300	300	250	150	100	0
2,400	550	550	550	500	450	450	400	400	300	250	100	0
2,200	800	750	750	700	650	650	600	550	400	250	0	0
2,000	950	950	850	850	800	750	700	550	400	0	0	0
1,800	1,100	1,100	950	950	850	800	750	550	0	0	0	0
1,600	1,150	1,150	1,100	1,100	900	850	750	450	0	0	0	0
1,400	1,200	1,200	1,100	1,000	900	850	650	0	0	0	0	0
1,200	1,200	1,200	1,100	1,000	850	800	0	0	0	0	0	0
1,000	1,200	1,150	1,050	950	750	700	0	0	0	0	0	0
800	1,150	1,050	950	800	500	450	0	0	0	0	0	0
600	1,050	950	750	550	0	0	0	0	0	0	0	0
400	900	700	0	0	0	0	0	0	0	0	0	0
200	600	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

The height of the upper edge of the protective field can allow reaching over into the hazard area. For this reason the minimum distance is calculated with allowance for an additional safety distance C_{RO}



4. Reaching over the protective field plane

Control Requirements
Where light barriers are used as safety devices, these must be of Type 2 in accordance with EN 1010-1, Clause 5.2.9.1, i.e. with a self-testing capability (EN 61496-1:2008 "Electro-sensitive protective equipment; Clause 1: General requirements and tests"). The testing should not only be in the form of start-up tests, but should be repeated as often as possible. Further electronic signal processing of the light barrier must take place in accordance with the risk evaluation. As a rule, printing and paper-converting machinery require a minimum required Performance Level PL_r of "d" or "c" for complete safety function.

Light barriers that regularly control access to the hazard area must conform with Type 4 (EN 61496-1:2008). In this case, the control system must meet a required Performance Level PL_r of "e" for complete safety function. Certain machines must meet more stringent protective equipment control requirements. These including the following:

- Guillotine-type cutters
- Manually-fed stand-alone platen presses
- Manually operated sheed-fed screen printing machines and
- Hand-fed index cutting machines

In EN 61496-1 the different types of electro-sensitive protective devices are assigned a required Performance Level PL_r or Safety Integrity Level SIL.

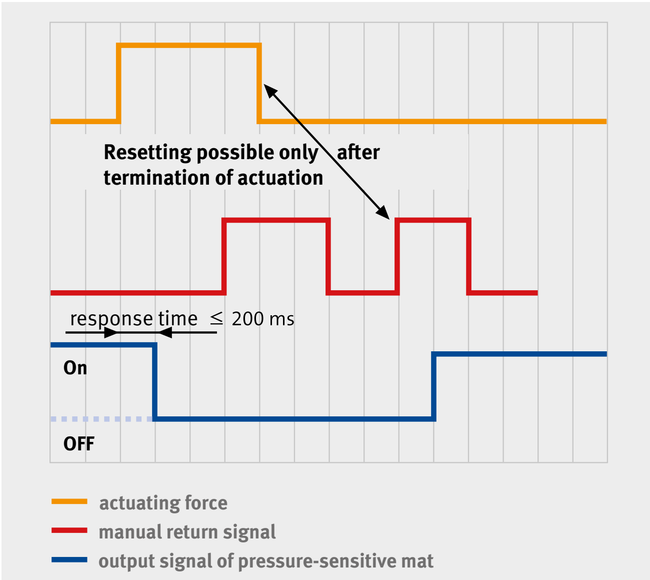
PL OR SIL DEPENDING ON THE TYPE OF ESPD

	Type		
	2	3	4
Required Performance Level PL_r or SIL that can be achieved by the ESPDs	PL_r = c or SIL 1	PL_r = d or SIL 2	PL_r = e or SIL 3

In normative terms, a required Performance Level PL_r of "b" is sufficient for the control systems of light barriers used for residual pile monitoring.

1.8.3.2 Pressure-sensitive mats

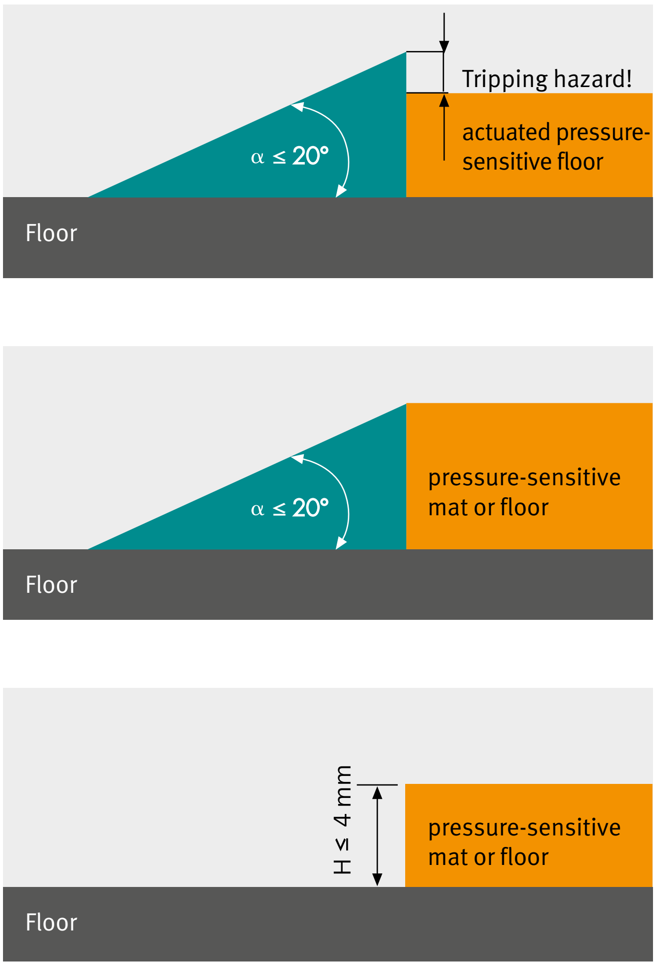
Pressure-sensitive mats and floors are intended to sense persons stepping on or being present on operative actuation surfaces. It is that part of a surface where the force of actuation triggers a safety function. The amount of actuating force required is specified in EN ISO 13856-1 on the basis of test pieces. In the case of pressure-sensitive mats, the pressure exerted on the operative actuation surface results in deformation of a limited area of the mat, whereas on pressure-sensitive floors actuation causes the plate to be depressed as a whole. In addition to the actuating force, the response time is another characteristic when specifying pressure-sensitive mats and floors. Response time and actuating force are set by the manufacturer and it must not be possible for users to modify them. According to EN ISO 13856-1 , the maximum response time is 200 ms. There are pressure-sensitive mats with a response time of about 20 ms available on the market.



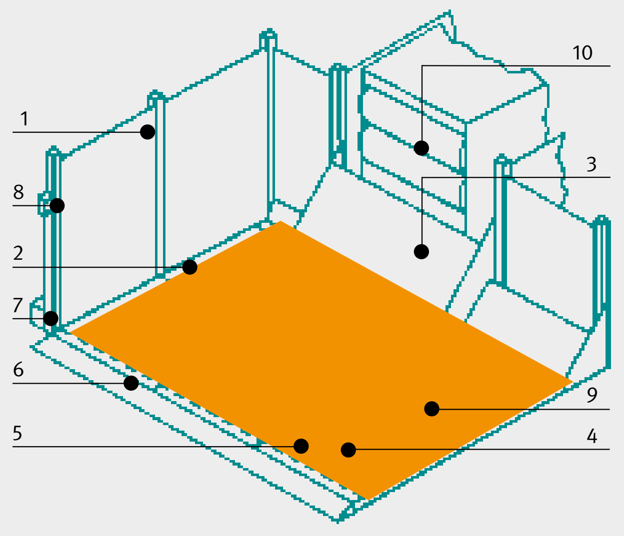
Relationship between actuating force, output signal of the pressure-sensitive mat or floor and return signal

Where heavy loads (for example industrial trucks) are moved in the area of pressure-sensitive mats or floors there is a high risk of damage to such devices. Manufacturers specify, for example, a maximum static load of 750 N/cm² for their mats. In order to avoid tripping hazards, it is advisable to design the mats or plates level with the floor. Tripping hazards must be expected if the difference between adjoining levels is 4 mm or more (EN ISO 14122-2, Clause 4.2.4.3).

If levels differ more than 4 mm, the risk of tripping can be reduced to an acceptable degree by providing a ramp trim with a slope angle of 20°. This ramp must be clearly highlighted using a contrasting colour or other marking. In particular on pressure-sensitive floors, an additional risk of tripping could be created by the actuating travel between the plate and the floor. Actuating travel should therefore be as short as possible.



Prevention of tripping hazards on pressure-sensitive mats and floors



1 Access to the danger zone is prevented by additional guards.
2 Additional guards located directly beside the pressure-sensitive mat or floor.
3 Inclined covers prevent persons from stepping under the pressure-sensitive mat or floor.
4 Adequate mounting of pressure-sensitive mat or floor.
5 Non-operative actuating surfaces are positioned in such a way that the safety function is not affected.
6 Tripping hazard avoided by ramp trim.
7 Cable ducts located outside the safeguarded area.
8 Reset command, entire danger zone can be observed.
9 Edges and junctions joining pressure-sensitive mats or floors are so designed that persons can be identified.
10 Danger point

Well-designed safeguarding system on a work area by using pressure-sensitive mats or floors

The required dimensions of pressure-sensitive mats or floors can be calculated according to the following equation:

$$S = 1{,}600 \times T + 1{,}200$$

If the pressure-sensitive mat or floor is installed on a raised platform, the necessary minimum distance S is reduced. The step is then regarded as an additional safety measure. In this case the calculation is performed using the equation:

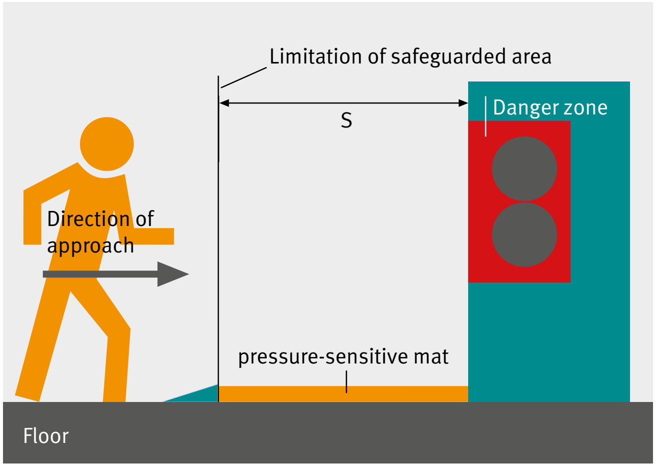
$S = 1{,}600 \times T + (1{,}200 - 0.4 \times h_S)$

($S \geq 750$mm)

S minimum distance in mm, measured from the danger area to the outer edge of the operative actuation area

T stopping time of the entire system in s

h_S height of a step between floor and surface of pressure-sensitive mat in mm.



Minimum width S of pressure-sensitive mat or floor

As outlined above, the presence of steps can lead to tripping or falling accidents. The application of this type of normative solution is only appropriate if the pressure-sensitive mat or floor is intended to control access to restricted areas. This solution is not suitable as a protective device in front of the operating area of a permanent workplace.

In order to reduce the risk of tripping and to achieve a significant reduction of the minimum distance S, the height of the step should be greater than 400 mm. It should be noted, however, that the minimum width S of a pressure-sensitive mat/floor must not be less than 750 mm.

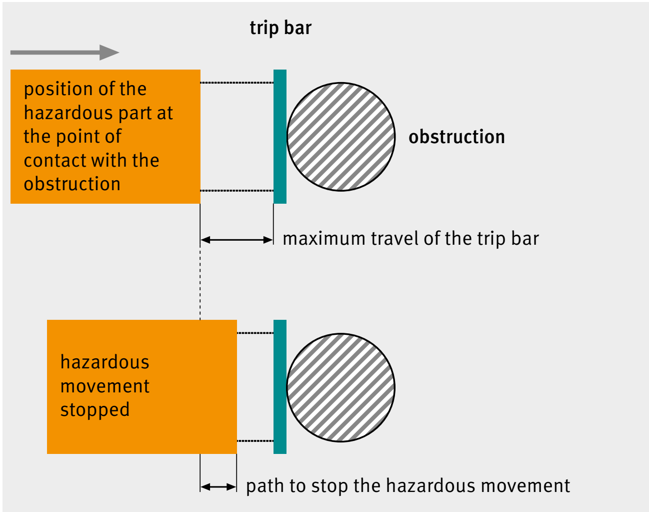
1.8.3.3 Trip bars

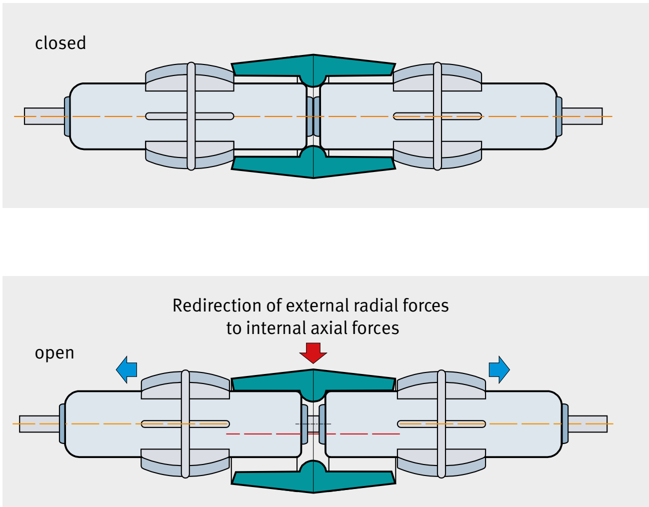
Where trip bars are used for safeguarding danger points special consideration must be given to the risk of persons being endangered if the stopping path of the hazardous movement is too long after the trip bar (pneumatic or mechanical) has been actuated.

Trip bars must therefore satisfy the following requirements:

The stopping path (braking path) of the machine must be shorter than the travel of the trip bar.

Pneumatic trip bars must comply with the requirements of EN ISO 13856-2 “Safety of machinery – Pressure sensitive protective devices – Part 2: General principles for the design and testing of pressure sensitive edges and pressure sensitive bars”.





Example showing a HAAKE system

1.8.4 Safety devices with continued actuation

1.8.4.1 One-hand hold-to-run control devices

Printing and paper converting machines may only be started manually or under hold-to-run control after guards have been opened or where persons accessed the danger zone and unprotected danger points can be reached.
For power-operated machines running under hold-to-run control the following requirements apply in the order given:

1. Operation under hold-to-run control with a maximum speed of 1 m/min or with a limitation of displacement of 25 mm.
2. Where such low speed would restrain the machine function and where a higher speed or greater displacement does not give rise to a considerably increased risk, the maximum hold-to-run speed may be increased to 5 m/min and the displacement be increased to 75 mm maximum.

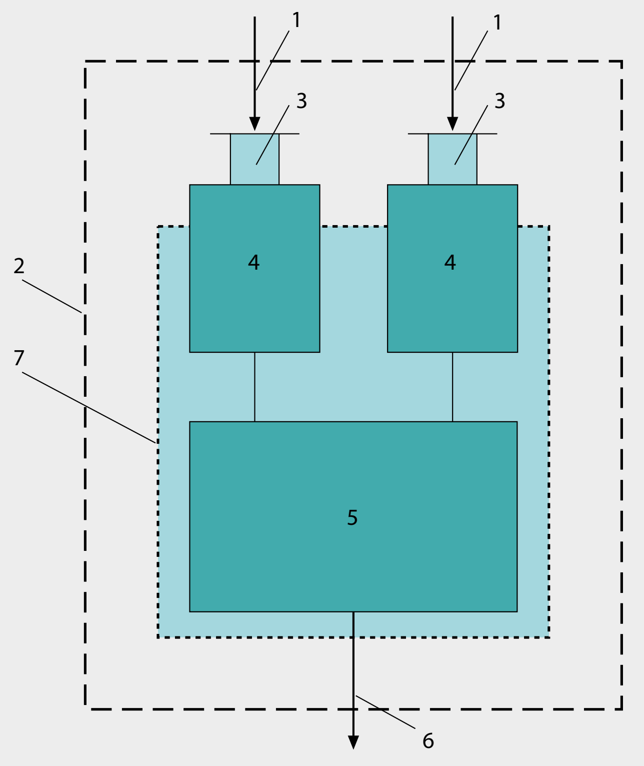
Higher hold-to-run speeds may be possible for certain machines (see EN 1010).

Where higher speeds are required for functional reasons, operation is permitted under two-hand control only, with the maximum speed if possible not exceeding 10 m/min. Speeds should be kept as low as feasible for the process.

1.8.4.2 Two-hand hold-to-run control devices

Two-hand control devices are intended to engage both operator hands on the control buttons so as to keep them away from the danger point. They can only protect the person operating the machine, and therefore the presence of other persons in the danger zone is not permitted. In printing and paper converting, two-hand controls are mainly used for protection during make-ready, setting-up and fault-recovery and where single-stroke operations are carried out near danger points.

It must be ensured that hazardous movements can be stopped at any time as soon as one of the two actuators is released.



1 input signal
2 two-hand control device
3 actuators
4 signal converters
5 signal processing
6 output signal
7 logic

Schematic illustration of a two-hand control device in accordance with EN ISO 13851

Minimum distances

For calculating the minimum distance S between the nearest actuator and the danger zone in accordance with EN ISO 13855, the following formula is used:

S = (1,600 x T) + C **where C = 250 mm**

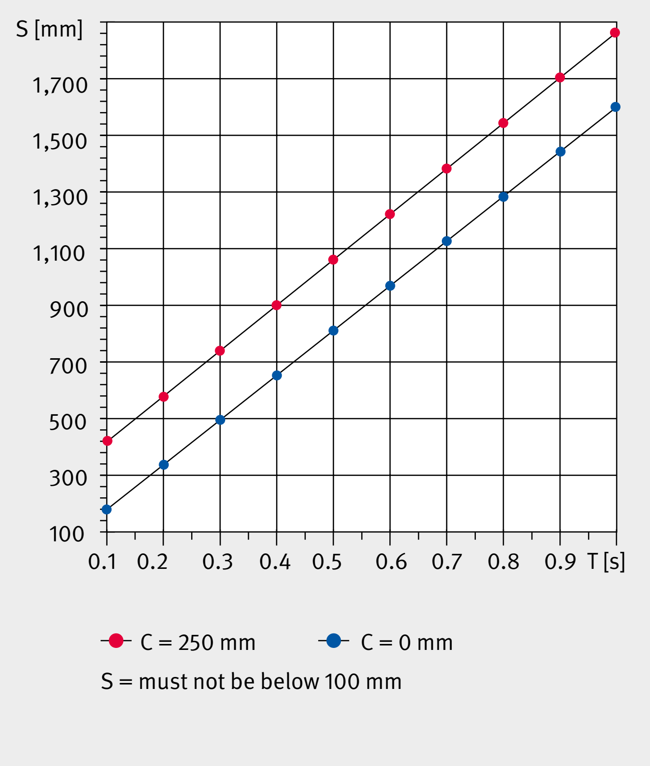
S is the minimum distance in mm;

K is a parameter in mm/s, derived from data on the approach speed of hands;

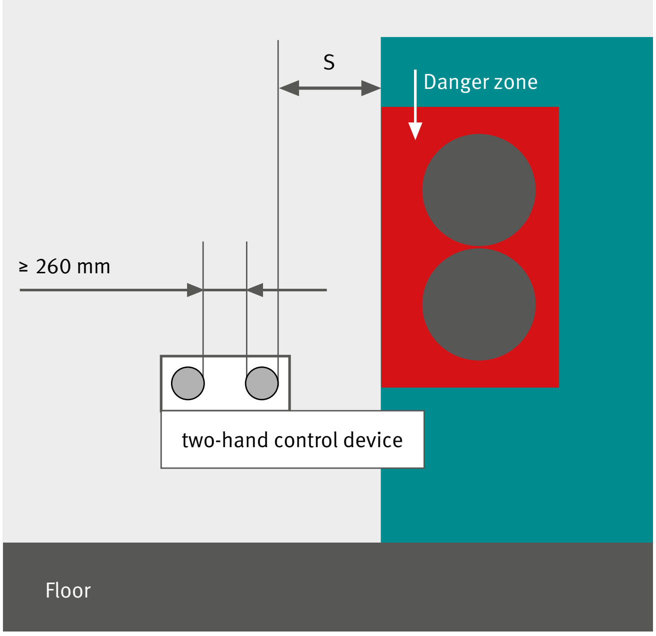
T is the stopping time of the entire system in seconds;

C is an extra distance in mm which takes account of the risk of access to the danger zone before activation of the safety device.

Where hands reaching the danger point is prevented by additional safety devices, the extra distance C can be dropped (C = 0).



S = f (t, d) for two-hand control devices in accordance with EN ISO 13855



Minimum distance S and minimum clearance of 260 mm between the two control buttons

The minimum distance S must not drop below the minimum of 100 mm. The clearance between the two control buttons must be at least 260 mm in order to avoid that both controls are actuated by one hand. This distance may be reduced by providing partitions or elevated areas between the two controls or by shrouding the buttons. The output signal must be created only if both controls are actuated synchronously (within 0.5 s).

For setting-up and fault recovery, two-hand controls may be placed on trailing cables connected to the control system. In such cases the minimum distance S (as per EN ISO 13855) as described in EN 1010-1, Clause 5.2.8.4 will not need to be applied. When designing machines, permanently installed two-hand controls are preferable. Two-hand controls on trailing cables should be regarded as an exception.

1.9 Start-up warning devices

On machines where overall vision is restricted and communication between operating personnel difficult, audible start-up warning devices must be provided. It is assumed that this is the case on printing presses which have more than one printing unit and exceed 1.60 m in height (measured from the level of operation).

On paper converting machines, this basically applies to all machines with a length of more than 7 m.

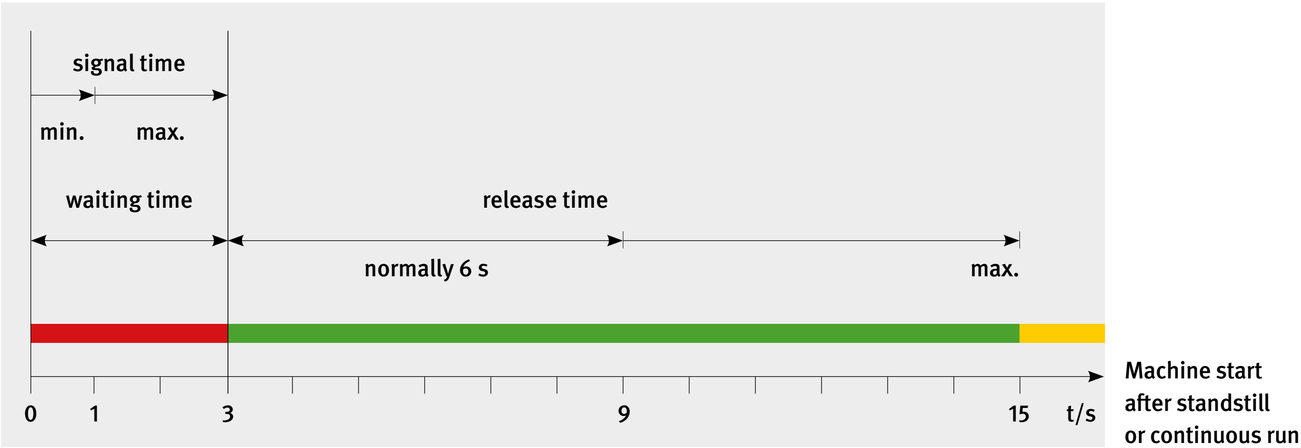
Start-up warning devices must give a clear audible signal before start of the machine. This implies that machines cannot start without a previous warning signal.

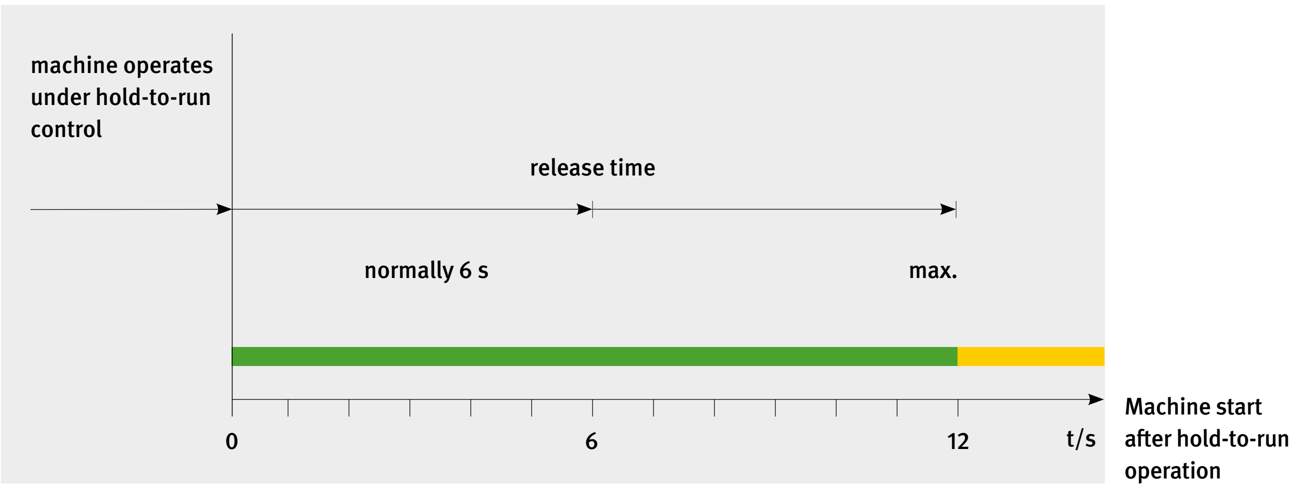
The control system must be so designed that, before machine start, there is an audible signal sounding for a duration of one second as a minimum and three seconds as a maximum (signal time). From the moment of actuation of the signal, at least three seconds must elapse before the machine can be started by actuation of the same or a different control element.

After elapse of the waiting time or after termination of a preceding machine run under hold-to-run control (no continuous mode), the machine may be started within zero to twelve seconds without previous audible warning (release time).

The release time starts when the waiting time elapses or the machine run under hold-to-run control is interrupted and should not exceed six seconds.

After the release time is elapsed or a stop control button or an emergency stop button has been actuated, machine restart is allowed only after repeated audible warning.





- restart possible (green)
- no restart possible (red)
- no restart or hold-to-run operation without previous warning (yellow)

1.10 Marking of machinery

Machines must be supplied with a type plate providing the following information:

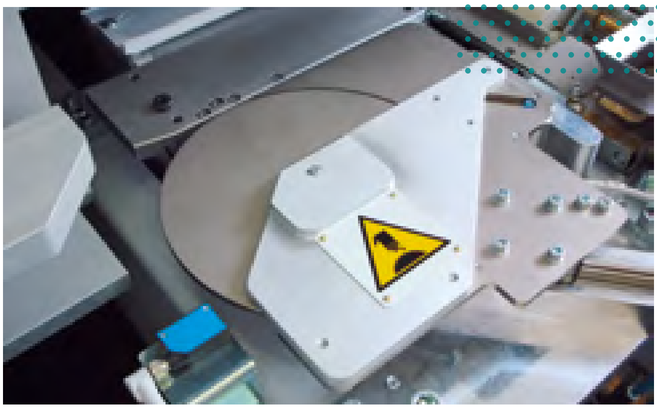
- Address of manufacturer or supplier
- Machine designation
- Type
- Year of manufacture
- Serial number

The type plate must be affixed to the machine, be visible and must be able to withstand production stresses. It must be legible even after several years of use.

It is general practice to affix the CE mark close to the type plate, the same applies to other optional test signs such as the GS mark.

The type plate must, where applicable, also contain basic data for the safe use of the machine (for example the flashpoint of solvents used).

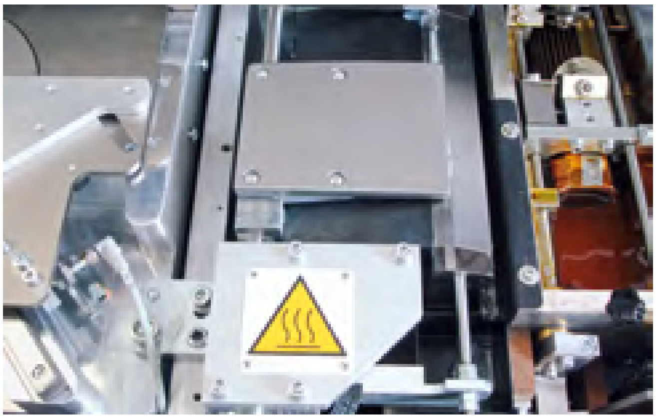
Safety warning signs must be provided on all danger points which are not adequately safeguarded by protective devices.



Warning of dangerous tools such as the milling cutter on a perfect binder

Signs must also be provided to inform about maximum loads of walkways and platforms and of pile carrier plates on feeding and delivery units.

Sign informing about admissible loads on a machine stairway



Hazard pictograms as warnings on hot surfaces, here: gluing unit on an adhesive binder

2 Integration of Safety – Special Requirements and Solutions

2 Integration of Safety – Special Requirements and Solutions

2.1 Technical safety requirements for printing and paper converting machines

According to their importance and effectiveness, safety measures are categorized in three priority levels of safety technology:

- First level – direct safety technology
- Second level – indirect safety technology
- Third level – warning safety technology

2.1.1 Avoiding mechanical hazards – direct safety technology

In the hierarchy of technical safety measures, **direct safety technology** is given the highest priority. Avoiding hazards by machine design is certainly the most effective and most economic approach to designing and constructing safe machinery. This includes, for example,

Safeguarding the crushing point between hold-down and news-paper package by limiting the force and providing foam rubber padding on the upper and lower side of the clamping bar for finger protection

1 avoiding or eliminating danger points by designed-in safety,
2 designing machines such that hazardous moving elements are located inside the machine housing so that they cannot be reached by persons,
3 limiting effective energy to a level which is not hazardous for persons and
4 limiting the stroke of moving parts to 4 mm maximum.

Crushing, shearing and drawing-in points are avoided where the minimum distances specified in EN ISO 13854 are applied. Which distance is actually selected depends on which part of the body is assumed to be able to reach the danger point.

Crushing points are considered non-hazardous where the crushing force does not exceed 150 N. If the parts exerting the crushing force have pointed or sharp edges, limit values are reduced. They can however be increased if the crushing parts are for example padded with elastic material.

Shearing points are avoided if the moving parts causing the shearing hazard are arranged at a safe distance or have a deflecting shape (see EN ISO 13854 "Safety of machinery – Minimum gaps to avoid crushing of parts of the human body").

Entanglement points on shafts are avoided if shaft ends

- are smooth
- do not protrude from the machine frame for more than one quarter of the shaft diameter and
- are not longer than 50 mm.

Inrunning nips are avoided if

- there is a minimum clearance of 120 mm between cylinders or between cylinders and fixed machine parts, unless there is the risk of harm to the head or the body trunk (EN ISO 13854).

- **Examples of solutions using direct safety technology**

2.1.1.1 Avoiding sharp edges, acute angles, protruding parts etc.

As far as possible for the use intended, accessible parts of machines must, according to EN ISO 12100, have no sharp edges, acute angles, rough surfaces and protruding parts which could give rise to injury and no openings risking entanglement of parts of the body or clothing. In particular, sheet metal edges must be deburred, flanged or trimmed and open tube ends be closed. Rotating parts are required to be located inside machines as far as feasible.

2.1.1.2 Rotating hand wheels, cranks

Hand wheels and cranks on power-driven shafts are hazardous and induce the risk of entanglement. On spoke hand wheels additional risks of crushing and shearing may exist.

According to EN 1010-1, hand wheels and cranks on powered machinery must be prevented from rotating automatically with the machine movement.

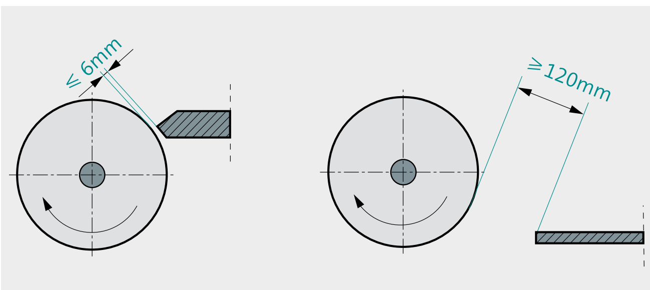
Possible safeguarding measures are:

- disconnection of the hand wheel already at the transmission stage
- disengagement of the hand wheel clutch; spring force keeps the wheel out of reach (safety hand wheel)
- isolation of the hand wheel drive from the electric power supply by means of a safety limit switch

2.1.1.3 Rollers in the vicinity of fixed machine parts

Inrunning nips between rollers and fixed machine parts (cross beams) are avoided if the gap between roller and cross beam is

- 120 mm minimum where there is a risk for fingers, hands and arms (figure on the right) or
- as small as possible, not exceeding 6 mm (EN 1010-1) or 4 mm (EN 1010-2) and designed as a suitable section.



The 120 mm requirement for gaps is taken from EN ISO 13854 stipulating minimum distances for avoidance of crushing of parts of the body.

Where only fingers are at risk, the gap can be reduced from 120 mm to 25 mm. Different minimum distances between moving machine parts are, however, applied where there is a risk of drawing-in of legs, the head or the whole body.

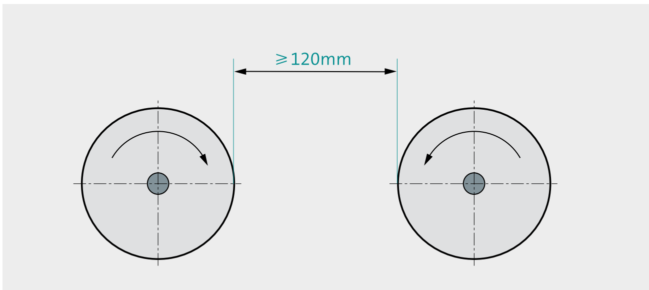
2.1.1.4 Cylinder and roller sets

Inrunning nips on cylinders, rollers, drums and rolls are danger points with the risk of drawing-in of parts of the body. For safeguarding inrunning nips by measures other than guards, a variety of design solutions are available.

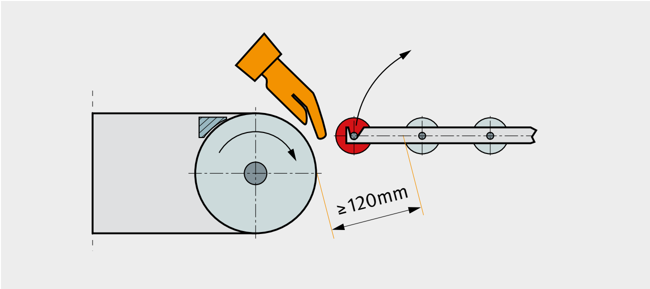
The following examples illustrate solutions for some typical applications:

When selecting the right solution for safeguarding inrunning nips, the designer will always have to look at the specific application. The examples shown below can, therefore, only be taken as a basis for his own inspiration:

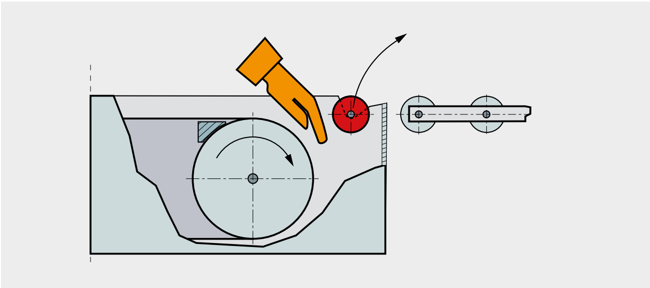
- Adequate distance between cylinders, rollers, drums and similar elements (according to EN ISO 13854).



- Sufficient deflection and light weight of rollers on roller conveyors. The slope of the hand causes the rollers to move upwards.
- Spring-loaded roller at the transfer point of a roller conveyor or belt drum; if a hand or arm or any object is drawn in, the roller will pop out of its bearing. No inadmissible forces are exerted on the drawn-in part of the body.



Spring-loaded roller on roller conveyor



Spring-loaded roller on drum belt

2.1.1.5 V-belt and rope drives

Hazardous movements created by rotating parts of V-belt and rope drives are in most cases protected by guards. Measures other than guards are allowed where there is sufficient elongation capability of belts or ropes (sliding out) or low mechanical strength of flat or cord belts (breakage).

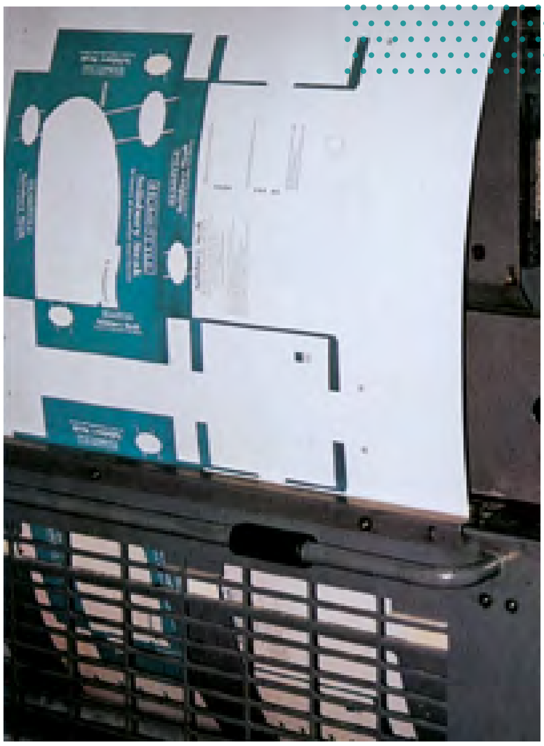
2.1.1.6 Machine parts with rectilinear or oscillating motion

Machine parts with rectilinear or oscillating motion often are the cause of hazards:

Crushing, puncture or cutting hazards are created, for example on stitching machines between lower and upper tool of the machine and the material being processed. Impact and crushing hazards exist where machine parts are opened and closed (platen machine).

On stitching, riveting, eyeletting and attaching machines and on gang stitchers, the danger points existing between the lower and upper tool must be avoided or be guarded. According to EN 1010-1, this requirement is satisfied where, for example,

- the gap between upper and lower tool in the open position does not exceed 4 mm (the closing distance of two parts from 4 mm to 0 mm is consequently considered safe) or
- the downward pressure of less than 50 N exerted by the downward tool and the operating force becomes effective only after, for example, a monitoring device has confirmed that there is no part of the body present between the movable tool and the work piece.



Movements created when clamping printing plates are considered sufficiently safe where the gap between movable and fixed part does not exceed 4 mm.

2.1.2 Safeguarding of mechanical hazards – indirect safety technology

According to EN ISO 12100, safeguarding (guards and protective devices) is required to protect persons from hazards which cannot be avoided or adequately designed-out.

Safeguarding measures may cover more than one hazard. For example, a fixed guard preventing access to a mechanical danger point can also serve to reduce the level of noise or radiation.

The insulated guard on the milling head of a perfect binder is also used for noise reduction.

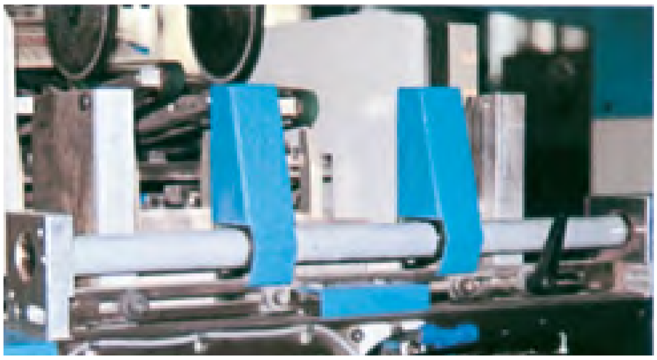
Examples of the application of indirect safety technology

2.1.2.1 Shafts, rollers

In order to prevent hair and clothing being drawn in, drive shafts can be safeguarded by:

- enclosures with taped helical springs, concertina-type guards or telescopic guards
- enclosures with sleeves which do not automatically rotate with the shaft

Safeguarding of shafts by means of tapered helical springs

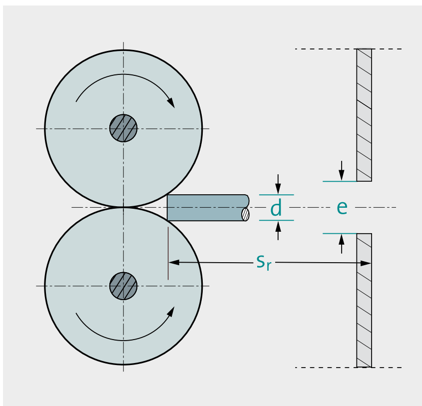


Safeguarding of shafts using sleeves which do not rotate automatically

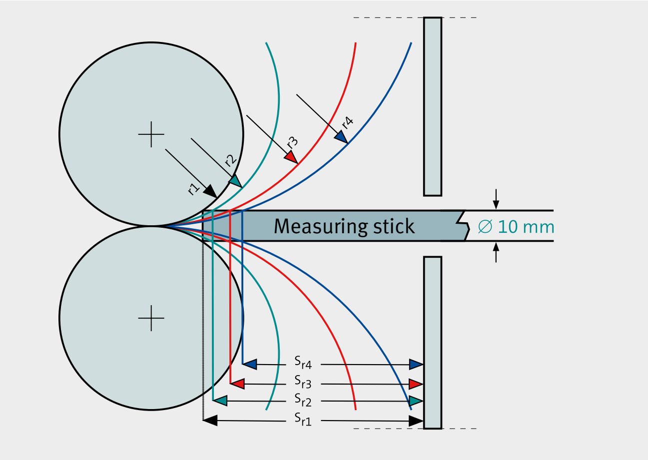
2.1.2.2 Cylinder and roller sets

Inrunning nips on cylinders, rollers, drums, rolls and similar elements can be safeguarded by guards or by trip bars observing the safety distances required by EN ISO 13857:

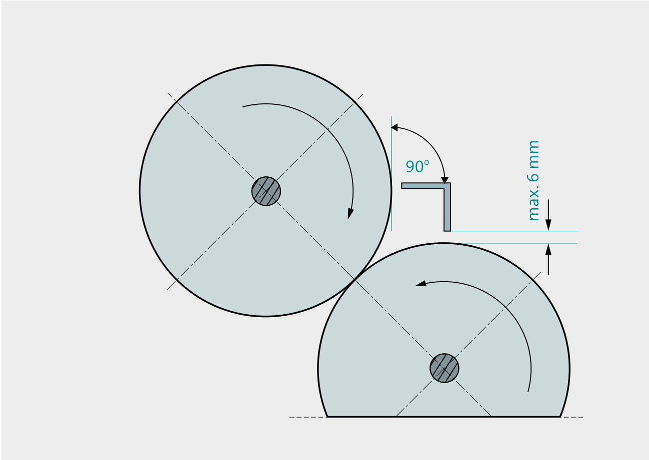
- **Fixed guards**
  (can be removed only by means of tools). Where openings are provided in the guards to allow feeding of material (for example sheets, blanks, web), the safety distance s_r to the danger point specified in EN ISO 13857 must be applied. The illustration below shows how the safety distance can be measured.



Safeguarding of inrunning nips by fixed guards

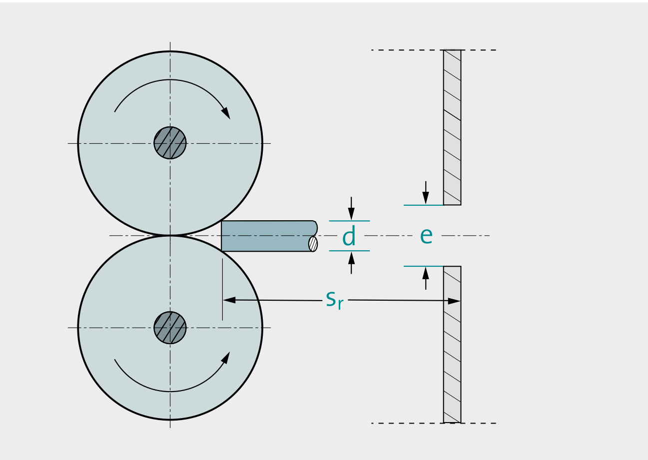


Measuring of safety distance on inrunning nips for varying roller diameters



Safeguarding of inrunning nip by suitable section

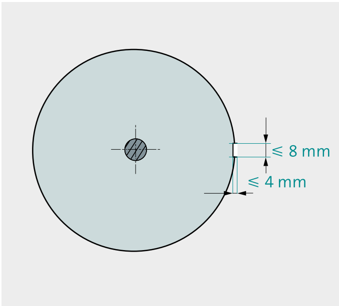
According to EN ISO 13857, the safety distance s_r is dependent on the opening width e. The safety distance is measured from that point where the gap between the roller surfaces is d = 10 mm.



Measuring of safety distance on inrunning nips

Smooth cylinders are rotationally symmetrical bodies which may have cut-outs or elevations of 4 mm maximum and with axial gaps of 8 mm maximum in the circumferential direction, without sharp or cutting edges (EN 1010-2).

Notwithstanding this requirement, rotary newspaper printing presses are allowed cylinder gaps of 19 mm instead of 8 mm.

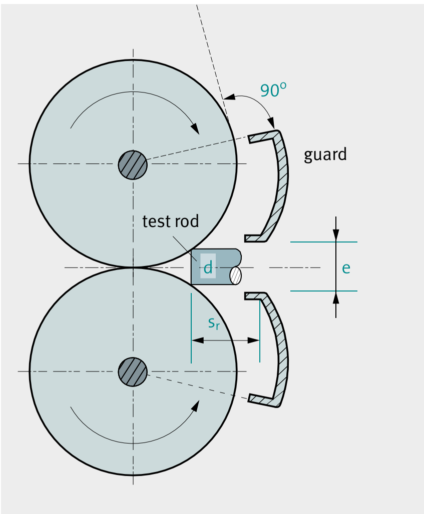


Smooth roller

- **Fixed guards designed as suitable angle sections** (extending across the entire working width, maximum gap between cylinder and sections ≤ 6 mm). Sections are suitable, for example, if they are shaped in such a way that their deflecting edges are perpendicular to the rotating surface. Such guarding is allowed only for smooth cylinders and rollers.

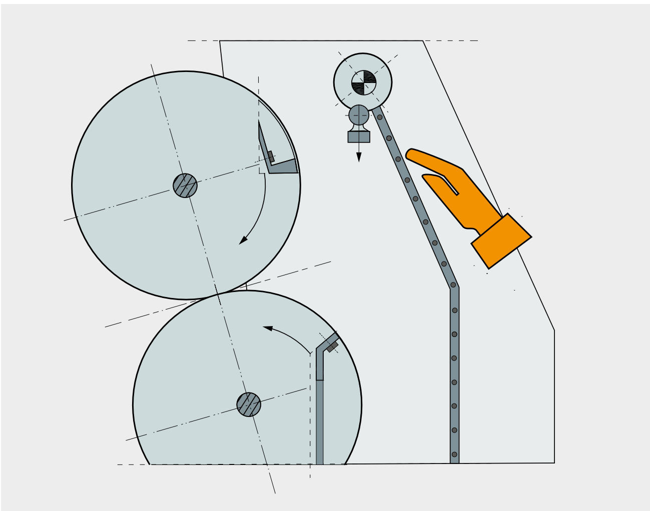
The deflecting edge of the guard must be perpendicular to the roller surface in order to avoid a wedge effect between guard and roller. Distances should be as small as possible and are limited to 4 mm maximum (EN 1010-2).

- **Angle sections as guards** with openings for feeding web material. The safety distance depends on the opening width (EN ISO 13857). For example, where the aperture on the infeed guard has a width e of 6 mm maximum, the safety distance s_r must be at least 10 mm.



Such guard design facilitates feeding of the paper web. The safety distance s_r is dependent on the opening width e as specified in EN ISO 13857.

- **Movable interlocking guards, enclosures**
  Guarding systems which have to be removed or opened frequently or for setting-up must be interlocked with the hazardous movement. Interlocking with guard locking is required where the risk of injury persists after opening of the interlocking guard (for example on shredders, sheeters).

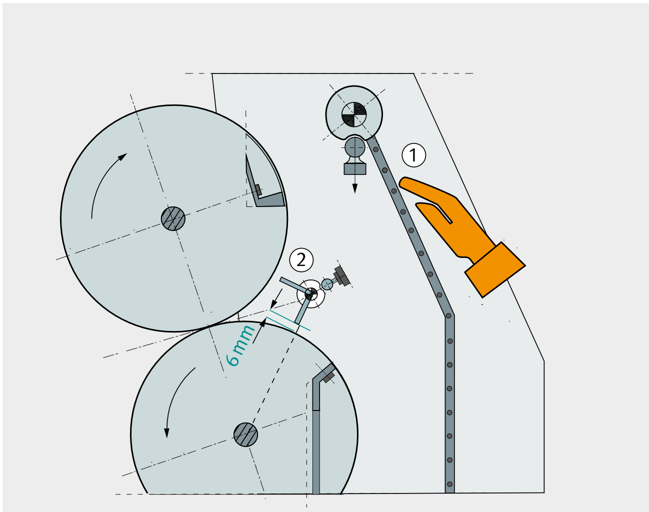


Safeguarding of inrunning nip by a guard interlocked with the machine drive

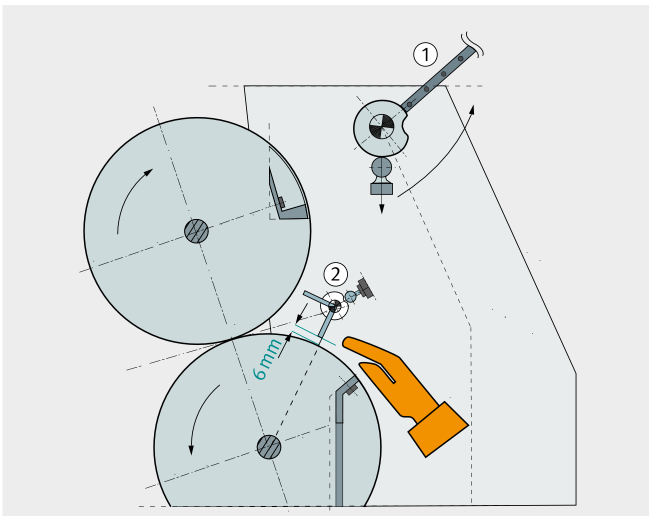
On sheet-fed offset presses, two protective devices are required to safeguard inrunning nips on rollers. For the continuous printing operation, a guard is provided (for example mesh guard) which is interlocked with the machine drive. After opening of this guard, a second safety device must become active, depending on the mode of operation. The second safeguard can be a protective device with approach reaction, for example a trip bar satisfying the following requirements: the travel of the bar must be more than the stopping path of the hazardous movement (cylinder rotation).

An alternative method of safeguarding would be to restrict machine operation to the hold-to-run mode once guards have been opened.

Safeguarding an in-running nip through a combination of different guards

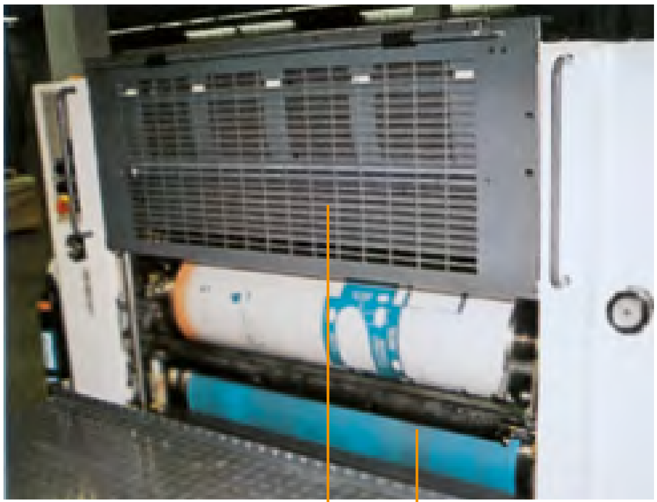


① **Large-area interlocking guard (closed)**
② **Trip bar directly in front of the danger point**



① **Large-area interlocking guard (open)**
② **Trip bar directly in front of the danger point**

Example of a combined guarding system on a sheet-fed offset printing press



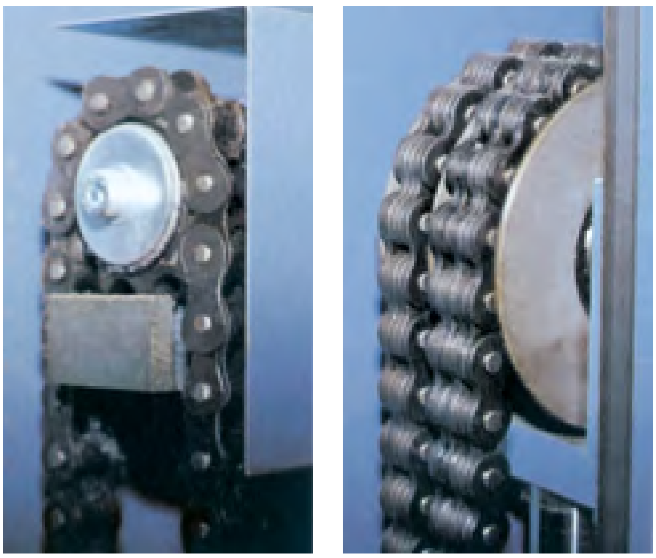
fixed guarding interlocked with the machine drive

trip bar

2.1.2.3 Chain drives

Chain drives, by the very nature of their design, are the source of hazardous wrapping points and must therefore be guarded by enclosures or by shaped fillers.

- **Drive chains**
  Wrapping points on chains must be safeguarded by guards. Complete enclosures should be preferred.
- **Pulleys**
  Deflection pulleys (chain tightening pulleys) and other types of chain wheels require enclosures for guarding.



Solutions for safeguarding wrapping points on chains

2.1.2.4 Geared drives and worm drives

Geared drives and worm drives create crushing and shearing points which must therefore be enclosed.

2.1.2.5 Belt and rope drives

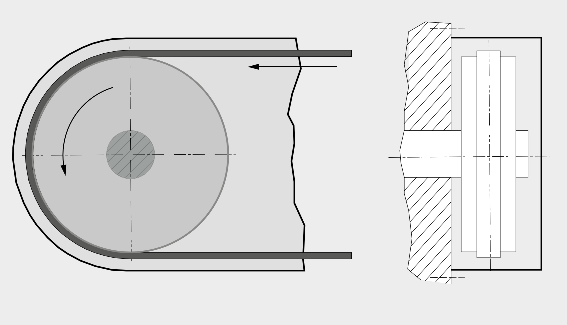
Flat belts, V-belts and rope drives must be safeguarded by enclosures. Where it is not possible to enclose the entire belt drive, inrunning nips must be guarded or protected by shaped filling pieces.

Inrunning nips on idler pulleys and tightening pulleys also require safeguarding.

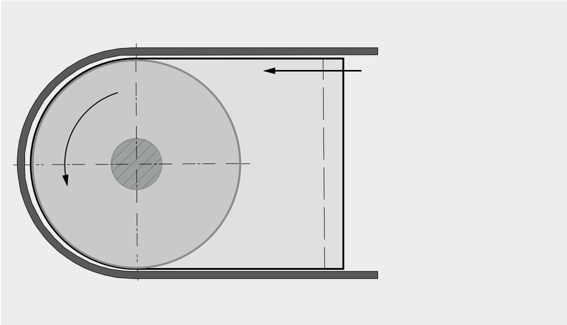
On printing and paper converting machines, threading of web must be a safe operation. Where powered devices are used for threading webs, access to danger points must be prevented by guards eliminating the possibility of reaching in.

Access to danger points is prevented if, for example

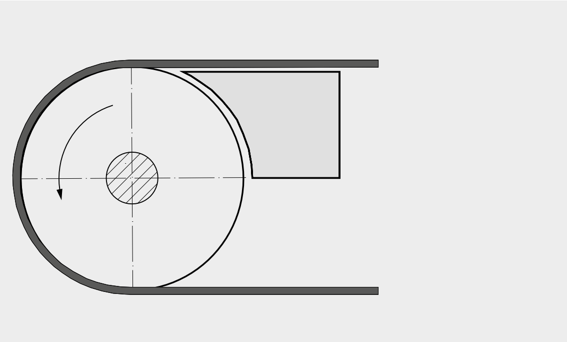
- the inrunning nips between threading ropes and idler pulleys are guarded. Safeguarding can be achieved, for example, by providing fixed guarding discs on the outside of the pulleys. Their diameter must exceed the pulley diameter by at least 120 mm.
- chain inrunning nips are safeguarded as far as possible by means of filler pieces.



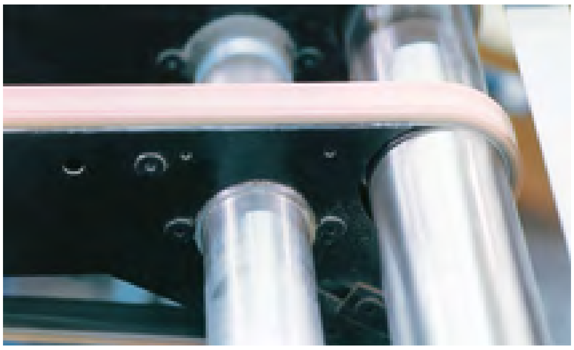
Complete enclosure



Guarding on the side



Shaped part fitting into the nip as filler



Example for fitting a filler piece

Safe design of a web threading device

2.1.2.6 Machine parts with rectilinear or oscillating motion

The hazards existing on these machine parts can be safeguarded as follows:

- **Fixed guards**
  a) Enclosures
  Guards which are removed or opened infrequently or only for maintenance must be fitted in such a way that they can only be removed or opened by means of tools or they must be interlocked with the drive. Knurled-head screws, wing-type screws and star knobs are not permitted.

Large transparent guard in front of the danger zone on a stitching machine

Large interlocking guard in open position

Guarding of the danger point on the stitching head of a stitcher by use of an adjustable guard

Large interlocking guard in closed position

b) Deflecting guard
On a lever-operated guillotine, for example, left-hand fingers are protected by a deflecting guard on that side where the left hand could reach the danger point in the course of the cutting operation. A deflector is also provided on the lever handle to prevent fingers of the hand holding the lever handle from getting between the upper and lower knife tool.

Finger protection on lever-operated guillotine

c) Adjustable fixed guards
On stitching machines where material is fed and removed manually (see figure on page 51) the guard must be adjusted to the material to be stitched.

- **Movable interlocking guards**
  Hazardous movements can only be carried out with the guard completely closed. When the guard is opened, the hazardous movement is stopped. Care must be taken that the stopping path of the tool is short enough to be safe.
- **Safety devices with approach reaction**
  For trip devices such as trip bars or handles, the travel of the bar must be longer than the stopping path of the hazardous movement.

Two-hand control: distance between actuators 260 mm minimum

- **Two-hand control devices**
  Two-hand controls are permitted only where the working stroke or cycle can be interrupted any time during the hazardous movement. The stopping time of the hazardous movement must be short enough to ensure that the danger has ceased to exist after release of the actuators (see also Clause 1.8.4.2, Two-hand controls).

- **Electro-sensitive protective devices (light barriers, light grids)**
  The hazardous movement is stopped as soon as any object or part of the body interrupts the light beam.

2.1.3 Warning of risks – warning safety technology

Where danger points can neither be avoided nor completely safeguarded, the conditions of safe use of the machine must be indicated. This is done, for example:

- in the instruction handbook
- by danger marking
- by warning signs.

Instruction handbooks should be clear and easily understandable. The minimum requirements for instruction handbooks are specified in EN ISO 12100. Operators must be in a position to reach the instruction handbook easily and anytime.

Detailed information about the requirements of danger marking in Germany is given in the Technical Workplace Regulation ASR A1.3 “Health and Safety Marking”.

Warning signs can, for example, be required for warning of hot surfaces behind guards which can be opened or warning of high voltage. Residual risks may also arise, for example, from protruding machine parts. Such parts must be padded and provided with a clear and durable danger marking where there is the risk of bumping.

Where persons cannot be easily freed out of a dangerous situation under the intended use of the machine, equipment must be provided to facilitate evacuating.

Danger marking on folding hopper of a newspaper offset printing press

Protruding machine parts must be padded and provided with clear and durable danger marking

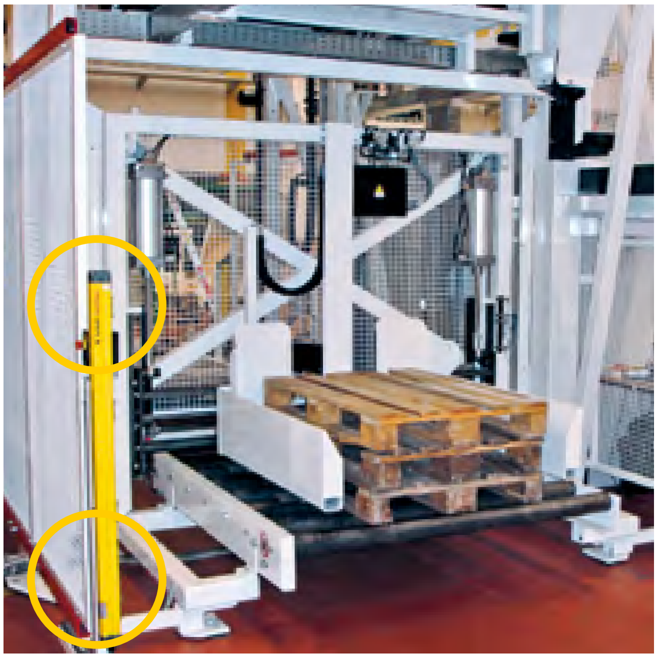
2.1.4 Further technical safety requirements

Perimeter fencing must be designed in such a way that the distance between floor level and the lower edge of the fence is a maximum of **200 mm,** and between floor level and the upper edge of the fence at least **1,400 mm.** The safety distances of EN ISO 13857 and EN 1010 must be adhered to.

Doors allowing access to danger zones guarded by fencing must be interlocked or access must be prevented by electrosensitive protective devices, i.e. light barriers arranged at a height of 400 mm and 900 mm.

On **carriages which travel on rails under power** (for example feeders on in-line machines), the crushing points between wheels and the runway must be safeguarded. This can be achieved, for example, by the provision of fixed foot guards with their lower edge not more than **15 mm** above the runway (EN 1010-1).

Machine parts, enclosures, guards and the like which are hinged must be secured against **unintended falling shut.**



Safeguarding of danger zones by perimeter fencing and prevention of access by light barriers at a height of 400 and 900 mm

Safeguarding against gravity falling of guards by means of gas pressure springs

Measures to prevent gravity falling are, for example,

- counterweights
- helical springs
- gas pressure springs
- latches which positively hold the lifted parts open
- ensuring that the centre of gravity of the lifted parts in the open position is sufficiently far behind the pivot point.

2.1.5 Working platforms, catwalks, steps and access stairs, passageways

Where work cannot be carried out from floor level because of the height of the operating position, adequate means of access and working platforms must be provided.

Plant visits and investigations into accidents have revealed that access stairs and steps, catwalks and working platforms which are not designed in compliance with safety regulations and neglect ergonomic aspects often give rise to tripping, slipping and falling hazards. Where fixed means are provided for access to raised workplaces on machines and equipment, consideration should also be given to additional risks caused by, for example, the need to take tools to the work place and the risk of material or objects falling down on persons under catwalks.

The safe design of access stairs, catwalks and platforms on machines and equipment must, therefore, be given the same attention as the actual safety measures on the machine.

Fixed steps or platforms must not reduce or impede the effect of protective devices or devices with safety function or facilitate their defeat by simple means.

Raised permanent workplaces should have a floor space of at least 1.5 m^2 per person and a minimum width of 1 m.

A proven method is colour marking of platform edges

Working platforms must be so designed that work can be carried out from positions at a height of between 500 and 1,700 mm (EN ISO 14122-2).

For safe and easy access to machine groups, **machine catwalks** must be provided with adequate means of access.

Floor covering of working platforms, catwalks and access stairs must be slip-resistant, for example by using textured plates.

In order to prevent slipping, for example, on spilled fluids, draining facilities (for example gutters, outlets) should be provided. Inclined surfaces help to speed up this process.

Accumulation of substances (dirt resulting from, for example, solvents or inks) must be prevented. Suitable surfaces are, for example, steel grates or perforated steel plates.

Floor covering must be even in order to avoid tripping hazards. The maximum permissible difference in level between adjacent floor elements is 4 mm.

In order to avoid persons walking under catwalks or working platforms being hit by falling objects, floor openings are restricted to a size where a ball of 35 mm in diameter cannot fall through.

Where work places, which are not only in occasional use, are located underneath catwalks or working platforms, floor openings are restricted to ball sizes of 20 mm maximum.

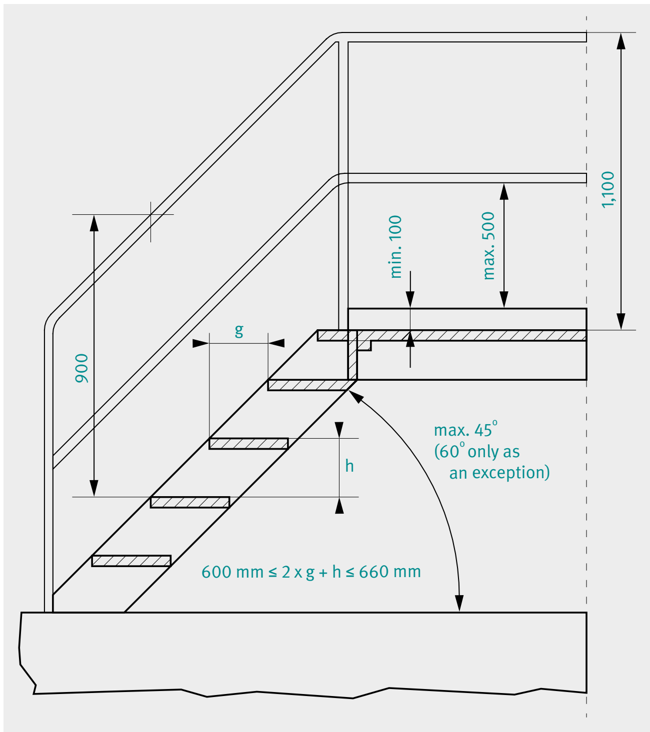
Toe boards are required where gaps of more than 30 mm between floor covering and adjacent parts exist in order to prevent objects from falling through.

Where removable or hinged type floor elements are provided, for example, for maintenance purposes, they must be safeguarded against unintended hazardous movements (for example by screwed connections). Fasteners must be accessible for functional inspection any time.

Platforms, catwalks and working platforms must be rated for the operating loads existing on the machine or equipment. The minimum is 2 kN/m^2 under distributed load for the supporting structure and 1.5 kN concentrated load applied in the most unfavourable position over a concentrated load area of 200 mm x 200 mm for the flooring. The deflection of flooring on the basis of the design load is limited to 1/200th of the span. The level difference between loaded and unloaded neighbouring flooring is limited to 4 mm, in analogy to the difference of level of adjacent floor covering.

Access stairs and passageways must have, unless prevented by exceptional circumstances, a clear **passage height of at least 2.1 m** (exceptions are rotary printing presses and varnishing machines etc. where the minimum height is reduced to 2.0 m). The **width** required is **0.6 m minimum**, preferably 0.8 m, which must be increased to 1.0 m where several persons need to pass or cross. For **stairs and stepladders** the required clear height is **2.3 m minimum**. Where the required heights are restricted by the building construction, protruding parts must be padded and provided with danger marking.

Non-slip covering and well-adjusted step height (ill. manroland)



Access stairs in compliance with regulations (dimensions in mm)

Access steps
A significant aspect when designing large installations is that access of operating and maintenance personnel moving around in particular areas of the machine must be safe. For assistance in selecting the appropriate fixed means of access between two levels of access refer to Annex C of EN 1010-1 in connection with EN 14122-1.

Access stairs
For access to permanent work places, stairs should be provided in accordance with the provisions of EN 14122-1 with a preferred pitch angle of 30° to 38°. The maximum permitted pitch angle is 45°. When selecting the appropriate pitch angle, it is important to bear in mind that stairs are often used to transport tools or work material and this must be accounted for in the design. Where stairs cannot be provided for constructional reasons, alternative means of access may be selected in accordance with Annex C of EN 1010-1 on the basis of risk assessment. The maximum pitch angle for stepladders is 75°. In cases where risk assessment has been carried out following the propositions in Annex C of EN 1010-1 and provided that spatial reason prohibits the use of stairs, the following exceptions are permitted, taking account of the existing risk.

PERMISSIBLE EXCEPTIONS OF PITCH ANGLES BASED ON BENCHMARK FIGURE E

E ≤ 6	Stepladders with a pitch angle of 46° to 60° maximum, positively secured against side-slipping and provided with handrails
E ≤ 3	Stepladders with a pitch angle of 46° to 74° maximum, positively secured against side-slipping
E ≤ 2 and E = 0	Ladders with a pitch angle of 75° to 90° maximum, positively secured against side-slipping

Fall-off protection on machine access by locating stairs sideways

BENCHMARK FIGURE E1

Frequency of access	**Benchmark figure E1**
Less than once per week	1
Not more than once per week	2
Not more than once per day	3
More than once per day	4

BENCHMARK FIGURE E2

Need to carry objects	**Benchmark figure E2***
No objects to be carried in hands	0
Light objects with a maximum weight of 5 kg	1
Fairly heavy objects with a maximum weight of 10 kg	2
Heavy objects with a weight of over 10 kg	3

*) If the distance between levels is not more than 1.6 m, E2 = 0 can be assumed

ADDITIONAL FACTORS A1 AND A2

Additional factors	
Need to carry cumbersome objects	A1 = 1
Distance between two levels is more than 3 m	A2 = 1

The benchmark figure is E, calculated as the sum of E1 + E2 + A1 + A2, i.e. E includes all specific evaluation factors to be considered (E1 – the frequency of access, E2 – valuating the need to carry objects and the two additional parameters A1 and A2).

Where access between two levels requires pitch angles of more than 75° up to 90°, EN ISO 14122-1 suggests using a fixed vertical ladder. The requirements for fixed ladders are specified in EN 14122-4.

When designing access stairs and steps, it is of special importance that step heights and tread lengths do not vary.

The **basic principle** is:
Pitch angles and step dimensions must be consistent over the entire flight of stairs, including the first and the last step.

Stairs must have at least one handrail. For stairs with a width of ≥ 1,200 mm and also for stepladders, handrails are required on both sides.

Footsteps are allowed for machine locations which are accessed infrequently so that they are no permanent work places. In order to avoid machine parts or free steps being used as handholds, footsteps must always be provided with at least one handle.

The number and arrangement of steps and handles must be such as to provide at least 3 possibilities of support (two hands and one foot or two feet and one hand).

Machine catwalks, working platforms and stairs with a height of 0.5 m or more must be fitted with **railings** and **toe-boards** for fall-off protection and prevention of hazards from falling objects.

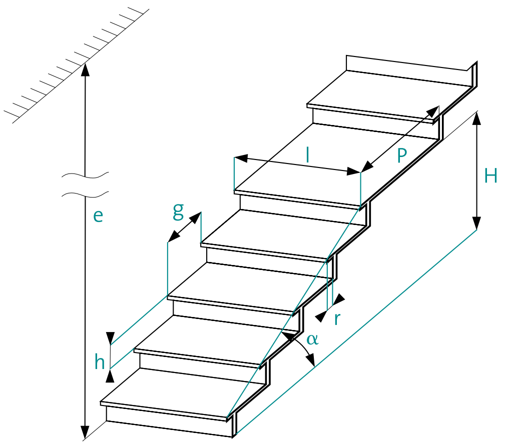
Railings consist of a handrail, at least one intermediate rail, one toe-board and posts. Instead of intermediate rails, vertical fill-in uprights may be used. Special attention must be given to the height of the handrail which must be at least 1,100 mm[1]. The requirement for toe-boards is a height of 100 mm minimum and a clearance from floor of 10 mm maximum. The clearance between toe-board and intermediate rail, between intermediate rails and between intermediate rail and handrail must not exceed 500 mm. For uprights fitted in place of the intermediate rail, the horizontal clearance between uprights is limited to 180 mm. Gaps in handrails must not have less than 75 mm clearance between individual segments and not more than 120 mm clearance in order to avoid crushing of the hand. For rail segments with round edges, combined requirements apply specifying a clearance of 180 mm between segments and a minimum railing height of 1,100 mm. Larger gaps need to be safeguarded by self-locking passage barriers (also see EN ISO 14122, parts 1 to 4).

Individual railing segments must not have friction-type connections as such connections can loosen on account of machine vibration. Connections must always be positively fitting. The maximum width between vertical railing posts should not exceed 1,300 to 1,400 mm.

Individual requirements for the design of stairs, working platforms, handles, railings, steps and machine catwalks are specified in the following tables.

[1] Notwithstanding the height requirements of handrails on working platforms and machine platforms, national building regulations may specify a handrail height of 1,000 mm for railings on platforms and galleries in buildings (not part of the machinery).

Design features of stairs, ladders and railings



H height of flight of stairs
g tread
e clear height
h pitch
p length of platform
r undercut
α pitch angle
l stairway width

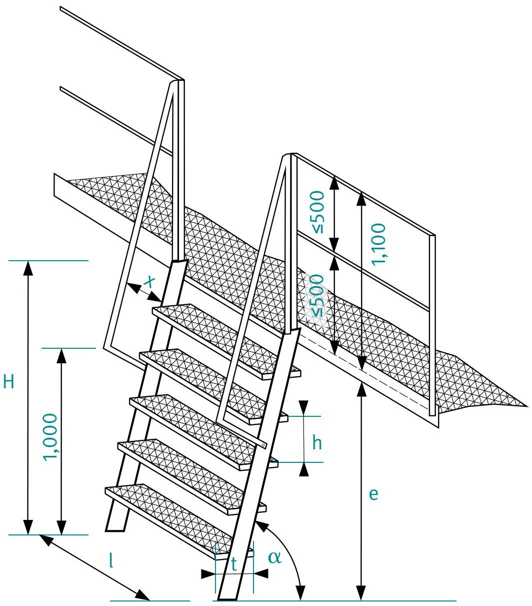
1. STAIRS

Component	Technical features			Design
Stairs	Dimensions	Pitch angle α		$\alpha \leq 45°$ recommended: $\alpha = 30°$ to $38°$
		Height of stairway H		$H_{max} = 3{,}000$ mm (per flight of stairs for stairways with several flights) $H_{max} = 4{,}000$ mm (for stairways with one flight of stairs) $H_{max} > 4{,}000$ mm: platform required with ≥ 800 mm length
		Tread height g Pitch h		$600 \leq g + 2h \leq 660$ (at $\alpha = 30°$ to $38°$) • Pitch h must be constant over the entire flight of stairs • the highest step must be level with the platform
		Width of stairway l when frequented by:	Single persons	l = 600 mm
			Low traffic	l = 800 mm
			Normal traffic by several persons	l = 1,000 mm
		Undercut r		r ≥ 10 mm
		Clear height of passage e		e ≥ 2,300 mm
	Strength	Design load	Single person without load	$q_{min} = 1{,}500\ N/m^2$
			Several persons with load	$q = 4{,}000\ N/m^2$
			Front edge of step	$q = \frac{1{,}500}{0.1 \times 0.1}\ N/m^2$ [2]
		Deflection		$y_{max} = l/300$ of the span under load, but maximum 6.0 mm
	Surface	Tread safety		slip resistant: • for example textured metal plate • flooring class R 10 [1]
		Material characteristics		corrosion-resistant

[1] acc. to EN ISO 14122-2

[2] acc. to EN ISO 14122-3: Along the tread direction the front edges of steps must be capable of taking up a load of 1,500 N on an area of 0.1 m x 0.1 m.

Design features for stairs, stepladders and railings



H height of ladder
g tread
e clear height
h pitch
p length of platform
α pitch angle
l stairway width
x distance between pitch and axis of handrail

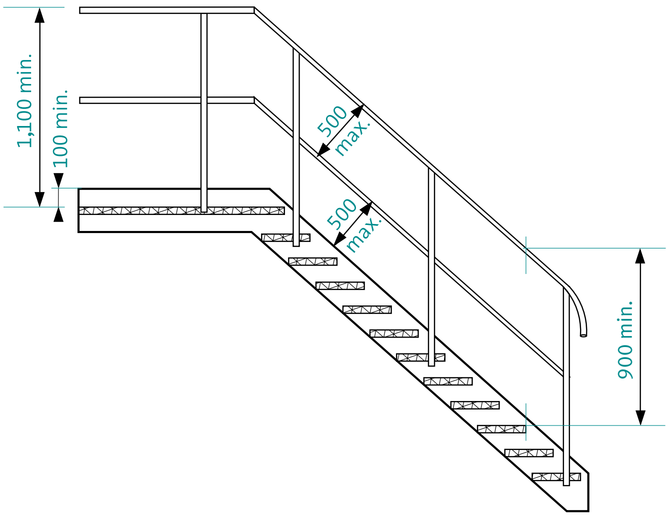
2. STEPLADDERS

Component	Technical features			Design
Stepladder	Dimensions	Pitch angle α		$46° \leq \alpha \leq 75°$ recommended: $\alpha = 46°$ to $60°$
		Height of stepladder H		$H_{max} = 3{,}000$ mm H › 3,000 mm: platform required with ≥ 600 mm length
		Tread length t		$t_{min} = 80$ mm
		Pitch h		$h_{max} = 250$ mm Note: Pitch h must be constant over the entire stepladder
		Width of stairway l		l = 500 mm–800 mm recommended: l = 600 mm
		Distance x between pitch and axis of handrail:		α (degree) / x (mm) 60 / 250 65 / 200 70 / 150
		Clear height of passage e		e ≥ 2,300 mm
	Strength	Design load	Single persons without load	$q_{min} = 1{,}500\ \mathrm{N/m^2}$
			Several persons with load	$q = 4{,}000\ \mathrm{N/m^2}$
			Front edge of step	$q = \frac{1{,}500}{0.1 \times 0.1}\ \mathrm{N/m^2}$ [2]
		Deflection		$y_{max} = l/300$ mm
	Surface	Tread safety		slip resistant: • for example textured metal plate • flooring class R 10 [1]
		Material characteristics		corrosion-resistant

[1] acc. to EN ISO 14122-2

[2] acc. to EN ISO 14122-3: Along the tread direction the front edges of steps must be capable of taking up a load of 1,500 N on an area of 0.1 m x 0.1 m.

Design features for stairs, stepladders and railings

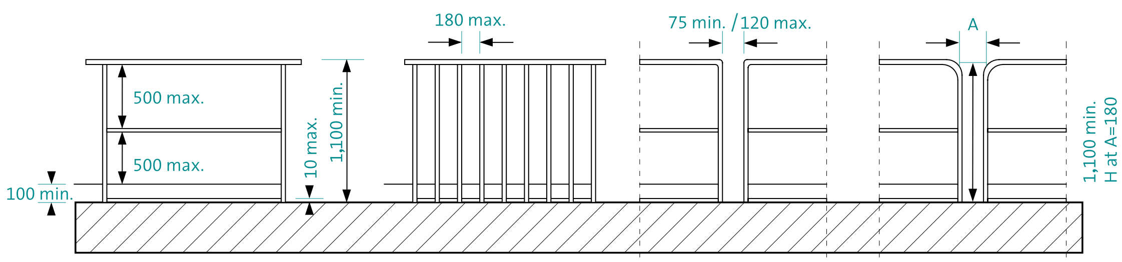


General requirements:

- Stairs must have at least one handrail
- For heights above 500 mm, a railing must be provided as fall-off protection
- Railings consist of one handrail, at least one intermediate rail and posts
- For stairs with a width of l › 1,200 mm and above at least two handrails/ railings are required, likewise for all stepladders.

3. RAILINGS

Component	Technical features			Design
Railings on stairs	Dimensions	Vertical height of handrails		900 mm minimum
		Distance of intermediate rail	from handrail	≤ 500 mm
			from side wall of stair	≤ 500 mm
		Diameter of handrail		consistent between 25 mm and 50 mm
Horizontal railings	Dimensions	Height of handrail		1,100 mm minimum
		Distance of intermediate rail	from handrail	≤ 500 mm
			from toeboard	≤ 500 mm
		Height of toeboard (not required for a fall-off height up to 1,600 mm)		minimum 100 mm; maximum 10 mm above tread level
		Distance of posts		max. 1,500 mm
		Distance of intermediate uprights		max. 180 mm
Common	Strength	Horizontal shifting load		F_{min} = 300 N/m² x distance between posts [m]
		Deflection		y_{max} = 30 mm (without permanent deformation)



Railing dimensions

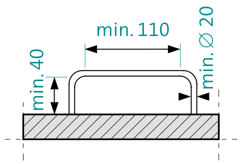
In deviation from the height requirements of handrails on machines national building regulations may specify a handrail height of 1,000 mm for railings on platforms.

Design features of single and multiple footsteps, handles

General requirements:

- Any footstep requires the provision of one or more handle(s)
- Handles must at least partly be seizable from the reference level

3. RAILINGS

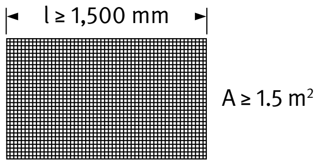
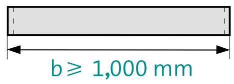
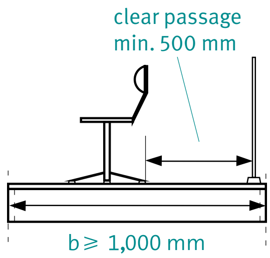
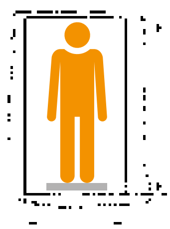
Component	Technical features			Design	
Single footsteps	Dimensions	Width b	for 1 foot	b_{min} = 200 mm	
			for 2 feet	b_{min} = 300 mm	
		Depth t		t_{min} = 300 mm	
		Step depth t (Access)		t_{min} = 200 mm	
		Height of step h for single steps		h ≤ 300 mm (h_{max} = 500 mm)	
Multiple steps		Height of step h for intermediate steps		h ≤ 300 mm	
		Height of upper step (standing area)		H_{max} = 1,200 mm	
		Width of reference level		500 mm minimum	
		Standing area		200 x 200 mm minimum	
	Material	Characteristics		corrosion-resistant	
		Surface		slip-resistant: • for example textured sheet plate • flooring class R 10 [1]	
Handles	Dimensions	Depth		40 mm minimum	 Round sections are preferred; if not, there shall be no sharp edges
		Length		110 mm minimum	
		Diameter		20 mm minimum	

1) acc. to EN ISO 14122-2

Design features of working platforms and gangways

Note: Working platforms must be fitted such that operating personnel can carry out operations at a height of 500 mm and 1,700 mm

DESIGN FEATURES OF WORKING PLATFORMS AND GANGWAYS

Component	Technical features			Design	
Working platforms (fixed)	Dimensions	Area A per person			
		clear width b	 Working in upright position		May be reduced depending on: • only used infrequently • reduction only for a short distance, then back to b ≥ 600 mm h ≥ 2,000 mm
			 Working in seated position		
Gangways			Walked on by one person	b ≥ 600 mm recommended: 800 mm	 If below minimum dimensions: • padding • danger marking (yellow/black) of danger zone
			Traffic by persons	b ≥ 1,200 mm	
			Use as escape route	b ≥ 1,200 mm in dependency of the specific requirements	
Common		clear height of passage		h ≥ 2,100 mm	
		Height of platform	from 300 mm	adequate means of access	
			from 500 mm	railing and toe board required	
	Strength	Design load	Distributed load supporting structure	$q = 2{,}000\ N/m^2$	
			Point load	$q = 1{,}500\ N/m^2$ (on an area of 200 mm x 200 mm at the most unfavourable position)	
		Deflection y		y_{max} = span width/200, resulting level difference ≤ 4.0 mm	
	Surface	Tread safety		slip resistant: • for example textured metal plate • flooting class R 10 [1]	
		Material characteristics		corrosion-resistant	

[1] according to EN ISO 14122-2

2.1.6 Ergonomic design

Printing and paper converting machines must be designed according to ergonomic principles. The relevant standards are the European standard EN 614-1 “Safety of machinery – Ergonomic design principles – Part 1: Terminology and general principles” and EN 614-2 “Safety of machinery – Ergonomic design principles – Part 2: Interactions between the design of machinery and work tasks”.

The following aspects need to be given special consideration when designing printing and paper converting machines:

- Awkward body postures during operation and feeding or removal of material and during maintenance and cleaning must be avoided. The technical means to improve this situation is the provision of steps and catwalks at adequate height.
- Where machine operation requires manual handling of loads (tools, substances, material) of over 25 kg, facilities should be provided to ease handling. EN 1005-2 “Safety of machinery – Human physical performance – Part 2: Manual handling of machinery and component parts of machinery” specifies that such facilities or equipment should also be available for smaller loads.
- Force limits for the operation of machines (gripping, pulling, pressing) specified in the European Standard EN 1005-3 “Safety of machinery – Human physical performance – Part 3: Recommended force limits for machinery operation”, must be applied.
- The design of actuators and displays should satisfy the requirements of the European Standards EN 894-1 “Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 1: General principles for human interactions with displays and control actuators”, EN 894-2; Part 2: “Displays” and EN 894-3; Part 3: “Control actuators”.

BG ETEM has produced a brochure on the subject of ergonomics (available in German only): *Ergonomie* (Order number MB008).

2.1.7 Braking devices and clutches

It must be ensured that hazardous movements are not possible when the braking device is switched off. This is generally the case when operators want to move machines or separate units by hand. A safe solution would be, for example, interlocking of the braking device with the hazardous movement.

On single-stroke machines, clutch or brake failure must not give rise to a hazardous movement. This can be avoided, for example, by clutches with positive action.

2.1.8 Hydraulic and pneumatic devices

While pneumatic devices are used for fast movement sequences, hydraulic devices are the first choice when large forces are required for tasks such as lifting heavy reels of material. These are often used to support simple motions, for example the lifting of material reels onto unwinds. They are often electro-hydraulic or electro-pneumatic control systems designed in such a way that the linkage of signals takes place in the electric component while the rates of volume flow to the drive elements are controlled by electromagnetic valves.

Design must comply with the requirements of the European Standards EN ISO 4413* and EN ISO 4414**.

The following comments relate to some of the essential technical safety requirements. Information on control elements and actuators and relevant valves (pressure valves, non-return valves, throttle valves and directional control valves) is given in the annex of this brochure.

* **EN ISO 4413**
“Hydraulic fluid power – General rules and safety requirements for systems and their components”

** **EN ISO 4414**
“Pneumatic fluid power – General rules and safety requirements for systems and their components”

General
Irregularities, interruption, failure and return of energy supply must not generate hazardous movements.

Electric connections of electrically operated valves must comply with the respective standards, for example EN 60204-1. Where electrically operated valves must maintain their switching capability, manually operated auxiliary devices may be provided, preferably of the non-engaging type.

Technical documentation and marking
For each system, a wiring diagram must be provided in accordance with ISO 1219-2. Wiring diagrams must depict all components, line connections, lines, metering points where applicable, setting values of safety-related components, external power supply connections and respective disconnecting devices and devices provided for energy discharge. It is of special importance that valve marking and numbering is consistent throughout all wiring diagrams.

Machine marking for safety-related functions must comply with the respective wiring diagram, especially where, for example, confusion of lines would give rise to hazards. Methods approved in practice would be:

- arranging connections in such a way that they cannot be confused or
- using different types of connections.

Mains control switches and devices for energy discharge must be clearly identifiable.

All components must be provided with legible and indelible signs indicating

- name and abbreviated address of manufacturer
- manufacturer product designation
- design pressure
- symbols in accordance with ISO 1219-1
- proper marking of all connections

For hoses, the date of manufacture is also required. In the event of tower-type interlinkage between elements, i.e. single components are mounted on top of each other and do not use pipes or hoses, it is advisable also to specify the order of occurrence.

Operating parameters must be clearly and permanently noticeable (for example minimum/maximum pressure, minimum/maximum temperatures, minimum/maximum volume flow). For example, the maximum permissible pressure should be indicated on the manometer by a red marking or by a marking in the vicinity of the manometer.

Where hoses must be replaced during repair or maintenance and inspection, the maximum pressure of replacement hoses must be indicated.

Energy-isolating devices
As in electrical systems, hydraulic and pneumatic systems also need to be provided with central command devices (stop-valve, shut-off device) which are easily accessible. Where unexpected energy supply can cause hazards, such switches must be lockable in the OFF position.

On machines where combustion engines or electric motors are used to drive a compressor or a hydraulic motor, isolation may be effected by switching off and prevention of subsequent restart.

For pneumatic systems, quick-disconnect couplings may be used as energy-isolating devices. These must be designed in such a way that hazards are not created when handling them. When disengaging quick-disconnect couplings, a whiplash effect may occur resulting in the plug nipple shooting out of the coupling like a projectile.

This effect is prevented on “safety quick-disconnect couplings” where the separation takes place in two stages, the first being controlled pressure relief (ventilation) and the second the mechanical disengagement.

Safeguarding against pressure overload
All parts of machinery must be designed for or safeguarded against pressure which exceeds the maximum operating pressure. Pressure-limit valves are appropriate means to safeguard machines against inadmissible pressure.

It is also possible to use pressure control valves if they satisfy respective requirements (“secondary relief”, adequate ventilation profile width).

Pressure-limit valves (pressure-relief valves) will open if the maximum operating pressure is exceeded.

Pressure-control valves (pressure-reducing valves) act to maintain pressure at a preset value, taking account of input pressure and variations in pressure demand.

Pressure valves must be protected against inadvertent change of setting by locking or covering. Depending on the specific requirements it may also be appropriate to seal the setting device.

Safeguarding against excess of the maximum operating pressure is also required where pressure may be increased by external forces/loads.

Check valves (non-return valves)

In pneumatic and hydraulic systems, certain components often need to maintain their stored energy even after disconnection, for example where loads must be kept uplifted by pressure or where the clamping force of clamping devices must be maintained.

Leakage due to, for example, breakage of hoses or valves may generate hazardous movements. For such cases, non-return valves are required which are located directly on the component and which can be unlocked. Uncontrolled lowering of loads must be prevented by adequate means, otherwise mechanical supports must be provided for lifted loads, a requirement especially in cases where repair work must be done below loads. Mechanical locking devices such as latches, self-locking gears, locking pins or braking devices are appropriate means to this end. Hose lines between check valves and, for example, cylinders or uplifted loads must be avoided.

Flow-control valves (throttle valves)

Flow-control valves control the speed of flow to consuming ends (cylinder or hydro motor) by adapting the profile width (increase or decrease). Adjustable flow-control valves must be safeguarded against inadmissible change of setting.

Venting

Even with the pressure-generating device switched off, pneumatic or hydraulic energies may remain stored in supply lines. Such pressure may give rise to hazards. Especially in pneumatic systems, check valves may depressurize under such conditions (blocking cylinders, for example).

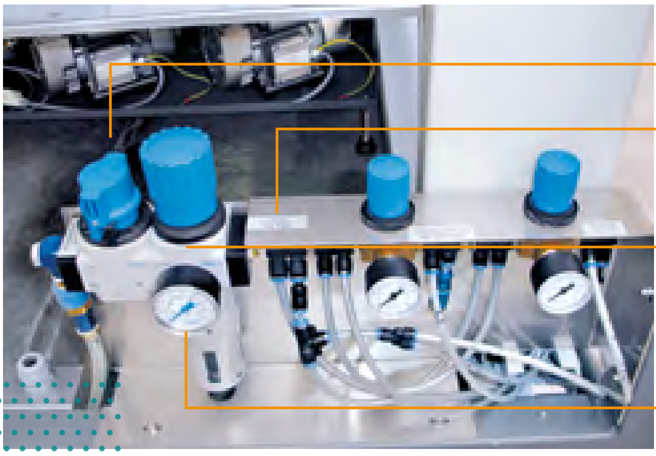
Air-vent valves are therefore required as a safety measure. Systems must also be provided with devices for complete pressure relief, for example where maintenance work must be carried out after isolation from power supply.

Vent holes must be so designed that energy is not discharged in the direction of operating personnel. They should also be provided with silencers.

In addition, the instruction handbook must inform about residual risks.

Directional control valves

This type of valve controls the direction of flow as well as START and STOP. Safety-related directional valves must be so designed that valves shift to a safe position after switching off (closed-circuit principle). Continuous valves such as proportional or servo valves can generally not satisfy this requirement due to their design. In most cases additional valves with discrete shifting positions will be required.



Drives which need to maintain or adopt a certain safe position in case of failure of the control system must always be valve-controlled to the effect that a defined valve position is maintained either by spring force or by a notch.

Manually operated valves must have adequate protection against inadvertent actuation of the operating element. All hand-operated valves, including those located outside control panels, must be provided with clear and permanent marking informing about their function and positions (marking for example by pictograms acc. to ISO 7000, see Annex).

Arrangement of piping and hose lines

Piping and hosing must be run in such a way that they cannot be misused for stepping or climbing on. All stresses from tension, pressure, bending and torsion must be avoided. Piping and hosing should be of adequate length and arrangement. Pneumatic piping and hosing must not be laid together with electric cables.

Monitoring

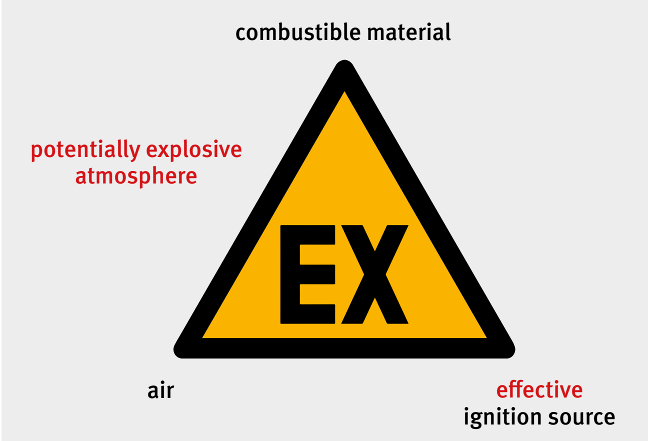
Changes in the operating parameters of the system which may lead to hazards must be clearly indicated.

2.1.9 Explosion protection

Mixtures of combustible gases, vapours and sufficiently dispersed dusts (particle size ‹ 1 mm) in air are in general potentially explosive when occurring within a specific range of concentrations. The potentially explosive range is limited by the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL).

The risk of explosion exists if the following three conditions occur simultaneously at the same place:

- combustible substance dispersed to a large surface and sufficient concentration
- effective ignition source
- air (oxygen as oxidizing agent).



Where a hazardous amount of potentially explosive atmosphere exists (10 l of a coherent substance in closed spaces is already considered an imminent danger), ignition may result in severe injuries and damage.

- **Primary explosion protection**
  Explosions can be prevented by either avoiding potentially explosive atmospheres or by adequately reducing them. This aspect should be given preference since avoiding risks is clearly a better solution than any protective measure.

– **Avoiding combustible substances**
The first step is to check whether combustible substances can principally be avoided or be replaced by substances which do not generate explosive atmospheres. Such substances should then be replaced as long as this does not conflict with technological or health requirements.

– **Manipulating the flash point of flammable liquids**
Liquids are considered flammable if they generate combustible vapour. Special attention must be given to the increased risk potential from flammable liquids with a flash point below 60°C.
The flash point is the lowest temperature at which the concentration of evaporated flammable liquid in air can form an ignitable mixture. The flash point is thus a criterion for assessing the hazard of a flammable liquid. The lower the flash point, the higher is the risk of inflammation. If the flash point is well below 60°C, potentially explosive atmospheres can be expected to build up already at normal room temperature and, with an effective source of ignition, to inflame at any time.

Substance	LEL (g/m³)	Ignition temperature (°C)	Flash point (°C)	Glowing combustion temperature (°C)
Isopropanol	50	425	12	N. A.
Toluene	39	535	6	N. A.
Anti set-off spray powder (virgin starch)	60	500	N. A.	410
Paper dust (gravure printing)	100	410	N. A.	340

Flash points can be manipulated by the admixture of other liquids. For example, by adding water to Isopropanol, the flash point can be considerably increased (10 mass-% of Isopropanol in water result in a mixture with a flash point of 39°C).

Liquids with a flash point above 60°C are not without problems and may also induce the risk of fire and explosion when heated to a temperature above their flash point or sprayed during the production process. Clarity can finally only be achieved by risk assessment and hazard identification which takes into consideration material as well as procedural aspects.

In many cases, it is possible to replace flammable liquids with a low flash point by liquids with a considerably higher flash point.

– **Limiting concentration**
Mixtures are flammable within a certain range of concentration. Mixtures below the lower explosive limit (UEL) are too lean to be ignitable. Mixtures above the upper explosive limit (UEL) are too rich; they will burn, but not explode.

The generation of potentially explosive atmospheres can be avoided by limiting concentrations to a level well below the lower explosive limit. A basic requirement to achieve this is a ventilation system which is adequately dimensioned and functional and effective under all operating conditions. For detailed information on the limitation of concentration see, for example, EN 12753 “Thermal cleaning systems for exhaust gas from surface treatment equipment – Safety requirements” and EN 1539 “Dryers and ovens, in which flammable substances are released – Safety requirements”.

- **Secondary explosion protection**
  Even when preference is given to the principles of “primary explosion protection”, there will remain some areas on equipment (for example gravure and flexo printing units) where potentially explosive atmospheres can occur. In these cases the aim is to avoid ignition sources becoming effective.

Main sources of ignition in the printing and paper converting industry are:

- hot surfaces, for example overheating of bearings
- open flames, for example in welding and cutting
- mechanically generated sparks
- electrically generated sparks
- electrostatic discharges

In order to determine protective measures appropriate to prevent the ignition of hazardous explosive atmospheres, areas have been classified into zones in relation to the probability of occurrence of hazardous explosive atmospheres:

The zoning of explosive areas is described in detail in the European Standard EN 1127-1 “Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology”. The classification into zones is of special importance under safety, but also under economical aspects. It is the basic principle underlying risk assessment for explosion protection. All protective measures to prevent ignition of explosive atmospheres are based on these aspects. Incorrect classification will result in needless expenses or incalculable risks. When classifying machines and equipment operating with combustible substances under safety aspects, normal operation must be considered as well as cases of disturbance. Examples of classification of the machines used in printing and paper converting are given in Annex A of EN 1010-1. These zones are based on calculations, measurements and experience and they indicate where there is a need for further measures to prevent ignition of explosive atmospheres.

As a basic principle, only apparatus, components and safety systems that comply with Directive 2014/34/EU (ATEX), may be used in potentially explosive areas (zones). The three categories reflect the technical safety levels required for specific zones.

Zones		
Gases, mists, vapours	**Dusts**	**Description**
0	20	Areas where hazardous explosive atmospheres consisting of a mixture of air and gases, vapours or mists occur continuously, for long periods or frequently (predominantly) or areas where hazardous explosive atmospheres consisting of a mixture of air and combustible dusts occur continuously, for long periods or frequently (predominantly).
1	21	Areas where hazardous explosive atmospheres consisting of a mixture of air and gases, vapours or mists occur occasionally under normal operating conditions or areas where hazardous explosive atmospheres consisting of a mixture of air and combustible dusts occur occasionally.
2	22	Areas where it can be expected that hazardous explosive atmospheres consisting of a mixture of air and gases, vapours or mists occur rarely and for short periods or areas where hazardous explosive atmospheres consisting of a mixture of air and combustible dusts occur rarely and for short periods of time.

RELATION BETWEEN ZONES AND CATEGORIES

Zones				
Gases, mists, vapours	**Safety of equipment must be ensured**	**Safety level of equipment**	**Appliance group**	**Application in zone**
0	even for rare disturbances	very high	1 G	0, 1 and 2
1	for frequent disturbances or malfunctions which are typically to be expected	high	2 G	1 and 2
2	in normal operation	normal	3 G	2

RELATION BETWEEN ZONES AND CATEGORIES

Zones				
Dusts	**Safety of equipment must be ensured**	**Safety level of equipment**	**Appliance group**	**Application in zone**
20	even for rare disturbances	very high	1 D	20, 21 and 22
21	for frequent disturbances or malfunctions which are typically to be expected	high	2 D	21 and 22
22	in normal operation	normal	3 D	22

RELATION BETWEEN ZONES AND SOURCES OF IGNITION

Dangerous potentially explosive atmosphere exists – Zoning			
	Constantly, for long periods or frequently	Occasionally	Seldom or for short periods
By gases, mists, vapours	Zone 1	Zone 1	Zone 2
By dusts	Zone 20	Zone 21	Zone 22

Avoidance of sources of ignition*			
By gases, mists, vapours and dusts	– under troublefree operation (normal operation) – foreseeable malfunction – rare malfunction	– troublefree operation (normal operation) – foreseeable malfunction	– troublefree operation (normal operation)

* In zones 20, 21 and 22 there is the possibility of ignition from dust deposits

Ignition sources

The Technical Rules for Hazardous Substances TRGS 723 and EN 1127-1 describe a great variety of protective measures. Here are some examples of designed-in solutions:

a) Ignition by mechanically generated sparks

Machinery and equipment consist of mechanical and/or electromechanical components and these parts in motion favour the formation of sparks. Sparking must be prevented by design measures. Examples are given below:

- Selecting and applying low-spark material in the construction of machinery
- Providing suitable protective devices to prevent solid contaminants from getting in between the mechanism of dynamic systems
- Adequate lubrication of bearings and shafts.
- Solid and rigid machine housing in order to prevent deformation by external forces.

Fan blowers provided for exhausting explosive atmospheres, for example, as well as clutches and brakes must be of explosion-proof design. For the design and material selection of explosion-proof fans the European Standard EN 14986 “Design of fans working in potentially explosive atmospheres” must be applied.

b) Ignition by hot surfaces

Hot surfaces can be effective sources of ignition and must therefore be avoided. It is important that the mechanical and electromechanical parts of machines are designed in such a way that inadmissible heating up of surfaces is positively prevented. The maximum admissible surface temperatures of apparatus relate to the temperature ranges relevant to possible combustible gases and vapours. The table below shows examples of the relationship between the temperature ranges of combustible gases and vapours and the admissible maximum surface temperature of electrical apparatus according to the standard EN 60079-0.

Exception: Where hot surfaces can be the source of ignition, safety distances must be applied. The temperatures of all surfaces with a likelihood of contact with potentially explosive atmospheres, for example in solvent continuous dryers, must not exceed 80% of the ignition temperature of the flammable gas or flammable liquid (limit temperature) in accordance with EN 1127-1.

c) Ignition by electrically generated sparks
On electrical equipment – even low-voltage – electrical sparks and hot surfaces can have the effect of ignition sources. Protective extra low voltage (PELV) is not considered an explosion protection measure since explosive atmospheres can be ignited even by low voltages.

d) Ignition by static electricity
When materials are separated at least one of which is capable of holding a charge, potentially explosive incendiary discharges can occur.

– V-belts and drive belts must be conductive. Repair requirements must be described in the instruction handbook.
– Pipes and hoses for inks and coating, varnishing and gluing substances and also pipes and hoses for solvent vapours must be conductive and be electrostatically earthed. Suction hoses and pipes for combustible dusts and other combustible material (paper, plastic etc.) must be conductive and electrostatically grounded (resistance $< 10^6$ ohm).
– Flooring must be conductive in an area extending 1 m beyond the zone 1 potentially explosive area. For countering electrostatic charges, static eliminators or ionizers must be provided wherever technically feasible.

- **Tertiary explosion protection**

Explosion-proof construction
Parts of equipment such as vessels, apparatus and piping are constructed in such a way that they withstand inner explosions without tearing (explosion pressure resistant and explosion pressure shock resistant design).

Explosion relief
Where explosions occur or after explosions have extended for a certain amount in a closed apparatus or vessel, for example a solvent dryer, a silo or a reservoir, a relief device is opened for a short time or is kept open after a preset reaction pressure is reached to relieve the pressure in a non-hazardous direction. The relief device will ensure that the apparatus is not strained beyond its explosion resistance limits. Relief devices can be bursting discs or explosion flaps.

Explosion suppression
Devices for the suppression of explosions prevent the maximum explosion pressure being reached by rapid injection of extinguishing agents in vessels and apparatus. In contrast to explosion relief, explosion effects are restricted to the inside of the apparatus or vessel. As extinguishing agents, powdered substances or water are preferred.

Temperature range	T1	T2	T3	T4	T5	T6
Ignition temperature in °C	> 450	> 300	> 200	> 135	> 100	> 85
Maximum surface temperature in °C [1)]	450	300	200	135	100	85
Examples	Propane Methane Ammonia	Ethylene Alcohol Acetylene	Benzene solvents	Diethylether		Carbon-hydrogen disulphide

1) For equipment with a surface area $< 10\ cm^2$, higher temperatures are also permissible in accordance with the standard.

- **Prevention of explosion propagation (explosion decoupling)**
  In order to avoid the propagation of explosions originating from explosive atmospheres caused by gases, vapours and mists through, for example, piping or through filling and emptying lines which are not constantly filled with liquids, flame-arresting devices such as sinter metal (flame-arresting filters) can be used, based on the principle of extinguishing fires in narrow gaps and channels. This principle cannot be applied for combustible dusts due to the risk of blockage. The propagation of dust explosion through connecting pipes and flame release on parts of the equipment can be prevented by approved devices such as extinguishing barriers, rapid-action valves, rotary valves and explosion diverters.

Approval of equipment
In accordance with the 2014/34/EU Directive, all electrical and non-electrical equipment which was newly placed on the market after 20.04.2016 must hold the relevant approval. This means that for electrical equipment categories 1 and 2, the manufacturer must be in possession of an EC type examination certificate. For non-electrical equipment this applies for category 1 and for combustion engines. The manufacturer documents the approval or suitability of the equipment to the user by means of a Declaration of Conformity and corresponding marking of the equipment. For equipment that was placed on the market prior to 01.07.2003 right of continuance applies, provided that it held the relevant approval at the time it was first introduced.

In **zone 0 and/or zone 20** only those types of electrical equipment may be used which have been type-approved for use in zone 0 and/or zone 20, as indicated in the type examination certificate issued by an appointed body (e.g. in Germany: PTB Braunschweig, BAM Berlin, IBExU Freiberg) (marked as II 1G or II 1D).

In **zone 1 and/or zone 21** only those types of electrical equipment are permitted that are explosion-protected through a single type or a combination of several types of permissible ignition protection. The safety of this electrical equipment must also have been tested by an appointed body (e.g. in Germany: PTB Braunschweig, BAM Berlin, IBExU Freiberg) (type examination certificate, marked as II 2G or II 2D).

Electric motors for driving recirculation pumps on supply tanks holding inks, coating or impregnating substances or glues can be of the protective type “d” as specified in EN 60079-1 “Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures ‘d’ ”. The electric drive used for viscosity control must have a clearance of at least 50 mm between the outer flange and the agitating device (EN 1010-1).

The requirements of **zone 2 and/or zone 22** are less strict, allowing also the use of apparatus for which no EC Certificate of Conformity has been issued by one of the testing bodies. Explosion proof equipment for use in zone 2 and/or zone 22 must be tested and marked by the manufacturer. It is also possible to use commercially available equipment which does not represent a source of ignition (for example sparking, arcing or temperatures above the ignition temperature of the flammable substance) under normal operating conditions (marked as II 3G or II 3D).

Conduit boxes, cables and ducting must however be designed for the zone applicable for their place of installation.

Types of ignition protection
The following table lists the types of ignition to be considered when designing machines. It is however only an extract and does not claim to be complete.

TYPE OF IGNITION PROTECTION FOR ELECTRICAL APPARATUS
General requirements
Flameproof enclosure
Pressurized enclosure
Powder filling
Oil immersion
Increased safety
Intrinsic safety
Encapsulation
Special requirements for the design, testing and marking of electrical apparatus group II, category 1G
Type of ignition protection “n” (zone 2)
Dust protection: protection by enclosure
Dust protection: pressurized enclosure
Dust protection: intrinsic safety
Dust protection: encapsulation

TYPE OF IGNITION PROTECTION FOR NON-ELECTRICAL APPARATUS
Basic method and requirements
Protection by flow restricting enclosure “fr”
Protection by flameproof enclosure “d”
Protection by constructional safety “c”
Protection by control of ignition source “b”

EXPLOSION PROTECTION MARKING ON ELECTRICAL APPARATUS

CE 0158 Ex II 2 G (E)Ex e II T4

- CE Declaration of Conformity
- Test House* Identification number in the sense of modules IV, V, VI, VII or IX
- Explosion protection marking
- Equipment group (I or II)
- Category (M1, M2, 1, 2 or 3)
- G = gas, D = dust (group II only)
- Standard-specific marking, where applicable
- Name and address of manufacturer
- Year of manufacture

* The test house mentioned on the declaration

2.1.10 Equipment for protection against emissions

1 Solvent vapours, dusts, gases, mists

Due to the industrial processes involved in printing and paper converting there is a high probability of substances being emitted, amongst others:

- solvent vapours (for example from solvents used in inks, cleaning agents and other substances)
- mists (for example ink fly generated on high-speed cylinders by decomposition)
- gases (for example development of ozone on UV dryers) and
- dusts (for example substrate abrasion, cutting and folding operations, spray powders etc.).

All these emissions are basically dangerous to health and/or explosive, they can penetrate human respiratory systems and must therefore be reduced to a minimum.

Priority must always be given to measures which prevent the emission of hazardous substances right from the start. There are a number of possible solutions such as the substitution of substances (for example replacing highly-volatile washing and cleaning agents by low-volatile substances) and designing low-emission machines.

Where technical equipment can be expected to emit hazardous or explosive dusts, gases, vapours or mists in a work process, it is the designer's responsibility to provide appropriate devices for air purification or suitable connections to fit the extraction system provided by the user. In such cases the requirements of EN ISO 14123-1 must be satisfied.

Industrial ventilation

Ventilation measures include the capture (extraction) of emissions at their point of origin or escape, room ventilation and the removal of emissions from exhaust air.

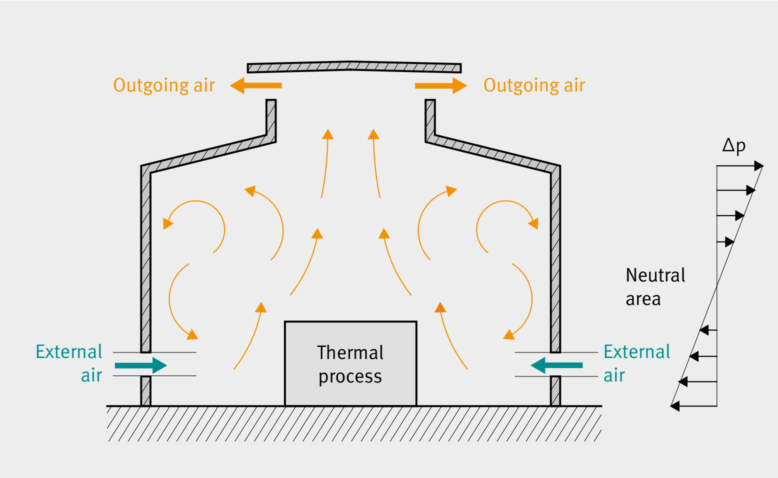
All industrial ventilation systems require that

- the routing of air flow is designed to support the direction of flow of contaminated air
- design of fresh-air intake is appropriate to support the air flow
- contaminated air is led away from the inhaling area of operating personnel.

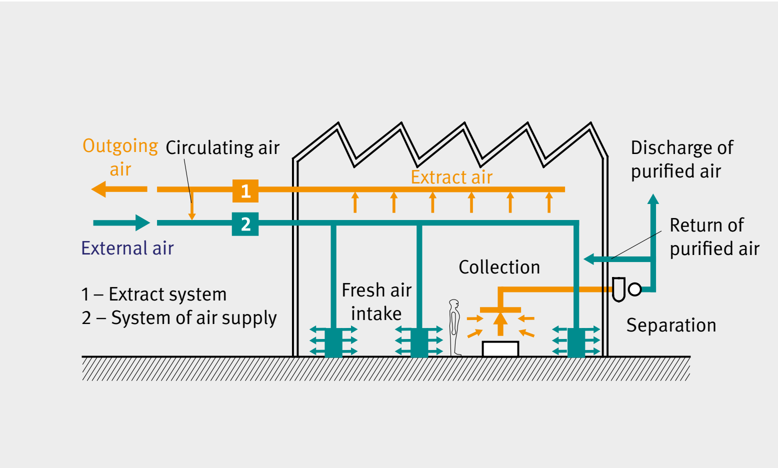
Extraction system on dryer of sheet-fed offset press

There are basically two different types of ventilation, i.e.

- natural (free) ventilation and
- mechanical (forced) ventilation.



Principle of natural ventilation



Principle of mechanical ventilation

The exchange of air in free ventilation systems is typically activated by the difference of temperature inside and outside the building. From experience, an air change rate of 2 per hour can be expected. Free exchange of air can be adopted as a method of ventilation only in cases where, for example, emission of hazardous substances is so low that there are no health risks.

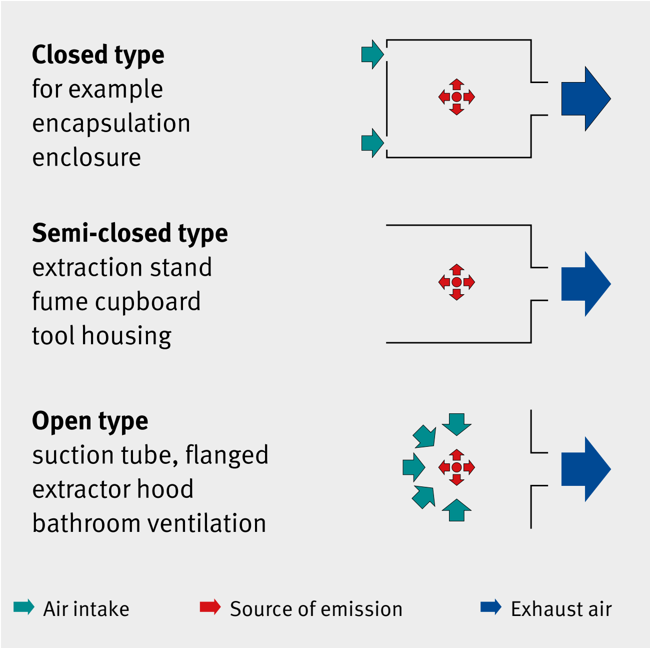
In general, mechanical or forced ventilation will be the better choice. The basic principle of mechanical ventilation is that

- hazardous substances are extracted directly at the point of origin or escape (ventilation extraction) and
- hazardous substances in work areas are suppressed or diluted by intake of non-hazardous air (room ventilation).

Room ventilation systems can generally help to reduce contaminated concentrations at the workplace. However, the reduction of concentrations of hazardous substances at the point of origin or escape requires high air change rates as not only the relatively highly contaminated air at the workplace must be evacuated, but also the remaining ambient air. In order to keep the need for air changing low and exhausting as effective as possible, suitable devices are required to collect contaminated air and extract it in a non-hazardous manner right at the point of emission.

Ventilation extraction

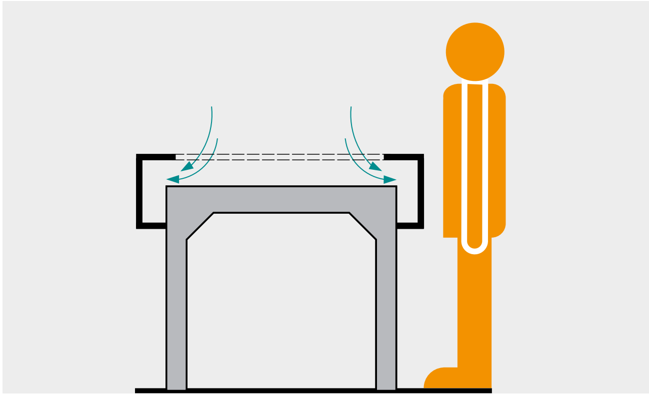
There are several types of equipment available for extracting air with different levels of effectiveness.



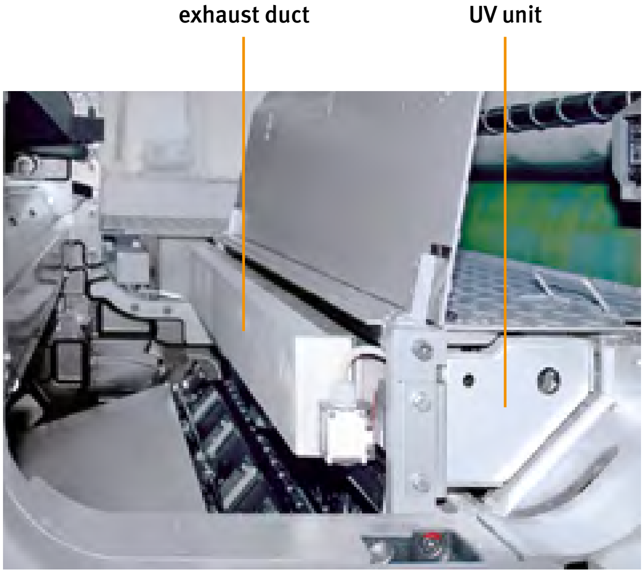
Types of ventilation extraction systems

The correct selection of suitable extraction equipment and their arrangement is of great importance. The best results are achieved by forced measures, for example if the point of origin of the contaminated emission is completely encapsulated. Collecting all hazardous substances on the spot allows low-capacity exhaust equipment to be used (energy-saving effect). Where this is not possible, special devices must be applied designed to extract contaminated air at the source of emission (for example ozone extraction equipment on UV dryers).

Measurements have revealed that air speeds drop considerably with increasing distance between the extraction device and the source of emission thus reducing the extraction capability. Consequently, extraction devices must be as close to the source of emission/origin as possible.



Designed-in extraction facility



Extraction of ozone on a UV intermediate dryer of a sheet-fed offset press

Fixed extraction hood for stack dryers in screen printing

At the origin of emission, a vacuum is produced strong enough to ensure that the speed of the extracted air flow exceeds the speed at which the pollutants spread, thus allowing complete collection of the contaminated emission. Knowledge of the physical properties of the contaminants is required for determining the correct arrangement of the extraction device. Substances which are heavier or lighter than the ambient air will need to be extracted above or below the point of origin respectively. In both cases, however, it is most important to extract the air within the respiratory range of the operating personnel. Even pollutants that are heavier than the ambient air rise initially, as a result of prevailing air currents. Each particular application should be studied carefully and the most appropriate shape designed accordingly.

Piping

A system of piping is used to connect the extraction device to air purifying equipment. Pipes are, depending on their application, subject to various influences such as gases, vapours, mist and dusts (for example chemical attacks, abrasion etc.). This requires some design principles which must be complied with:

- tightness to withstand existing vacuum and overpressure
- interior surfaces which are as smooth as possible to avoid accumulation of particles and ensure low flow resistance
- pipes which can be easily dismantled for cleaning and inspection
- adequate resistance against corrosion and abrasion
- flow-enhancing design of shaped parts
- complying with the requirements for fire and, where applicable, explosion protection

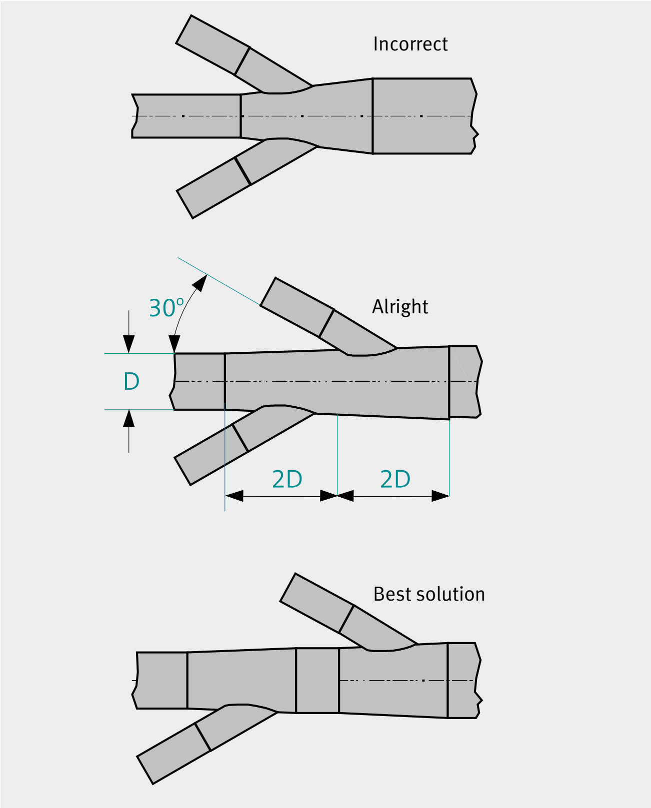
The cross section of ducts should be designed on the basis of the individual specific requirements; consultancy from ventilation engineers is advisable.

Another aspect is the careful selection of the material to ensure undisturbed operation of the extraction device. The following are well-tried materials/constructions to be selected according to the respective application:

- **Folded and spiral-seam pipes** (metal sheet thickness 0.6 – 1.2 mm, see EN 12237) are most commonly used, as they are easy to manufacture and to assemble. Their use is restricted to non-abrasive dusts and pressures up to about 2000 Pa.

Folded and spiral-seam pipe

- **Rectangular ducts** should only be used for fresh air in order to avoid accumulation of dust in corners and edges.



Design of pipe branches

- **Welded** pipes (sheet thickness 1–4 mm, see 24153) are applicable for increased requirements with respect to wear resistance and pressure-tightness and are explosion-proof where appropriate.
- **Plastic pipes** made of flame-resistant polyethylene or polypropylene (PE or PP) are capable of withstanding corrosion and are therefore preferred in areas where acidic air or condensate vapours occur.
- **Flexible pipes** made of aluminium can be compressed or stretched in length and allow narrow bending which makes them especially suitable for use as connecting element between apparatus and fixed pipes and in narrow spaces. Their ribbed walls make them inappropriate for dust and grease containing air.
- **Plastic hoses** are generally made of film with an outer spiral spring wire. They are generally used for vibration-free connection of machines and fixed pipes.

Avoid explosion hazards

When exhausting flammable gases, vapours or dusts, mixtures with air will necessarily develop which are potentially explosive within a certain concentration range. This range is limited by the lower explosion limit (LEL) and the upper explosion limit (UEL). Where a hazardous amount of potentially explosive atmosphere exists (an amount of 10 l of coherent substance in confined spaces is already considered hazardous), ignition may cause severe injury to persons and damage of material (see clause 2.1.9 – Explosion protection). Equipment for emission protection must therefore be so designed that the hazard of explosion is safely prevented. Basic principles of design are explained in detail in clause 2.1.9.

Testing

Ventilation systems must be tested regularly for their efficiency. Testing must be done before commissioning and after substantial modification and on a regular basis at least once a year by an authorized person. Test results must be documented in writing. For clarity, testing includes functional measurements (for example volume flow rate, air speed).

Summary

Ventilation systems are generally individual systems designed to take account of a specific application. The following aspects, for example, need to be considered:

- Space requirements
- Workplace (permanent, variable)
- Type and amount of generated substances
- Air speeds
- Volume flow rates
- Air intake
- Air routing
- Cross airflows and thermal flows
- Type of extraction device
- Clean air return
- Filtering
- Heat recovery.

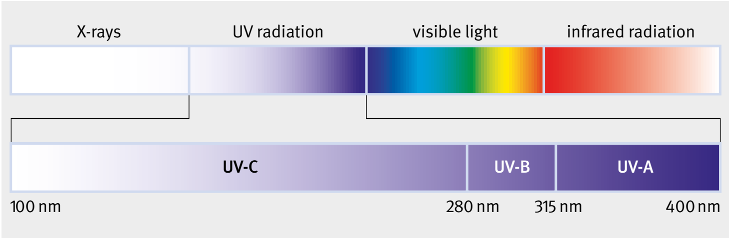
It is evident that effective extraction systems will need comprehensive professional consultancy based on the respective user-site conditions. Basic sample solutions will generally not be adequate to take account of specific requirements and to ensure the effects intended.

2 UV technology

Typical areas of application are, for example, curing (drying) of inks and varnishes and glues, siliconisation and exposure of printing plates.

Examples of the application of UV technology: web printing, siliconisation

Ultraviolet (UV) radiation is part of the spectrum of electromagnetic rays. It is next to the short-wave part of visible light and extends as far as ionising radiation. According to the Directive 2006/25/EC, radiation is called ultraviolet in the wavelength band of 400 nm to 100 nm. Wavelength bands are subdivided in three sections:

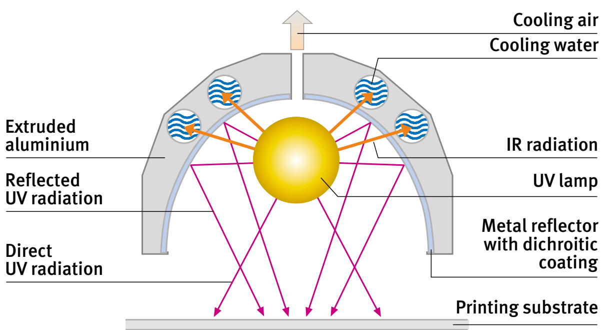


UV radiation as part of the electromagnetic light spectrum

The hazards created by the application of UV technology are partly identical to those generated by conventional techniques without UV radiation. There are, however, additional hazard potentials caused by the source of UV radiation, for example ozone, generated by the UV rays reacting with the oxygen contained in the air surrounding the UV lamp and by the UV rays themselves.

UV Drying Systems

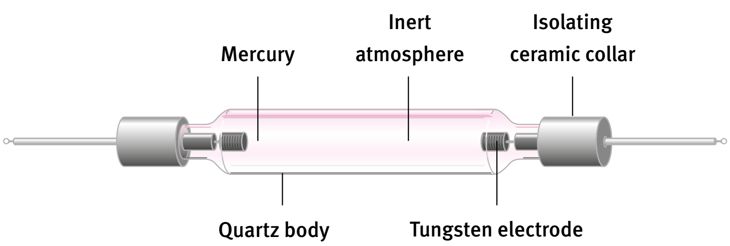
- **Medium Pressure Mercury Lamp Technology**
  A good, high-performance UV system needs to consist of multiple, mutually compatible components in order to achieve effective curing of the UV inks and varnishes. Apart from the electrical infrastructure for the lamp, cooling and exhaust systems etc., these components are:



Schematic diagram of a UV drying system

- **Lamp**
  The lamp is also referred to as a burner (commonly: "mercury-vapour lamps"). It generates UV radiation. UV lamps consist of a quartz glass tube containing mercury. The body of the lamp is made from high-quality quartz allowing high UV light transmittance. This quartz glass body must be able to withstand an inner temperature of up to 1100°C. Temperatures of up to 900°C are reached on the surface.

- **Reflector**
  This can be made of a variety of different materials, is usually elliptical or parabolic in shape and its function is to focus the UV radiation and reflect it onto the printing substrate. Dichroitic reflectors, also known as cold-light mirrors, only reflect the UV light, whilst transmitting the infrared light onto a water-cooled absorption profile.



Schematic diagram of a UV mercury vapour lamp

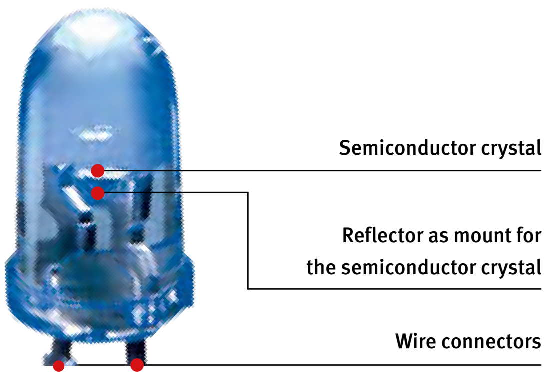
- **Cooling**
  As a large percentage of the energy consumed by the lamp is converted not into UV radiation but into visible light and infrared radiation, cooling is required.

- **Extraction**
  An exhaust system is required to deal with the ozone produced in the UV lamp and to remove the high heat load.

- **Safety devices**
  These ensure that, in case of interruption, the lamp is immediately shut off, dimmed or swivelled, as otherwise there is danger of the printing substrate igniting.

Doped Mercury Lamps (H-, HR-, LE- or LEC-UV)
These lamps differ from conventional medium pressure mercury lamps in that the mercury lamps are specially doped, usually with iron. The various printing machine manufacturers use different terminologies for these types of lamps: e.g. LE-UV (Low Energy, Heidelberg); HR-UV (Highly Reactive UV technology, KBA); H-UV (Hyper-UV; Komori) and LEC-UV (Low Energy Curing, manroland). Compared to conventional UV lamps, doping causes a shift in the lamp's spectrum towards the longer wavelengths of the UV-A range. This has a number of significant consequences for the printing process. As ozone is only generated in the short-wave range of UV radiation (below 240 nm), using this type of radiation source will suppress the formation of ozone.

However, these types of UV lamp cannot cure conventional UV inks and varnishes. Specially adapted highly-reactive inks/varnish systems with compatible photoinitiators are required. The high reactivity of the inks and varnishes means that, as a rule, the number of lamps in the printing press can be reduced. Together with lower costs for cooling and exhaust extraction, the procurement and operating costs for this type of lamp technology are reduced compared to UV printing with conventional mercury vapour lamps.



Structure of an LED light source (Ill. Guy Pracros/Fotolia)

LED Technology
LEDs or Light Emitting Diodes are based on semiconductor compounds that emit light when a voltage is supplied. The wavelength of the radiation (UV-range, visible light or infrared radiation) depends on the bandgap of the semiconductor material used and how it is doped. The base material

for UV light-emitting LEDs can consist of InGaN (Indium gallium nitride), for example. This semiconductor material has a bandgap that emits radiation in the near-UV range upon recombination of the charge carriers.

This radiation has only a very narrow wavelength range, as a comparison between the emission spectra of a standard UV lamp and a UV LED shows. The current standard UV LEDs emit radiation with wavelengths between 360 nm and 410 nm. Wavelength generally has a significant effect on efficiency. The shorter – and thus more energetic – the radiation waves, the less effective the LED and the higher the manufacturing costs. Unlike conventional UV curing methods, LEDs do not require a warm-up period and are immediately ready for operation. This means that when they are used, intermittent operations are possible, whereas continuously operating mercury vapour lamps require mechanical shutters when not in use.

Because it emits light in only a narrow wavelength range, this technology produces no infrared radiation, which leads to lower heat generation at the drying site, meaning reduced demands on the cooling system and printing substrate. This offers advantages when using temperature-sensitive materials such as plastics, foils and films. However, cooling cannot be completely dispensed with, as increased temperatures have a negative effect on the service life of light emitting diodes and also compromise the efficiency of the LED. Water cooling is usually the method of choice, as its compact design requires only a minimum of space.

Comparison of the hazards of dryers using mercury vapour lamps with those using LEDs

- Material
  The interiors of conventional UV lamps contain highly toxic mercury. This type of lamp requires special disposal when it is changed.

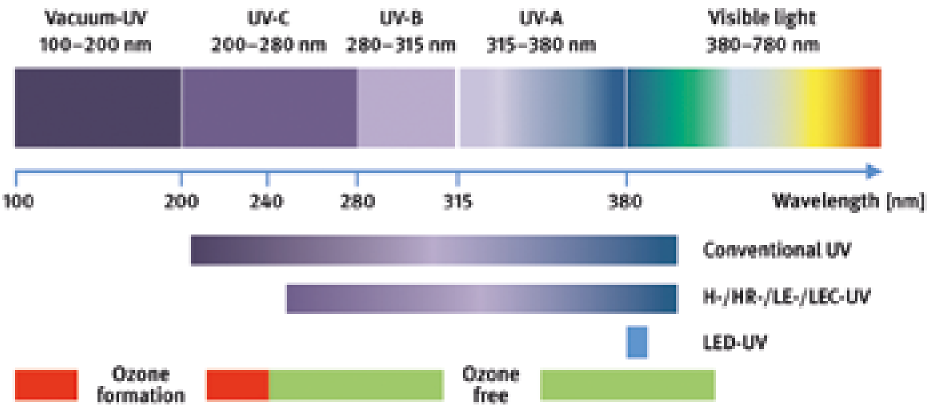
  Although the much smaller diodes contain no toxic substances, they must nevertheless not be disposed of as normal household waste. Thanks to the exceptionally long service life of LEDs (approx. 15000 hours), however, they very seldom need to be replaced.

- Radiation
  Mercury vapour lamps emit UV radiation as well as radiation in the visible range. As protection against radiation, these lamps must have complete light-proof shielding. Because of the visible component of the radiation, these leaks can be seen with the naked eye.
  The radiation from UV LEDs is not visible to the human eye. However, looking directly at a UV LED radiation source can still damage the eyes, which means that here (just as with conventional UV radiation sources) there must be no possibility of eye contact with the diode. The emitted light must have complete radiation-proof shielding so that there are no health risks for employees and passers-by. This also applies for any stray UV light that might leak. The LEDs must immediately cut off when the radiation protection shield is opened.

- Extraction
  With most conventional UV lamps, the irritant gas ozone is produced. Stationary extraction devices must be installed directly at the point of origin to ensure that there is no leakage into the work area. Extraction equipment also serves to remove heat emissions and volatile hazardous substances.

  Although no ozone is generated through the emission of radiation in the near-UV range when curing is carried out using doped mercury vapour lamps or UV LEDs, extraction at the dryer may still be necessary, because volatile hazardous molecules can also occur here, as may be the case where there is incomplete curing of the printing ink, for example.

Inks and varnishes for doped mercury lamps and UV LEDs
When exposed to radiation of a certain wavelength, the photoinitiators in UV inks and varnishes trigger a reaction, which causes the printing ink to be cured. Conventional UV inks and varnishes are designed to match the line spectrum of UV medium pressure lamps and thus they cannot be adequately cured using a UV LED system. The narrow wavelength range of the UV LEDs, in particular, makes it necessary to adjust the photoinitiators to the wavelength of the LED radiation. The problem is, however, that these wavelengths lie in a similar range to the long-wave UV components of daylight or artificial lighting. So new ink systems need to be developed which will cure in the wavelength range of UV LEDs, but where daylight will not cause premature polymerisation of the printing inks in the ink reservoir.



Emission spectra of conventional mercury lamps, iron-doped mercury lamps and LED lamps

The development of UV LED technology now offers interesting application opportunities in the various different printing processes and already some specific areas of printing have emerged where the particular advantages of LEDs can be used. Two examples are large-format inkjet printers and offset systems, where, in some cases, UV LED drying units are already standard features.

Radiation Protection Measures

Direct eye contact with the UV lamp must be prevented. Reflected radiation must be shielded to such an extent that there are no health hazards, either for employees working on the system or for people walking past, i.e. the exposure level of the ultraviolet radiation must not exceed the limit values of Category 1 as specified in EN 12198-1.

This applies to the areas of regular workplaces as well as to locations only infrequently occupied by people. Special metres are used to verify compliance with the permissible limit values for the effective irradiance E_{eff} ($1.0 \times 10^{-3} W/m^2$ for UV-A/B/C radiation, limit value for 8-hour shifts, in accordance with EN 12198-1 or EN 1010-1 respectively). The results must be documented. The amount of UV radiation is fundamentally determined by the position of the dryer within the printing press. An evaluation can thus only be made for a corresponding combination of printing press and UV dryer.

Category of radiation emission	E_{eff} [W/m²] (180–400 nm)	Measures, information, training
0	$E_{eff} \leq 0.0001$	–
1	$0.0001 < E_{eff} \leq 0.001$	Possible restrictions, information
2	$E_{eff} > 0.001$	Restrictions, information, training where possible

Correlation between effective UV irradiance and radiation emission category

End-of-press or interdeck UV dryer module (removable)

Ozone

In conventional UV dryers, ozone occurs when UV rays react with the oxygen of the atmosphere inside the housing of the UV lamp. The ozone concentration level depends upon the type of lamp used, the routing of air flow inside the machine and the design of the ventilation system, which is usually installed by the operating company. Any ozone generated must not be allowed to leak into the work area in hazardous concentrations and must, if necessary, be extracted or removed at the point of origin. Ozone extraction equipment must be designed in such a way that the dryer can only be operated when the extraction system is running. Compliance with the permissible limit value for ozone (up to January 2006: 0.1 ppm in accordance with TRGS 900) must be measured and documented.

Simple measuring of ozone concentration by means of detector tube

Protective measures when using the inert gas nitrogen

In certain cases radiation curing is effected in an oxygen-free or oxygen-reduced atmosphere (“inertization”), as is the case, for example, in coating technology (“siliconization”). The nitrogen used for inertization is normally stocked in liquid form (at a temperature of -196°C).
The liquid nitrogen is converted into a gaseous state by means of an evaporator and is then distributed via pipe systems to the individual dryer modules which are specially designed for curing with UV inert gas. In order to prevent liquid nitrogen from leaking into the printing press, temperature monitoring of the nitrogen feed unit is essential. The nitrogen supply to the printing press must be automatically cut off if the temperature falls below the critical limit.

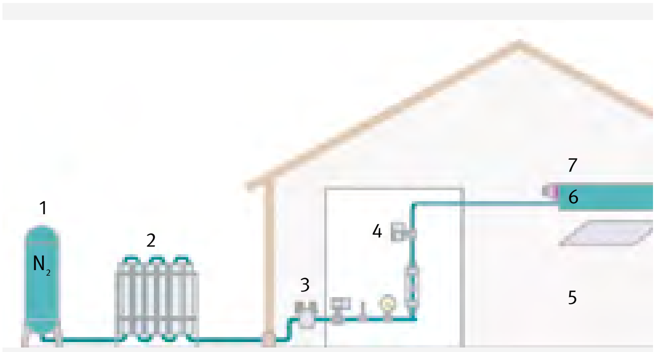
Nitrogen is a normal constituent of the air we breathe and is non-toxic. Higher concentrations of nitrogen can, however, result in a displacement of atmospheric oxygen and the danger of suffocation. Air exchange is required to prevent a build up of nitrogen in the respiratory air. Pipes and hoses must be installed in such away that they are protected against damage. Feed lines must be inspected at regular intervals. Leakages can lead to suffocation. It is essential that the installation and maintenance of such systems be carried out by authorized specialist firms.

Switch-off

UV drying systems must be designed in such a way that no uncured products occur in case of malfunction (e.g. overheating). Uncured paper waste can cause problems if it comes into contact with skin. In the case of a simple operational disruption of the UV system on a sheet-fed offset press, for example, the feeder would be switched off and the printing of the products still in the machine would be completed. On a web-fed printing press, the printing process would be immediately terminated. The paper transport is stopped when the production job in progress has left the final element of the drying system.

Electrical equipment and control system

The electrical equipment must comply with the requirements of EN 60204-1.



1 Nitrogen reservoir
2 Vaporizer
3 Pressure reducing/control device
4 Distributor module for UV inert gas dryer
5 Cover of printing channel
6 Inertization chamber
7 UV drying system

Application of the inert gas nitrogen in UV dryers

In order to verify the function of safety-related signals and their interconnection with the control system, manufacturers must provide evidence in answer to the following catalogue of questions:

- Does actuation of the emergency stop switch result in the complete shutdown of the dryer?
- Does the dryer shift to full load only after cylinders are in ON position?
- Does the dryer shift to partial load immediately after the cylinders are in the OFF position?
- Can the dryer only be operated when the extraction system is running?

These safety-related functions must be implemented in the control system at Performance Level PL_r = d, in accordance with EN ISO 13849-1. In case of emergency, rapid, safe disconnection must be ensured.

Fire protection
Care must be taken that material cannot be ignited by the lamp. To prevent fire, the UV dryer may only deliver its full capacity onto the printed material whilst the machine is running. Manufacturers must provide detailed information of their specific fire protection requirements, for example: when the dryer is disconnected, the extraction/ ventilation systems must remain in operation long enough to remove heat.

Separation of washing device and UV dryer
Situations involving the simultaneous use in a machine of UV dryers and washing systems for rubber blankets or cylinders have particularly high hazard potential. The heat of the dryer (tube temperature of 800 – 950°C) can cause solvents used in the washing systems to evaporate to form a potentially explosive solvent-air mixture, which can be ignited. Measures must therefore be taken to prevent washing agents from automatic cylinder or roller washing systems being dispersed by the printing substrate.

Web-fed printing presses are generally cleaned while the machine is running. In order to prevent potential explosion hazards (EN 1539 and EN 1010-2), measurements to verify the limitation of concentration in the dryer must be taken before commissioning (below 25% of the LEL of the washing agent used).

In the past, sheet-fed offset printing presses were normally fitted with an interlocking device between the washing unit and the UV dryer, so that the washing process could only be started when the temperature at the dryer was at a nonhazardous level. There are now various new systems on the market where measurements have proven that the UV dryer can be safely operated in standby mode during the washing process. These measurements require great expertise and sophisticated metrological equipment.

The hoses which feed washing agents to the washing bar of the rubber blanket and cylinder washing systems must be installed in such a way (resistant material, EN 1127-1), that leakages in hoses or couplings do not allow solvents to penetrate accidentally into hot areas of the continuous dryer. A safe method of preventing this is to place all hoses and coupling elements outside the side walls of printing presses, or to isolate them from the UV dryer using permanent fixtures such as partition plates. Particularly with regard to hoses, consideration must also be given to accelerated ageing through the effects of UV radiation.

Misting from inks and varnishes
Where mists from inks and varnishes (aerosols) occur in potentially harmful quantities, they must be eliminated, e.g. by means of an extraction system with filter units.

Ink mist exhauster on the printing unit of a sheet offset press

Mechanical safety
Detailed checks must be carried out to make sure that there are no inrunning nips, cutting, impact, entanglement, crushing or shearing points, caused for example by the closing motion of the shutters on the dryers or their system components. It is important to ensure that the quality of the sheet metal working is clean and accurate. Sharp corners and edges can lead to injuries.

Dissipation of high contact temperatures

Despite water and air cooling of the lamps, UV drying involves a high energy input into the printing press. Lamp housings must thus be shielded against accidental contact. After several hours of dryer operation, the accessible area around the lamp must be checked for excessive surface temperatures. Burn injuries can be prevented by improved insulation and cooling or the use of safety guards. For commonly used materials the maximum permissible contact temperature is 60°C (EN ISO 13732-1). Those parts of UV dryers that are accessible after interlocking guards are opened and which exceed the temperature limits must carry an appropriate warning notice.

Noise

UV dryers are not generally a significant noise source. Noise emissions are usually generated by the printing press in which the dryer is incorporated. Noise emission must be measured and documented.

Ergonomic aspects

Where UV drying systems or components have to be removed for cleaning or maintenance, suitable handles or recessed grips must be provided.

Accessibility

Where steps and access platforms are necessary for cleaning and maintenance work, they must meet the requirements set out in EN 1010-1. All steps and platforms must have suitable handholds.

Installation of power supply lines and pipes

Control cabinets for the dryer, detection sensors and cooling units are generally located on the drive side of the machine. Numerous power cables, water pipes (cooling water) and air exhaust ducts (ozone and heat extraction) run between these devices and the printing press. These must be laid correctly and covered to prevent tripping.

Documentation

Each UV dryer must have its own instruction manual in the national language of the country in which it is to be operated.

3 Laser technology

Laser equipment is used in a number of areas in the printing and paper converting industry such as laser exposure, laser printing, engraving of anilox rollers and gravure cylinders and for laser cutting.

Depending on the type of equipment, laser devices can emit radiation in the wavelength range of 100 nm to 1 nm. Lasers differ from most other sources of radiation by their ability to concentrate beams, thus creating a higher radiation intensity.

For the human body, the major risk lies with openly accessible laser radiation causing the exposed tissue to become hot and possibly burn. Exposure to radiation can also cause chemical reactions in the tissue.

High risks exist especially for the human eye. The particular optical characteristics of the human eye cause the light passing through the pupil to be focussed on one point on the retina. As a result, exposure of the heavily pigmented tissue will be about 100,000 times stronger than the original beam.

The consequences can be partial burning of the retina or, in extreme cases, even total loss of sight.

Skin, on the other side, is capable of sustaining considerably higher levels of exposure to laser radiation. Extreme radiation levels can, however, also lead to pigmentation, ulceration and charring of the skin and the organs lying underneath. Important parameters for assessing the risk of harm to the human body are the wavelength, energy content and pulse characteristics of the laser beam. On the basis of these risk parameters, laser equipment can be classified in the following categories (wavelength range from 180 nm to 1 mm) in accordance with EN 60825-1 “Safety of laser products – Part 1: Equipment classification and requirements”:

Note

Laser class 1C relates to devices for cosmetic/therapeutic laser treatment of the skin and is not included here.

Class 1

The accessible laser radiation (AEL) is not hazardous under reasonably foreseeable conditions.

Note

Reasonably foreseeable conditions are considered observed if the equipment is used as intended.

The accessible emission limit (AEL) specified in EN 60825-1 in the wavelength range of 400 nm to 1,400 nm for laser classification is the same for all exposures between 100 s and 30,000 s. Negative effects cannot therefore be excluded for long exposures.

Class 1M

The accessible laser radiation is in the range of 302.5 nm to 4,000 nm and is not harmful to the eye unless the cross-section of the beam is reduced by optical instruments (magnifying glasses, lenses, telescopes)!

Note
Where optical instruments cumulating the laser beam are not used, the risk involved for laser radiation Class 1M is similar to that of Class 1.

Where optical instruments are used, hazards may occur which are comparable to those of Class 3R or 3B.

Class 2

The accessible laser radiation is in the visible spectrum (400 nm to 700 nm). It is not hazardous even for the eye in case of short-time exposure (up to 0.25 s). For additional fractions of radiation outside the range of 400–700 nm, the conditions of Class 1 apply.

Note
On laser equipment Class 2, there is no harmful potential for the eye if exposure is incidental and short, i.e. maximum duration of exposure of 0.25 s. Class 2 equipment may therefore be used without further protective measures if it is ensured that the respective application does not require deliberate looking into the laser radiation for more than 0.25 s nor repeated staring into the laser source or reflecting radiation.

The usual eyelid's closing reflex cannot be regarded as eye protection: For lasers Class 2 with continuous radiation, the value for accessible laser radiation is limited to $P_{limit} = 1$ mW (with $C_6 = 1$).

Class 2M

The accessible laser radiation is in the visible spectrum (400 nm to 700 nm). It is not hazardous even for the eye in case of short-time exposure (up to 0.25 s) unless the cross-section of the beam is reduced by optical instruments (magnifying glasses, lenses, telescopes)! For additional fractions of radiation outside the range of 400–700 nm, the conditions of Class 1M apply.

Note
Where optical instruments cumulating the laser beam are not used, the risk involved for laser radiation Class 2M is similar to that of Class2.

Where optical instruments are used, hazards can occur which are comparable to those of Class 3R or 3B.

Class 3A

The accessible laser radiation becomes hazardous for the eye if the cross-section of the beam is reduced by optical instruments. It is not hazardous if not reduced by optical instruments (magnifying glasses, lenses, telescopes)!
If this is not the case, radiation emitted in the visible spectrum (400 nm to 700 nm) is not hazardous under short-time exposure (up to 0.25 s). For the other spectral ranges long-time exposure is also not hazardous.

Note
Laser equipment of Class 3A is equipment classified under the previous standard.

Unless optical instruments reducing the cross section are used, the hazards involved for laser equipment Class 3A, which radiate in the visible spectrum only, are comparable to those of Class 2. For laser devices Class 3A, which radiate in the non-visible spectrum only, the hazards are comparable to those of laser equipment Class 1.

Class 3R

The accessible laser radiation is in the wavelength band of 302.5 nm to 10^6 nm and is hazardous for the eye. The power or energy is maximum five times the limit value of the admissible radiation of Class 2 in the wavelength band of 400 nm to 700 nm.

Note
The risk potential of laser equipment Class 3R for the eye is identical to the risks of Class 3B. The risk of eye injury is reduced by limiting the critical value for accessible laser radiation in the visible wavelength band to five times the limit value for accessible radiation for Class 2, in the other wavelength bands to five times the limit value for accessible radiation for Class 1.

Class 3B

The accessible laser radiation is hazardous for the eye and often also for the skin.

Looking directly into the laser beam of laser equipment Class 3B is dangerous. Ray beams can be observed safely by means of a diffuse reflector if the following conditions coincide:

- The minimum observation distance between screen and cornea of the eye is 13 cm;
- observation time 10 s maximum;
- there are no directed fractions of the beam which may reach the eye.

Ray beams can be observed via a diffuser only where directional fractions of the beam are not directed into the eye.

For laser equipment class 3B, skin is at risk when the values of the maximum admissible radiation are exceeded.

Class 4

The accessible laser radiation is extremely hazardous for the eye and hazardous for the skin. Diffuse radiation can also be dangerous. Laser radiation can give rise to fire and explosion hazards.

Note
Class 4 denotes high-performance laser equipment with output power or energy exceeding the limit values for accessible laser radiation for Class 3B.

Radiation emitted from laser devices Class 4 is so intense that any type of exposure will result in eye or skin damage.

When using laser equipment Class 4 it is always necessary to check if adequate protection against fire and explosion has been considered.

The potential risks created by laser equipment require a considerable number of safety measures which are specified in the standard EN 60825-1. Special attention must be paid to the following provisions:

- The range of the laser beam must be marked (from Class 2 upwards)
- Safety devices and personal protective equipment.

Other possible hazards associated with the use of lasers are, for example, fire and explosion, air pollution from vaporising material, hazards from collateral UV and IR radiation, dangers from high voltages (sometimes in excess of 1 kV) and from energy stored in capacitor banks.

SAFETY MEASURES WHEN USING LASER BEAMS

Requirements: Clause	Classification				
	Class 1/1M	Class 2/2M	Class 3R	Class 3B	Class 4
Description of danger class	Safe under reasonably foreseeable conditions	Low performance: Eye protection normally ensured by eyelid closing reflex	As Class 2: Staring into the laser beam may be hazardous when using optical instruments	Direct staring into the beam may be hazardous	High performance: Diffuse reflection may be hazardous
Protective housing	Required for all classes; possibilities of access restricted to access required for the function of the device				
Safety interlocking of protective housing	Prevents removal of covers as long as the values of accessible radiation are not below the limit values specified for the respective class				
Remote control	Not required			Simple option to allow external safety interlocking of the system	
Key-operated switch	Not required			Laser cannot operate if the key has been removed	
Warning of radiation	Not required			Generates visual or audible warning signals if laser is switched on or capacitor banks of pulsed lasers are being loaded	
Attenuator	Not required			Allows temporary interruption of laser beams in addition to using ON/OFF switches	
Position of control devices	Not required		Control devices must be located such that adjustments can be made without risk of access to radiation above the limit values of Class 1 or Class 2		
Viewing optic	Radiation at viewing apertures must be below the limit values specified for class 1, if applicable				
Directional radiation	Failure in the deflecting mechanism must not lead to upgrading in class				
Marking of class	Hazard symbol and required text		Hazard symbol including stipulated wording		
Marking of radiation aperture	Not required		Specified text		
Marking of inspection aperture	As required for the class applicable for accessible radiation				
Marking of muting of safety interlocking	Required under certain circumstances according to the respective class				
User information	Instruction handbooks must give instructions for safe operation				
Sales and service information	Advertising material must inform of the warning signs applicable for the respective class; maintenance manuals must contain safety information				
Medical devices (also see IEC 601-2-22)	Special instructions for calibration required Special instructions for calibration, measuring instruments and beam target indicator required				

Note: This table gives an easily understandable summary of requirements. For more detailed specifications, please refer to the text of EN 60825-1.

4 Noise

Noise can lead to hearing impairment and other diseases. It can be the cause of damage to health and can severely affect work in all industrial areas (production, service, administration etc.) by, for example:

- an increased risk of accidents where, for example, warning signals and warning cries are not clearly heard or personnel misbehaves on account of fatigue,
- reduced performance, especially in jobs with great mental stress,
- stresses combined, including body vibrations, heat, cold, draught, hazardous substances or work under time pressure or in complicated fields.

In February 2006, the Noise Directive 2003/10/EC on “Minimum health and safety requirements regarding the exposure of workers to the risk arising from physical agents (noise)” came into force. Due to the tightened legal requirements laid down in this directive, noise reduction on machinery is becoming a paramount challenge.

The Directive gives priority to measures reducing noise emission by selecting equipment with a low level of noise. It is especially important to eliminate noise right at the source as this is more effective than the subsequent provision of protective measures, for example enclosing machines. Protective measures may be accompanied by a number of negative effects, such as operating personnel having a reduced perception of useful information, undesirable heating up, the need to reduce the apertures required for feeding and removal of work pieces.

Systematic approach

The development of low-noise machinery principally requires a systematic approach. Basic principles of design are based on the European Standard EN 11688-1 “Acoustics – Recommended practice for the design of low-noise machinery and equipment – Part 1: Planning”. The following examples are only intended to provide guidance for designers.

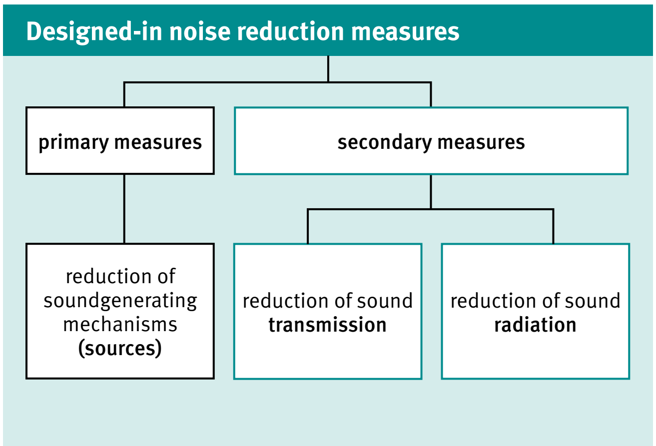
A systematic approach requires the designer to first of all the study the noise mechanism and the respective possibilities of control.

Noise mechanism	Machine structure	Possibilities of influencing by design
sound generation ↓	source ↓	→ **source**
sound transmission ↓	machine structure, media ↓	→ **transmission**
sound radiation	surface, openings	→ **emission**

Sound propagation chain according to EN 11688

The basic principles of noise mechanisms are the generation of sound and its transmission and radiation. The three elements together form the so-called “sound propagation chain”. Each of the three elements can be influenced to a greater or lesser extent. When relating these principles to a real machine structure, sound originates from dynamic processes produced by machine components and such components are therefore considered the source of sound. Sound is then propagated by the machine structure and by media such as liquids and is finally radiated from the machine surface as structure-borne noise or as airborne noise via apertures in the machine housing.

Hence, engineers who want to design quietness into their machinery have the choice to pinpoint better sound performance at the source, during propagation and at the point of radiation. Measures can be distinguished between primary and secondary measures:



Classification of primary and secondary measures

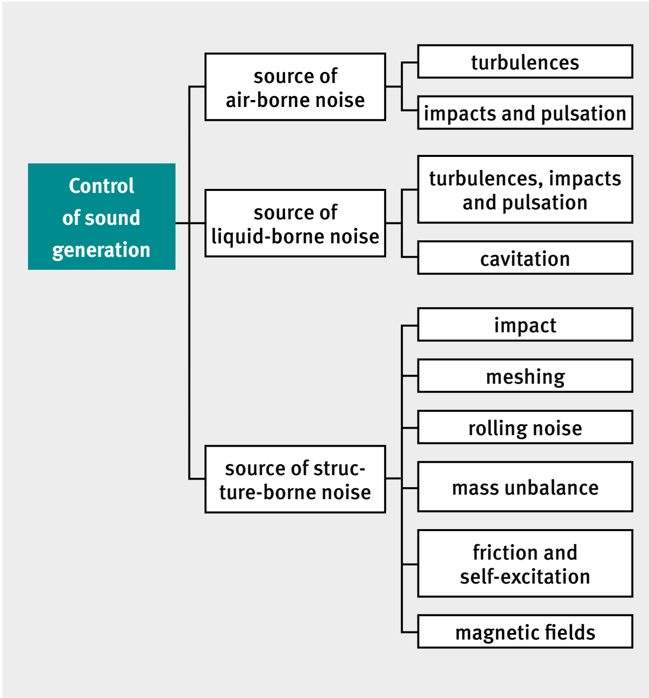
Where sufficiently low levels cannot be reached by design measures at the source, secondary noise reduction measures are required. Special attention should be given to measures applied to the sound transmission path, for example:

- by encapsulation and acoustic insulation of the noise-generating sources or
- by providing screening walls and silencers and measures to reduce noise at the point of exposure, for example on control stations.

When analyzing the sound performance of a machine, the following approach should be adopted:

1 Subdividing machine parts into sound-generating (active) components and sound-transmitting (passive) components
2 Identifying sound sources in air, liquids and bodies
3 Tracing sound paths in air, liquids and bodies
4 Determining the noise-emitting areas of the machine
5 Identifying which of the elements of the noise mechanism (source, sound path, radiating bodies) have the greatest share in the development of noise.

It is then possible to study the possibilities of noise control in the individual areas following the design rules laid down in EN 11688-1.



Design principles for influencing sound generation

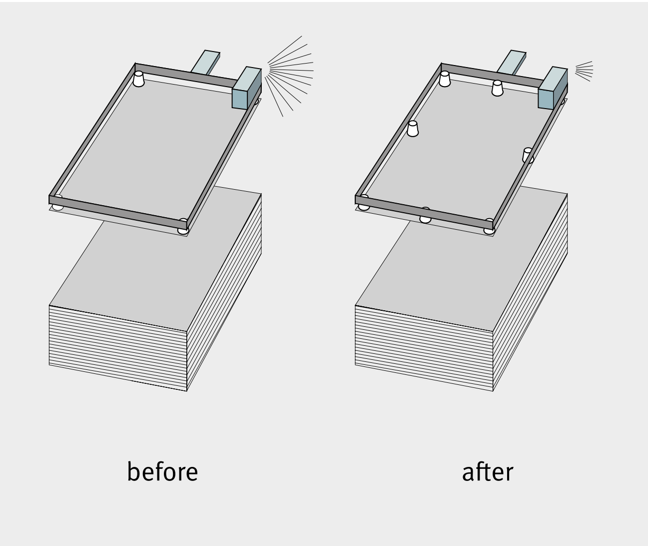
Control of sound generation

- **Control of sound sources**
  The generation of sound at the source can be reduced, for example by
  – reducing working pressure,
  – minimizing flow velocity (for example on ventilation mufflers),
  – reducing free jet outlet dimensions aiming at the reduction of flow rates in the free jet section (for example by means of multiple tubular jets)
  – reducing the circumferential speed of rotors.

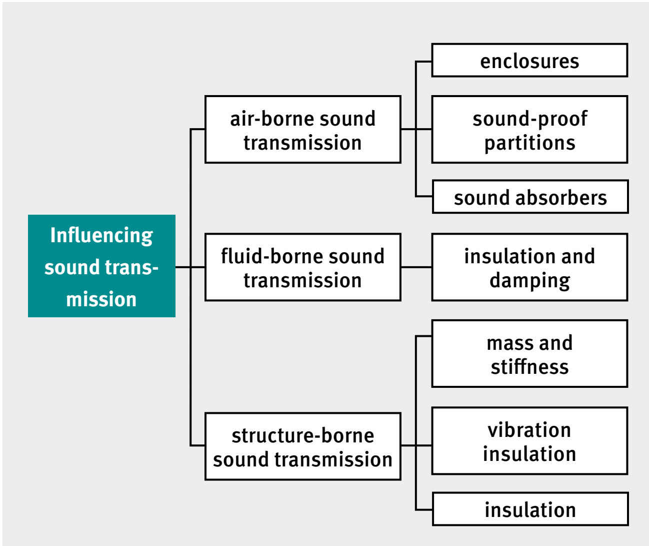
  Example: Paper transport system
  Paper sheets are gathered and transported by means of suction heads where a vacuum is produced. When the sheets reach the delivery position, the vacuum is removed so that the sheets can drop. This causes a flow sound in the vacuum/blast nozzle.

Required measures:
- reducing the vacuum, for example by 0.5 bar which contributes to a considerable reduction of the sound power
- duplication of the number of suction heads in order to make sure the suction power required for safe conveying of the sheets is available.

Control of sound transmission
An often used secondary measure of sound reduction is complete enclosing of machines or machine assemblies which it is however very cost-intensive.



Paper transport system before and after noise reduction



Design principles for reducing noise transmission

Control of structure-borne sound generation
Structure-borne sound generation is caused indirectly. Typically, a machine structure is excited by varying motive powers and produces vibrations. From there sound is transmitted to acoustic weak points, for example prone surfaces, where it is radiated as airborne noise. Structure-borne sources can be influenced by, for example, the following measures:

- reduction of noises from gearing, for example, by
  - reducing driving point impedance by using helical gearing,
  - using plastic gearing (for small loads).
- reduction of rolling noises by
  - using friction bearings instead of ball bearings,
  - improving the accuracy of bearing adjustments,
  - on roller conveyors, using plastic rollers instead of metal rollers.
- observing tight manufacturing tolerances
- using high-quality surfaces for power transmission
- balancing unbalanced rotating parts
- using gear belts instead of chains or gear drives

Such measures seem to be appropriate, for example

- where a hood already exists for other protection reasons which can be modified to serve as noise control hood or
- where noise standards cannot be satisfied by primary noise reduction measures.

Principles of noise enclosure design
The following principles must be applied for the design of noise enclosures:

- Soundproofing of the structure (seals for doors and flaps); even small gaps and apertures (for example slots, joints) are relevant and must be sealed.
- Using firm plates (sound-proof material) for the outer surface of the enclosure.
- The inner walls of the enclosure must be lined with sound-absorbing material (incombustible, resistant, nonfibrous, cleanable).

- Providing sound-absorbing baffles on ventilation ports, outlets of cables and pipes and apertures for material delivery etc., where required.
- Separation of the enclosure from the machine by avoiding fixed connections and/or reducing the number of fixing points.

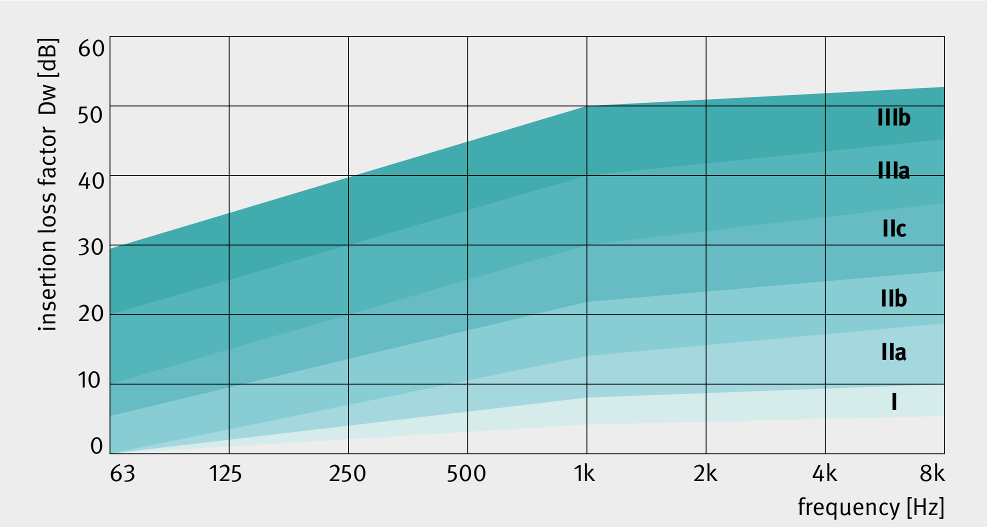
The following table specifies enclosure designs with regard to types of construction and their potential effectiveness. Enclosure design is classified into three groups: Group I represents simple sound-reducing mats, Group II single- shell enclosures and Group III brickwork or double-shell enclosures.

TYPES OF ENCLOSURE DESIGN AND THEIR EFFECTIVENESS (VDI 2711, WITHDRAWN WITHOUT REPLACEMENT)

Group	Type of enclosure	Weight per unit area [x] of enclosure lining	Admissable aperture area (proportion of enclosure surface) [o]	A-weighted sound level reduction (depending on spectrum) D_{pA}
I	sound-proof mats	5 to 6 kg/m²	overall aperture area ‹ 10%	3 to 10 dB
IIa	single-shell enclosure with non-sound-absorbing lining	5 to 15 kg/m²	overall aperture area ‹ 5%	5 to 15 dB
IIb	single-shell enclosure with sound-absorbing lining	5 to 15 kg/m²	overall aperture area ‹ 0.5%	7 to 25 dB
IIc	single-shell enclosure with sound-absorbing lining	20 to 25 kg/m²	overall aperture area ‹ 0.1%	10 to 30 dB
IIIa	double-shell enclosure with sound-absorbing or brickwork lining	5 to 10 kg/m² je Schale, etwa 100 kg/m²	overall aperture area ‹ 0.01%	20 to 40 dB
IIIb	double-shell enclosure with sound-absorbing or brickwork lining	10 to 15 kg/m² per shell, approx. 400 kg/m²	to be avoided, where possible, including decomposition	30 to 50 dB

[x] without supporting structure, sound-absorbing lining and cover (the overall lining weight can be multiple this weight)

[o] not taking into account existing baffled outlets



Achievable insertion loss values D_w* as a function of frequency

* Difference of the sound power level radiated by a noise source without and with enclosure.

D_w allows for the frequency dependence of the sound insulation material.

Special case: Noise protection hood (small enclosure)
Noise protection hoods have a low mass for easy handling and are made partly of transparent materials for process observation. The machine frame often forms the support structure for the enclosure.

The insertion loss factor of a noise protection hood is particularly dependent on the materials used and the thickness of the enclosure panels.

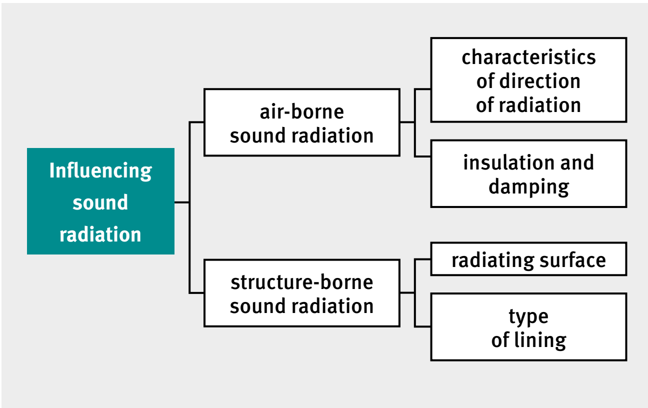
Leaks between the noise protection hood and the frame must be sealed with elastic strips.

Due to lack of space, it is usually not possible to install effective silencers. Therefore, necessary openings should be kept as small as possible. The bypass transmission of structure-borne sound (e.g. via the paper) should preferably be reduced by vibration damping.

Design principles for control of structure-borne sound transmission
The following principles should be applied:

- Increasing masses in the area of excitation (only for medium and high frequencies)
- Increasing stiffness in the area of excitation (for high frequencies only)
- Vibration isolation of the sound source
- Increasing the damping (effective for medium frequencies)
- Reflection at discontinuity points with additional damping on the input side (for medium and high frequencies only).

Control of sound radiation



Design principles for influencing noise radiation

Air-borne noise radiation can be reduced by measures such as:

– locating openings on the most favourable side (directional characteristic of radiation) and
– using baffles or baffle collectors in front of openings.

Structure-borne noise radiation can be reduced by, measures such as:

– reducing the radiating surface and
– using panels with a low rate of radiation (for example perforated plates or plates lined with damping material).

Construction examples
Design examples for the construction and assembly or installation of enclosure elements, for the design of soundinsulated openings for ventilation, material transport and other wall ducts, as well as examples of seals and elastic mounts for the prevention of structure-borne sound transmission are provided in EN ISO 15667 "Guidelines for noise control by enclosures and cabins".

Guidance for measuring and determining the emission sound pressure levels on printing and paper converting machines
For every machine manufactured or placed on the market, binding and verifiable information on the machine's noise emission must be provided. Within the framework of European harmonisation, noise emission values must be determined on the basis of the European standard EN 13023 "Noise measurement methods for printing, paper converting, paper making machines and auxiliary equipment – Accuracy grades 2 and 3" and respective European generic standards since October 2003.

The determination of emission sound pressure levels on printing and paper converting machines is described in detail in the Test Body Information No. 917 published by the Printing and Paper Converting Division. It is intended for manufacturers who want to take measurements themselves.

It is guidance for those who want to make the necessary measurements and determine respective noise emission characteristics.

In addition to summaries of normative requirements, the information sheet also gives assistance in taking measurements and determining noise values and includes an example of a noise measurement report.

It is, however, recommended to have the necessary standards available for reference as noise measurements require routine practice. Especially in case of inexperienced personnel it will be helpful to refer back to generic standards in detail for better understanding. For the actual measuring process, the machine-specific standard EN 13023 must be applied which specifies individual measuring points and operating conditions.

5 Applicators of PUR hotmelt glues

The following information relates to PUR premelters and PUR hotmelt glue applicators in perfect binders where the intended application specifies the use of reactive PUR hotmelt glues on the basis of Methylene diphenyl diisocyanate (MDI).

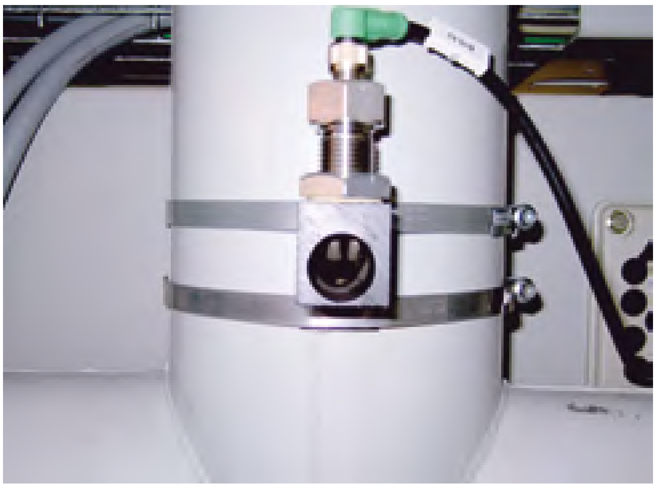
The basic requirement is that the process of applying PUR glues in perfect binding must be so designed that it is ensured that hazardous MDI concentrations are not emitted under any operating condition.

Safety measures
Manufacturers designing machines or plants where hazardous substances may be used must ensure that users can work with such machinery without risk. This also applies to machinery intended for the use of low-emission reactive PUR hotmelt glues which are not classified as hazardous substances. Manufacturers need to provide technical safety measures and they must inform users in the instruction handbook about procedural measures and personal protection required under the intended use. Safety measures and instructions must be reported in the Technical Documentation. Technical measures must also be listed in the instruction handbook.

Designed-in safety measures

- Premelters and applicators must be so designed that harmful vapours are not released during the process, for example by
  - gas-dense glue premelters,
  - containment of vapours by enclosure as far as possible,
  - provision of exhaust equipment with a capacity of at least 500 m³/h directly on the perfect binder or direct source extraction on the applicator.

Note:
Slot-nozzle gluing systems are of low-emission design. Cleaning is not required. There are also no emissions when keeping hot applicator units outside the enclosed applicator system as the slot nozzle is closed.



Sensing device monitoring exhaust performance

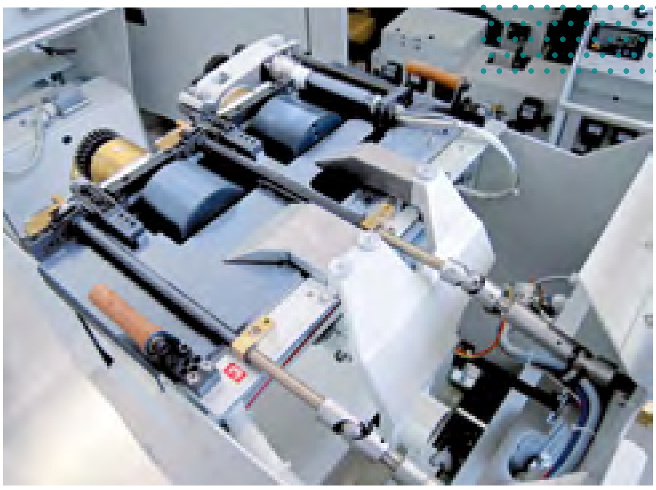
Exhaust equipment with activated carbon filter on a perfect binder

- On premelters and applicators, technical measures must be provided to prevent overheating of reactive PUR hotmelt glues to a temperature above the processing temperature specified by the glue supplier (generally 130 °C), for example by temperature control devices with separate limit value monitoring for all heated elements.

Preheater integrated into the glue applicator

Note:
Premelters have low emission when provided with a temperature control device limiting the temperature at 100°C so that no MDI escapes into the respiratory air when feeding the preheater.

- When replenishing premelters with reactive PUR hotmelt glue, an effective exhaust device with a capacity of at least 150 m^3/h must be provided for the duration of the replenishing procedure, with exhaust vapours being dissipated to the outside or via suitable filters. On premelters integrated into perfect binders, the additional exhaust device on the premelter may be dropped if the vapours generated during barrel changing are extracted by the exhaust system for the glue duct.
- Spilling of hot glue, for example caused by bursting of PUR glue reservoirs when pressure-cleaning feed pipes or empty containers (container melting device) must be prevented by technical measures (for example by covers resistant to bursting).
- Technical measures are required to ensure that the emission of MDI is prevented during setting and removing disturbances of perfect binders, when pulling out, heating, storing and cooling down applicator units outside the perfect binder or when cleaning the applicator. This can be achieved by, for example
  - by covering ducts, inserting ducts into cleaning stations with extraction equipment or under extraction hoods or
  - by covering ducts and providing direct extraction equipment on the gluing unit.
- Where removal of roller basins, draining of glue, dismantling and cleaning of rollers takes place at the end of the working time an extraction system must be provided to safeguard these operations.
- Facilities for draining the reactive PUR hotmelt glue inside the perfect binder.



Extractor located directly on PUR gluing unit

Extraction hood

PUR gluing unit on a perfect binder

- Extraction monitoring by adequate sensing devices, failure in the extraction equipment must result in a warning signal, the perfect binder must run dry and further production must be prevented.
- Taking sample measurements to verify if limit values for workplace exposure of 2,2'-MDI, 2,4'-MDI and 4,4'-MDI or total concentration of reactive isocyanate groups (TRIG) are observed, using well-tried measuring methods.

User instructions in the instruction handbook
Safety instructions in the instruction handbook are dependent on the specific application. The list below only gives examples and does not claim to be complete.

Technical and organisational safety measures
- ensuring adequate ventilation of the workplace in compliance with ASR A3.6 and VDI 2262. In the case of additional air humidification, reference must be made to the BG regulations on the operation, cleaning and maintenance of humidifiers.
- Reactive PUR hotmelt glues must only be used in premelters and applicators suited for the process.
- Provision of an extraction system with adequate capacity in the area of the applicator and the preheater (minimum exit air volume of 500 m^3/h on the applicator and 150 m^3/h on the preheater).
- Manufacturer instructions for removing hot applicator units from the perfect binder, especially when changing applicator units and when cleaning (for example requiring covers to be inserted when removing applicator units, instant insertion under the extracting device, draining of PUR quantities remaining in the perfect binder).
- Only undamaged PUR glue containers may be used. Empty containers with heated remains must not be left open; containers must be protected against sunlight
- Indication of residual risks where the intended use is not respected. Acute effects of MDI: irritation of the eyes and respiratory tract. Through changes to the immune system it can also cause respiratory and lung diseases.
- Providing users with the results of sample measurements as proof of compliance with occupational exposure limits for 2,2'-MDI, 2,4'-MDI and 4,4'-MDI or the total concentration of reactive isocyanate groups (TRIG) when used in conformity with its intended purpose. Indication that new measurements must be taken by the user if the applicator or the preheater have been substantially modified or when glues with more than 4% monomer MDI content or where the prescribed application temperature is exceeded.
- Occupational medical preventive checks are required if the system is used as intended. If operations differ from the intended use, it is the user's task to provide evidence that the workplace limit values are observed and there is no regular skin contact. Otherwise medical preventive checks must be carried out in compliance with guideline G 27 "Isocyanates".
- Indication of the need for users to set up operating instructions for handling PUR hotmelt glues on the basis of the safety data sheet and the instruction handbook. Operating personnel must be informed about the intended use and existing residual risks at regular intervals.

Personal protective and hygienic measures when handling reactive PUR hotmelt glues

- Where it cannot be entirely excluded that MDI is released into the respiratory air when removing hot applicators from the perfect binder, when cleaning or when replenishing hotmelt glue, protective masks with filter A (brown) or B (grey) must be provided and instructions for use be given.
- Skin contact must be avoided, for example when unpacking hotmelt glues, when cleaning or manual handling of new products. The use of protective gloves, for example coated cotton gloves, is required.
- Heat-resistant work gloves, for example leather gloves, must be used when replenishing hotmelt glues or during cleaning. Where the risk of spilling of hot glue exists, protective glasses must be worn.
- At the end of working time and before breaks, thorough cleaning of hands is required. Adequate skin care of personnel must be ensured.
- Clothes contaminated with hotmelt glue must be changed immediately.

Measurement of hazardous substances

Isocyanates can cause serious health problems if the occupational exposure limits are not observed and skin contact is not prevented.

Isocyanate is absorbed mainly by the respiratory system, but also by the skin, and can cause irritation of the eyes and respiratory tract. Sense of smell cannot be relied upon to warn of hazardous concentrations of isocyanate.

The properties that make isocyanate harmful relate to free, unbound isocyanate, which can be inhaled in the form of vapours or aerosols. Reactive PUR hotmelt glues contain between › 0.1% and 4% of unbound isocyanate, which can escape into the respiratory air in harmful concentrations when heated above 100°C. Glues with ‹ 0.1% isocyanate are not considered harmful when used in conformity with their intended purpose. There are no risks from completely cured glues after processing, except when products are decomposed in fire incidents.

It is thus essential that the effectiveness of technical safety measures be verified by sample measurements of a standard glue (›0.1 to 4%) to be taken by the manufacturer. At the same time, compliance with the occupational exposure limits for 2.4'-MDI and/or 4.4'-MDI in accordance with TRGS 900, or the total concentration of reactive isocyanate groups (TRIG) in accordance with TRGS 430 must be ensured, when used for the intended purpose.

The information sheet No. 904 published by the Test and Certification Body Printing and Paper Converting provides detailed information and practical guidance on sample measurements such as measuring conditions, location of measuring points, number of measuring points and evaluation of measuring results.

Exhaust air

Removal of exhaust air must take place as close to the source of emission as possible, taking into account air flows created by the machine speed.

Fan blowers may be used to discharge exhaust air, either to the outside of the building or recycled after cleaning. Exhaust air which has not been cleaned must not be redirected into the work area.

The exhaust capacity must be a minimum of 150 m^3/h on the preheater and a minimum of 500 m^3/h on the applicator. Where exhaust devices are incorporated into central ventilation systems, the exhaust capacity on the unit or perfect binder must be measured by means of a flow meter.

Cleaning of exhaust air is possible via water filters or active carbon filters. Their effectiveness must be verified by before-after measurements. Where active carbon filters are used, a replacement interval must be specified.

Suitable materials:

- for vessels, pipes and pumps: stainless steel, ferrite steel, boiler plate
- for sealing: Teflon (PTFE), fluorinated polymer rubber (FKM, FPK, FFKM)

Unsuitable materials:

Copper, other non-ferrous metals and zinc. Many synthetic and rubber materials are subject to degradation and quickly become brittle.

2.1.11 Pressure equipment

For pressure devices and sub-assemblies which are subjected to an **internal gauge pressure of more than 0.5 bar,** special requirements apply with regard to their construction and fittings, testing and conformity evaluation as well as their marking.

A general distinction is made between:

Pressure vessels according to the EU Directive 2014/29/EU on simple pressure vessels.
According to this directive, simple pressure vessels are vessels which are welded and produced in series, and which

- are intended to contain air or nitrogen,
- are not intended for firing,
- have stress supporting elements which are made of non-alloy steel or aluminium,
- are designed for a maximum operating pressure of 30 bar,
- are designed for a maximum energy content of 10,000 bar x l,
- are designed for operating temperatures of -50°C minimum and 300°C maximum for steel vessels and 100°C maximum for aluminium vessels and
- are of simple design, for example cylinders with hemispherical bottom.

Simple pressure vessels, for example storage containers in pressure-generating devices, must comply with the essential safety requirements set out in Annex 1 of this Directive. This does not include smaller pressure vessels of which the pressure capacity product P_S x V does not exceed 50 [bar l]. These must be constructed in accordance with the good engineering practice in force in a Member State and do not require a Declaration of Conformity.

Assessment of conformity
Manufacturers of pressure vessels with a pressure capacity product PS x V ›50 [bar l] must provide evidence of an EU-type examination by a notified body. In addition, depending on the size of the pressure capacity product, further conformity assessment procedures are required in accordance with the table below.

Pressure content product PS x V [bar x L]	**conformity assessment procedure in accordance with Annex II of the Directive**
≤ 50	Not applicable
› 50	Prior to manufacture: EU-type examination (Module B)
50 ‹ PS x V ≤ 200	Prior to manufacture: EU-type examination (Module B) and additionally prior to placing on the market: internal production control • without supervised vessel testing (Module C) or • with regularly supervised vessel testing (Module C1)
200 ‹ PS x V ≤ 3,000	Prior to manufacture: EU-type examination (Module B) and additionally prior to placing on the market: internal production control with supervised vessel testing • regularly (Module C1) or • at random intervals (Module C2)
› 3,000	Prior to manufacture: EU-type examination (Module B) and additionally prior to placing on the market: internal production control with regularly supervised vessel testing (Module C1)

Marking and Declaration of Conformity

Simple pressure vessels with an EU-type examination (vessels with P_S x V › 50 bar x L) must carry a clearly legible and indelible CE marking as well as the last two digits of the year in which the CE marking was affixed. The CE marking must be followed by the identification number of the notified body involved in the production control phase.

In addition, the pressure vessels must bear the following information:

- maximum working pressure (PS in bar);
- maximum and minimum working temperature (Tmax/min in °C);
- capacity of the vessel (V in L);
- trade name and address of the manufacturer;
- type and
- serial or batch identification of the vessel.

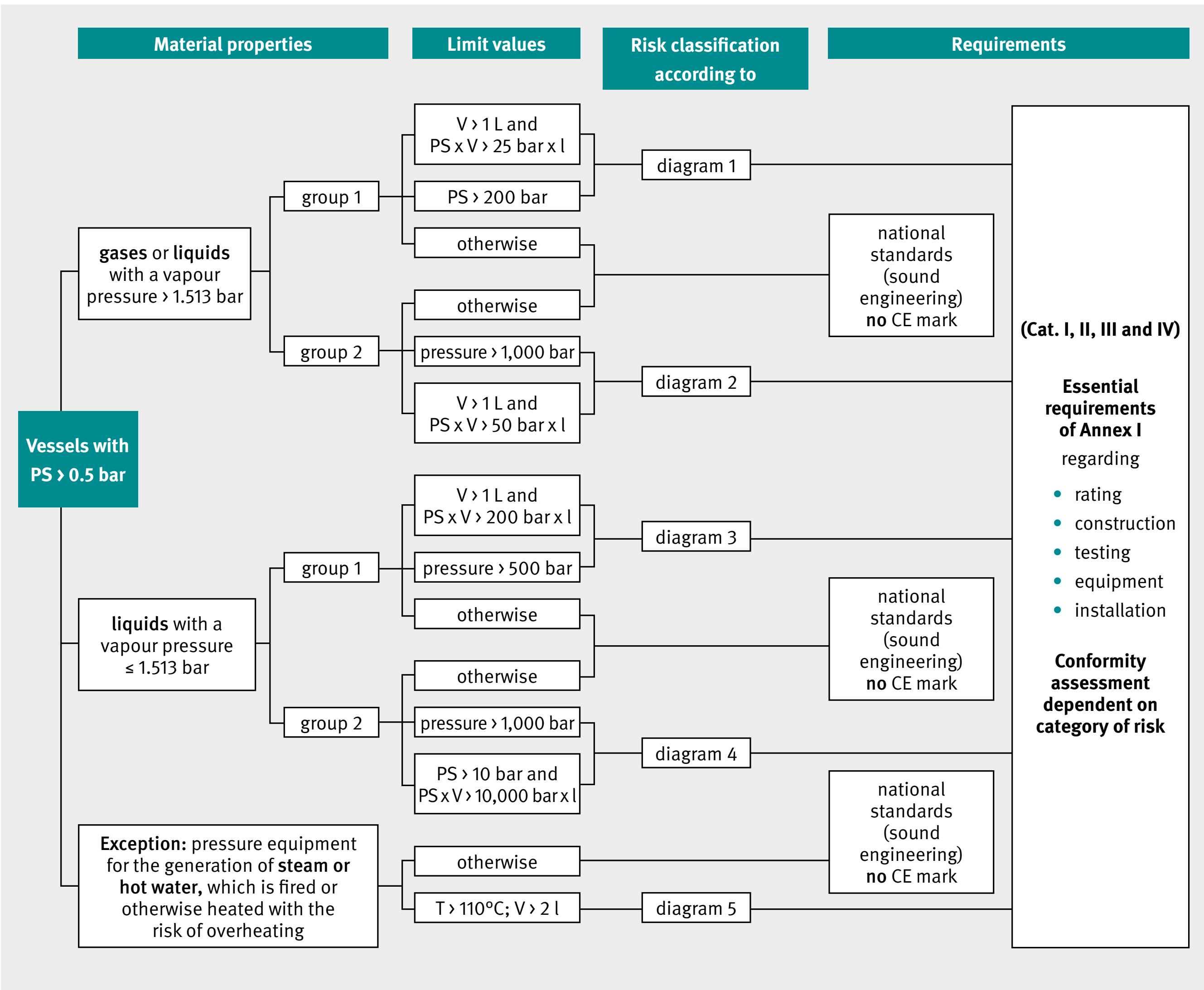
Operating Instructions

The pressure vessel must be accompanied by operating instructions containing the necessary safety information, the intended use and the maintenance and installation requirements.

Pressure equipment according to the EU Pressure Equipment Directive 2014/68/EU (PED)

The PED must be observed for all equipment to which the Directive on simple pressure vessels does not apply. According to the PED, pressure equipment is defined as:

- vessels
- piping
- accessories
  - with safety function (e.g. safety valves)
  - with pressure function (e.g. shut-off devices).

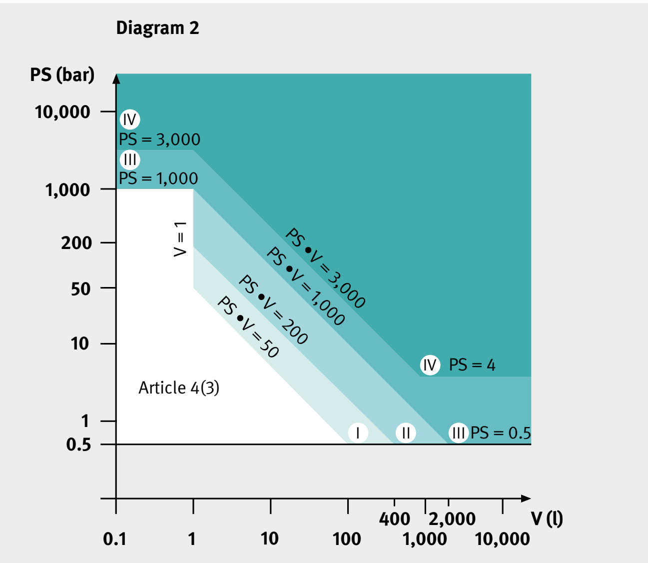


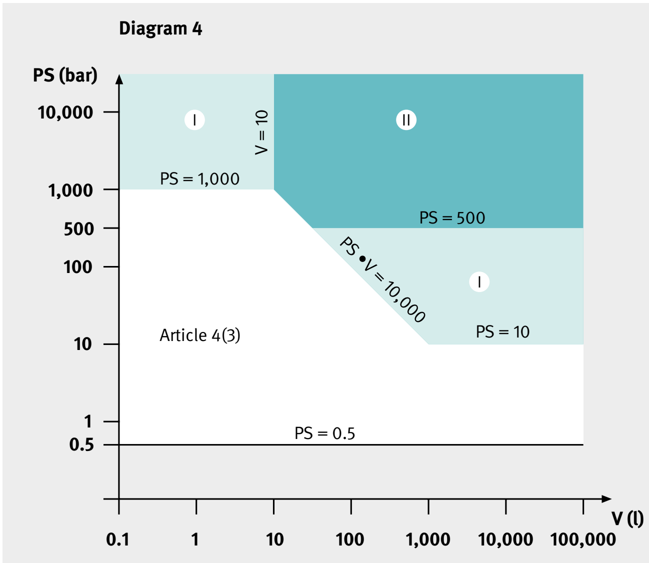
The Pressure Equipment Directive (PED) excludes equipment which is already covered by other directives such as the Machinery Directive 2006/42/EC and for which the pressure hazard is classified as category 1. An example would be lifting cylinders.

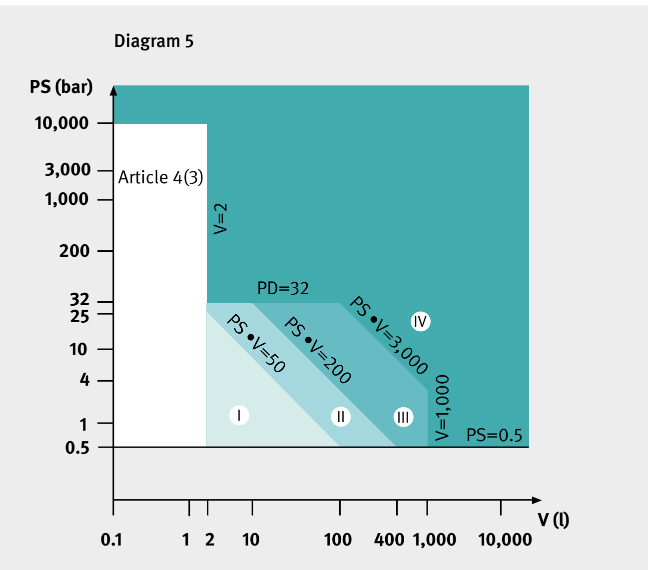
The scope of the Directive also excludes pressure equipment which is over dimensioned or where the main stresses are other than pressure. For such devices, pressure is not a constitutive design factor. They are primarily designed to move, to turn or fulfil functions other than to sustain pressure. An example would be steam heated cylinders inside machines.

According to the Pressure Equipment Directive, the risk potential of pressure equipment determines its classification in one of the Risk categories (I-IV). Classification is carried out with the aid of the diagrams in Annex II of the PED and is based on the stored energy and the properties of the medium used. Fluids, for example, are categorized in two groups, according to their characteristics :

- Group 1:
  hazardous liquids (for example flammable, explosive, toxic)
- Group 2:
  all other liquids (for example harmful, corrosive, irritant)







Diagrams 2, 4 and 5, Article 4, Annex II, for pressure vessels and fluids in Group 2

Most of the fluid substances used in pressurized form on **printing and paper converting machines** (for example water, hydraulic oil, hydraulic liquids etc.) are classified in Group 2.

Pressure equipment where pressures **exceed the limit values** specified in the Pressure Equipment Directive must

- comply with the essential safety requirements of Annex 1 of the Directive
- be subjected to the process of conformity evaluation and
- carry a CE marking

Pressure equipment below or equal to the **limit values** set out in the PED (Article 4(3)) must

- comply with the rules of sound engineering practice, i.e. they must be designed to take account of all relevant factors affecting safety. It must also be constructed and tested to ensure its safe operation under all foreseeable or reasonably foreseeable conditions of use for its intended life
- have operating instructions attached
- be provided with the manufacturer's address and
- **not have** CE marking.

Piping applied in printing and paper converting is generally below the limit values. For gases Group 2, for example used in compressed-air supply lines, limit values are exceeded only where the nominal diameter DN is more than 32 mm and the product of PS x DN is more than 1,000. On hydraulic lines, limit values are exceeded where the pressure PS is more than 10 bar, DN is more than 200 mm and the product of PS x DN is greater than 5,000.

Conformity Assessment Procedure
For the conformity assessment procedure, test modules or combinations thereof are assigned to Categories I-IV; manufacturers are free to make their own choice.

The modules basically consist of three points:

- Description of the procedure to be used by the manufacturer to ensure and declare that the pressure vessels in question comply with the requirements of the Directive.
- Specification of the test and surveillance measures to be carried out by a notified body.
- Specification of the documentation to be drawn up.

With the exception of module A "Internal production control", which applies to pressure equipment of Category 1, all other modules require the participation of a notified body.

Notified bodies are test houses certified by the European Union. They take over the role of a neutral third party in cases where neutral positions are required in the evaluation process.

RELATIONSHIP BETWEEN CATEGORIES AND TEST MODULES AND/OR COMBINATIONS

Category	Selection of module without Quality Assurance (QA)	Selection of module with Quality Assurance (QA)
I	**A** Internal production control	–
II	**A2** Internal production control with approval monitoring	**D1** Production QA **E1** Product QA
III	**B (production type) + C2** Production type examination + conformity to type **B (design type) + F** design examination + product tests	**B (design type) + D** Design type examination + production QA **B (production type) + E** Production type examination + product QA **H** Comprehensive QA
IV	**G** Individual test **B (production type) + F** Production type examination + product tests	**B (production type) + D** Production type examination + production QA **H1** Comprehensive QA with design type examination + approval monitoring

Within categories II-IV, manufacturers can choose between modules with product examination by a notified body (sample tests or individual tests) and modules with quality assessment (QA).

Marking and Declaration of Conformity
Pressure equipment which comes under one of the categories (I-IV) of the Pressure Equipment Directive must be provided with **CE marking.** Equipment from category II onward must also show the **identification number of the notified body** mandated with production control.

In addition to the CE marking, manufacturers issue a written EU Declaration of Conformity. This declaration gives, in particular, the following details:

- product, type, batch or serial number
- name and address of the manufacturer and, where applicable, his authorised representative
- references to the relevant harmonised standards
- the conformity assessment procedures followed
- where applicable, the notified body responsible for production monitoring
- references to existing certificates, if applicable, and specifications used

Pressure equipment must carry the following information:

- manufacturer identification (name, address etc.)
- year of manufacture
- type, serial number or the like
- allowable upper/lower limit values (max. pressure, max./min. operating temperature etc.)
- other technical data (volume, nominal width, test pressure, test date, performance etc.)
- warning signs where required

Operating instructions
All pressure equipment which is placed on the market must be accompanied by instructions for the user, containing all the necessary safety information relating to **installation, putting into service, use and servicing**. Instructions must include the data given on the name plate and, where applicable, technical documents, drawings and diagrams required for full understanding of the operating instructions. They must further point out residual risks and hazards from misuse.

Approval examination
All pressure equipment is subject to approval examination. This is where the material provisions of the Pressure Equipment Directive and the operating requirements of the ordinance concerning the protection and safety of health in the provision of work equipment converge.

Approval examination includes:

- compliance checks (e.g. documents must satisfy the requirements of the Pressure Equipment Directive)
- equipment checks
- assembly checks
- establishing the inspection intervals for periodic checks

2.2 Specific technical safety requirements for certain assemblies of printing and paper converting machines

2.2.1 Cutting machines and tools

Knives must be safeguarded in their rest position and in their working position in such a way that the cutting edge cannot cause injuries.

The following protective measures are required:

- **Stationary knives**
  Knife blades must be protected by guards as far as possible.

- **Rotary cutting tools (circular cutters, perforating knives, rotary slitting knives**)
  On cutting machines working with rotary knives, the inrunning nips and that part of the knife perimeter that is not used for cutting must be protected against inadvertent contact, for example by either guarding each knife separately or by providing one guard protecting the entire working width (all knives).

Safeguarding rotary knives: the guard must cover the entire perimeter except for the cutting point

2.2.2 Feeding and delivery units (pile lifting and lowering devices)

In order to make load-carrying equipment (for example steel link chains) and pile lifting and lowering devices safe, the following requirements must be satisfied according to EN 1010-1:

- For production format sizes over 2.5 m² the breaking strength of the steel link chains must be at least 6 times the admissible static load.
- For production format sizes below 2.5 m² it must be at least 3 times the static load.

Pile lowering and lifting devices for format sizes above 2.5 m² and a lifting height of 1.5 m must be so designed that in the event of breakage of the load-carrying element they do not move more that 100 mm.

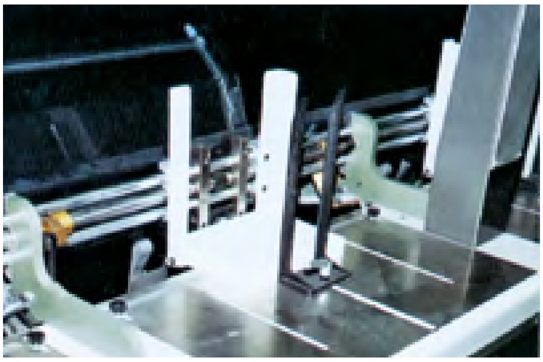
The danger point between the edges of the pile carrier plate and the floor space must be protected as follows:

Automatic lowering must only be possible down to 120 mm (clearance between the lower edge of the plate and floor level). Further lowering must be allowed under hold-to-run control only under the following conditions:

- Feeder size (production format size) of 1 m² maximum
- Delivery size (production format size) of 0.175 m² maximum.

Where larger formats are processed, at least one of the following measures must be taken:

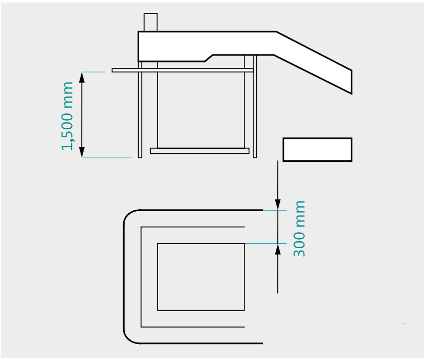
- resilient, non-switching, overhanging shields mounted on the pile carrier plate with their forward edges protruding over the hazardous edge by at least 250 mm
- ESPDs in front of the pile carrier plate
- horizontal distance of 300 mm between the vertical projection of the outer machine frame and the hazardous edges. The deflecting parts of the machine must not be higher than 1.5 m above the base. Carrier arms projecting into the safety distance (300 mm) shall have a clear space of 120 mm minimum from floor
- trip bars or handles
- clearance between the hold-to-run button and the nearest crushing point between the plate and floor space must
- be 850 mm minimum (applies to feeders only)



On feeders of gathering machines injuries from the movement of separating elements must be prevented. A solution is for example residual pile monitoring on feeders where blanks are fed from the bottom of the pile

Safeguarding by deflecting parts of the machine frame on the delivery of a sheet-fed offset printing press

On feeders used in paper converting, some of the danger points are concealed by the material. Material may be used for safeguarding danger points if a residual pile monitoring device is provided ensuring that the feeder has stopped before the last sheet has been fed or removed. Stopping of the feeder can be triggered by interlock switches and/or photoelectric beams.



Safeguarding by deflecting parts of the machine frame (dimensions)


Safeguarding the danger zone on the reel changing unit of a magazine offset printing press by ESPD

2.2.3 Reel unwinding and rewinding devices on machines

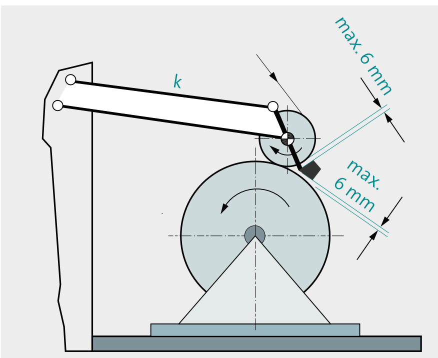
The inrunning nips at reels and pressure rollers and reels and support rollers of reel unwinding and rewinding equipment must be protected by guards or by safety devices with approach reaction.

The safety measure selected must be effective for all reel diameters. Side access to the inrunning nip must be prevented.

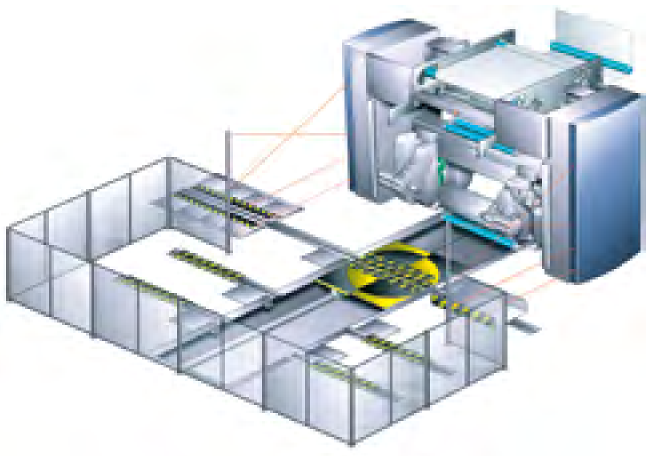
Chucking cones must only be inserted under hold-to-run control with the position of the hold-to-run button located in such a way that the danger point on the chucking cones and the reel can be observed. Hold-to-run speeds are limited to 5 m/min.

Where danger points between single lifting arms or turrets and machine frame cannot be avoided or safeguarded by design, the lifting arms must only be movable under hold-to-run control and the operator must be able to view the danger point.

On manual and automatic reel loading systems, the entire danger zone on the reel unwind must be safeguarded by ESPDs or guards. The requirements for semi-automatic loading systems are specified in EN 1010-1.

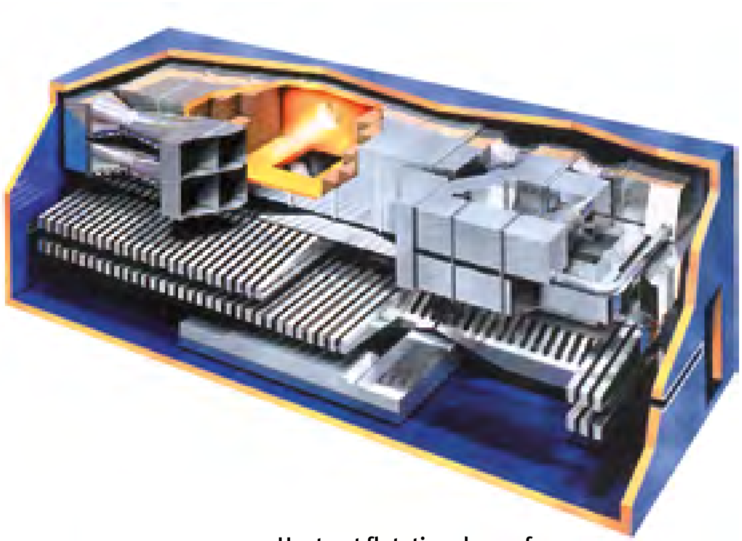


Safeguarding the inrunning nip on a reel rewind with safety device adapting to changing reel diameters


Where danger zones are safeguarded by ESPD, an additional photoelectric device is required on the reel changing unit which remains active while the two lower light beams are muted when the reel passes the area

2.3 Technology of drying printed products

The term drying designates all processes taking place after ink application and resulting in the substrate forming a solid compound with the ink and causing the ink to solidify. Dependent on the structure of the ink, drying can be achieved by chemical reaction (oxidization or polymerisation) or by physical processes (penetration, evaporisation) or by a combination of both.



Heat-set flotation dryers for web offset printing presses

2.3.1 Evaporative drying

In web offset printing (heatset) special printing inks are used, which contain a high proportion of quick-hardening binding agents. The solvent component consists of about 35% high-boiling mineral oils in the boiling range 250–290°C. At drying temperatures of up to 315°C, up to 85% of the oils used are evaporated in the hot air flow.

The mechanical ventilation of through-flow solvent dryers (heatset/flotation dryers) must be designed and operated in such a way that at no point can hazardous, potentially explosive solvent vapour-air mixtures form during the evaporation of ink solvent inside the dryer. A special requirement for through-flow solvent dryers is that the solvent concentration inside the dryer be limited to 40% of the LEL (lower explosive limit) at drying temperature. Where additional requirements in compliance with EN 1539 have been fulfilled, 60% or 65% of the LEL at drying temperature are permissible.

On the basis of a given exhaust volume of the dryer, the highest admissible solvent throughput, i.e. the maximum solvent quantity per hour, can be calculated according to Annex B.2 of the European standard EN 1539. Calculation results must be verified by metrological methods on commissioning of the dryer. They must consider the most unfavourable conditions which may be the cause for the maximum solvent concentration:

- highest dryer temperature
- highest web speed
- maximum web width
- low-grammage paper
- maximum application thickness.

Where automatic blanket washing devices are used, the correct setting of the exhaust volume rate in combination with the maximum admissible throughput of washing agents is of special importance under explosion protection aspects. The maximum throughput of washing agents on blanket washing devices must be adapted to the possible exhaust volume of the dryer.

Measurements must be taken to verify that the amount of washing agent does not exceed the maximum permissible throughput value. Measurements must also be made under the most unfavourable conditions which may be the cause for the maximum solvent concentration in the dryer:

- highest dryer temperature
- lowest production speed (lowest washing speed)
- maximum web width
- minimum washing time
- maximum calculated input of washing agent.

Measurement reports must adequately document calculations and also basic machine conditions.

For drying printing inks containing low-boiling solvents such as they are used in gravure and flexo printing, mainly jet-type dryers are used. Drying temperatures are generally below 100°C.

Solvent	Ignition temperature (°C)	Flash Point (°C)
Ethanol	400	12
Ethylacetate	470	–4
Toluene	535	6
Pentadecane ($C_{15}H_{32}$)	220	122

2.3.2 UV drying

UV inks and UV varnishes can be applied in practically all common printing methods, for example

- UV flexo printing
- UV offset printing
- UV gravure printing
- UV screen printing and UV pad printing
- UV inkjet printing

Unlike conventional or physical drying methods, UV drying is a chemical drying process where curing is effected by means of UV radiation.The high-energy UV radiation in the dryers and the reactive UV inks and UV varnishes require special measures to ensure health protection.This applies specifically to the protection of hands and skin from UV inks and UV varnishes, protection against direct or indirect exposure to UV radiation – depending on the type of dryer – and protection against ozone.

Radiation must be shielded by screens, protective filters or blinds, so that no harmful radiation can escape to the outside. Guards and enclosures that have to be removed frequently or for setting up, must be interlocked with the radiating source in such a way that the source is positively switched off when the guards are opened or removed. (DGUV Regulation 113-002, No. 4.5.1).

Conventional UV dryers should always be operated with sufficiently powerful air extraction systems, in order to ensure that not only the heat generated by the UV radiation, but also the ozone formed in the dryer, are prevented from reaching the workspace. The exhaust system must be designed in such a way that the UV dryer can only be operated with the exhaust system running.

There is an increased risk of fire and explosion when UV dryers and automatic cylinder washing devices are operated simultaneously. Either the washing device and UV dryer must be interlocked, or the Professional Association (Berufsgenossenschaft) must be presented with conclusive measurement data (surface temperature and solvent vapour concentrations inside the printing press in the close vicinity of the dryer) to prove that safe simultaneous operation is permissible.

2.3.3. Infrared (IR) drying

Infrared heating systems of infrared solvent continuous dryers must be explosion-proof unless adequate air flow is provided to ensure that the heater is surrounded by fresh air only and solvent enriched air cannot reach those parts of the heater which have a higher temperature than the ignition temperature. Fresh air intake to these parts must last until the temperature has dropped to below the limit temperature (limit temperature = 80% of the ignition temperature). In the event of breakdown of fresh air supply or the transport mechanism, the heater must switch off automatically (see also DGUV Regulation 113-002, No. 4.3).

2.3.4 Electron beam (EB) drying

For operating personnel working on electron beam continuous dryers and being permanently exposed to radiation in areas which can be generally accessed, those limit values apply which are specified for areas that can be accessed by the public. Admissible limit values for stray radiation (X-rays) are dealt with in the Radiation Protection Ordinance and the Regulations on X-rays.

The design of EB dryers requires enclosures and guards which have to be removed frequently or for setting up to be interlocked with the source of radiation causing the source to be positively switched off when guards are opened or removed. This requirement also applies to enclosures and guards which must be removed for, for example, maintenance and repair, if this occurs at least once per working shift. In addition, radiation monitoring must be provided on the safety-critical parts of the electron beam through-flow dryer, where required (see also DGUV Regulation 113-002, No. 4.6 and the German Radiation Regulation RöV §5 in conjunction with §§2b, 19 RöV).

2.4 Collaborative Robot Systems

Collaborative robot systems (cobots for short) are increasingly being used in the printing and paper processing industry for tasks such as stacking products on pallets.

The goal of a cobot application is to allow humans and robots to work together without barrier-type safety guards. Many applications with a robot are cooperative rather than collaborative. This means that the operator does not work hand in hand with the robot and direct contact with the robot is not intended. For example, removing full pallets from a cobot stacker and loading the cobot stacker with empty pallets is a cooperative activity.

2.4.1 Legal Basis

The robot itself is an incomplete machine in the sense of the Machinery Directive. This means that not all risks of the robot's movements are covered. This is the responsibility of the manufacturer of the finished application, who must carry out a conformity assessment procedure and a risk assessment, whereby not only the intended use must be considered, but also possible foreseeable uses in all operating situations, and in particular reflex actions, e.g. in troubleshooting situations.

2.4.2 Standards and Explanatory Documents

The standards

- EN ISO 10218-1 “Industrial robots – Safety requirements – Part 1: Robots” and
- EN ISO 10218-2 “Industrial robots – Safety requirements Part 2: Robot systems and integration”

specify requirements for industrial robots and also cover collaborative operation.

The Technical Specification

- ISO/TS 15066 “Robots and robotic devices – Collaborative robots”

specifies safety requirements for collaborative industrial robot systems and the working environment and supplements the requirements and guidance for the operation of collaborative industrial robots given in ISO 10218-1 and ISO 10218-2.

Among other things, it defines force and pressure limits for contact with humans (Table 1).
The DGUV information sheet

- FB HM-080 “Collaborative robot systems – Design of systems with “power and force limiting” function”

explains ISO/TS 15066 and describes general requirements as well as a measuring system for checking compliance with the limit values.

<table>
<tr><th colspan="3">Body localisation</th><th colspan="2">Quasi-static contact (clamping)</th><th colspan="2">Transient contact (free impact)</th></tr>
<tr><th colspan="2">Specific localisation</th><th>Body region</th><th>Peak pressure P_S [N/cm²] (Note 1)</th><th>Force F_S [N] (Note 2)</th><th>Peak pressure P_T multiplier (Note 3)</th><th>Force F_T multiplier (Note 3)</th></tr>
<tr><td>1</td><td>middle of forehead</td><td rowspan="2">skull and forehead</td><td>130</td><td rowspan="2">130</td><td>none</td><td>none</td></tr>
<tr><td>2</td><td>temple</td><td>110</td><td rowspan="4">2</td><td rowspan="4">2</td></tr>
<tr><td>3</td><td>masticatory muscle</td><td>face</td><td>110</td><td>65</td></tr>
<tr><td>4</td><td>neck muscle</td><td rowspan="2">neck</td><td>140</td><td rowspan="2">150</td></tr>
<tr><td>5</td><td>seventh neck vertebra</td><td>210</td></tr>
</table>

6	shoulder joint	back and shoulders	160	210	2	2
7	fifth lumbar vertebra		210			
8	sternum	chest	120	140		
9	pectoral muscle		170			
10	abdominal muscle	abdomen	140	110		
11	pelvic bone	pelvis	210	180		
12	deltoid muscle	upper arms and elbow joints	190	150		
13	humerus		220			
14	radial bone	lower arms and wrist joints	190	160		
15	forearm muscle		180			
16	arm nerve		180			
17	forefinger pad d	hands and fingers	300	140		
18	forefinger pad nd		270			
19	forefinger end joint d		280			
20	forefinger end joint nd		220			
21	thenar eminence		200			
22	palm d		260			
23	palm nd		260			
24	back of the hand d		200			
25	back of the hand nd		190			
26	thigh muscle	thighs and knees	250	220		
27	kneecap		220			
28	middle of shin	lower legs	220	130		
29	calf muscle		210			

Table 1: Biomechanical Limit Values

Note 1:

The specified values for peak pressure were determined as part of study carried out by an independent institution [7]. 100 subjects from industry and the general public were experimentally examined. The specified limit values represent pain onset thresholds, i.e. the threshold at which a perceived sensation of pressure turns into pain. The specified peak pressures correspond to the third quartile identified in the study. The study used special, purpose-built apparatus. The study was commissioned by German Social Accident Insurance (DGUV) and includes advisory input from ISO/TC/184/SC 2/WG 3 and DIN NAM 60-30-02-AA.

Note 2:

The specified values for force were determined as part of a literature study carried out for this purpose by the Institute for Occupational Safety and Health (IFA)[8]. 180 literature sources were evaluated. The specified limit values refer to injury occurrence thresholds below AIS 1. On the basis of previous experience, the limit values are deemed to be sufficiently conservative. Preparations are underway for further research to specify force limit values.

Note 3:

The limit values for transient contact should be used as a factor (multiplication of the values for quasi-static contact). They are derived from the literature sources [12, 13]. The literature references indicate factors of at least two, but generally greater than two. The specified limit values are deemed to be sufficiently conservative. Preparations are underway for further research to specify transient biomechanical limit values.

Literaturhinweis:

[7] Scientific final report on project FP-0317: “Collaborative robots – Determination of pain sensitivity at the human-machine interface” University Medical Center – Institute of Occupational, Social and Environmental Medicine, Obere Zahlbacher Straße 67. 55131 Mainz

[8] Regulation on safety and health protection when using work equipment (Ordinance on Industrial Safety and Health – BetrSichV) of 3 February 2015 (BGBl. I p. 49), last amended by Article 1 of the Regulation of 13 July 2015 (BGBl. I p. 1187)

[12] Yamada, Suita, Ikeda, Sugimoto, Miura, Nakamura: Evaluation of Pain tolerance based on a biomechanical method for Human-Robot Coexistence. Transactions of the Japan Society of Mechanical Engineers. 1997. Page 2814–1819

[13] D. Mewes, F. Mauser: Safeguarding Crushing Points by limitation of Forces. International Journal of Occupational Safety and Ergonomics (Jose), Vol. 9, No. 2, 177–191

2.4.3 Requirements and Measures

The protection concept most commonly used for cobots is based on the safe limitation of physical parameters such as the force and speed of the robot's movements. However, there are further requirements which need to be fulfilled. These are described below.

The key requirements for a cobot application are:

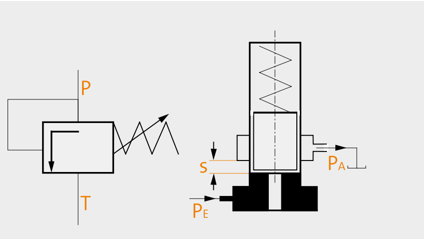
- During intended and foreseeable use, any contact with the head and larynx of humans must be prevented altogether! In all other cases, only very low speeds and moving masses are permitted, in order to stay within the limit values, or the robotic workspace must be safeguarded using devices such as safety guards.
- The robot may only be operated without protective measures if the forces or pressures do not exceed the limit values of ISO/TS 15066!
- In order to make an assessment it is thus essential to know the forces and pressures that can occur when the robot comes into contact with the operator. This data must be obtained by taking measurements at critical points and documenting them in a measurement report. Special equipment is required for these measurements and this is available from sources such as the BG ETEM, the Institute for Occupational Safety and Health of the DGUV (IFA) or from the robot integrators.
- If forces or pressures are too high or if the head needs to be protected, the robot's workspace can be monitored using non-contact protective measures such as laser scanners. The separation distances of these protective devices must be dimensioned in such a way as to ensure that the robot movement slows down sufficiently quickly to achieve safe force and pressure values by the time the operator comes into contact with the robot. Guidance is provided by the EN ISO 13855 standard on approach speeds.
- Special design considerations apply to the gripper arm with its gripper tool. Not only does it have to hold the product securely, but, more especially, it has to move in time with the production process. At the same time, its speed must be selected in such a way that the forces and pressures that occur when it comes into contact with a human being are as low as possible. For this reason, the gripper should be made of flexible material and designed with curves of large radii. Other measures such as the magnetic mounting of the gripper so that it breaks away on contact are also a possibility. If the breakaway feature were activated, it would alert the control system, which could then stop the robot instantly. In order to avoid the risk of hand injury by shearing when the gripper grasps the product, the gripper should be designed to deflect upwards, using spring force, for example.
- The risk assessment must also take into account the products moved by the cobot. There may be dangerous impact points due to unyielding or sharp-edged materials. And hazards resulting from falling or ejected products must be prevented. When products fall, reflex grasping actions by employees are always to be expected.
- Pick-up and set-down points, as well as any lifting equipment that may be present, must be designed to be safe. Otherwise, suitable protective features must be integrated.
- The cobot‘s control system integrates safety functions such as safely limited speed, limitation of the robot arm's operating range, safe standstill monitoring, etc. For this reason, the control systems must be certified by an approved test centre!
- Outside the hazard zone, at least one emergency stop command device and an acknowledgement button are required. After the emergency stop is activated, the cobot must stop immediately and the restart can only take place after manual acknowledgement.
- If no safety guards are used, the cobot’s maximum range of movement should be clearly marked.
- Only the certified overall system is permitted to be movable, subject to compliance with safety distances from fixed elements.
- Administrative changes to security-relevant settings in the programme must be prevented using suitable measures (e.g. password).
- The handover protocol of the cobot application must contain the checksum of the security programme. The current checksum must be readable at any time. This would make it possible to see whether changes have been made to the configuration

Annex

Graphic symbols on valves, actuators and control devices

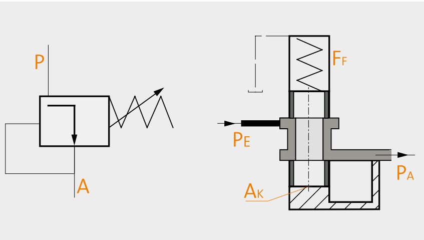
Pressure control valves

- **Adjustable pressure relief valve (overpressure valve):**
  The function of this valve is to limit pressure to a preset value by controlling the intake pressure of the valve. In case the limit value set by spring loading is reached or exceeded, the valve opens and the pressure medium flows back into the tank (hydraulics) or is released to the open air (pneumatics).



Graphic symbol/Pressure limiting valve as gate valve (hydraulics)

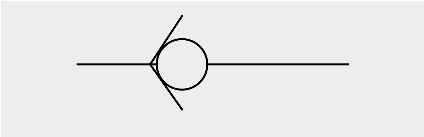
- **Adjustable pressure control valve (pressure reducing valve):**
  This valve reduces the outlet pressure (consuming end) of the liquid and keeps it at a constant level.



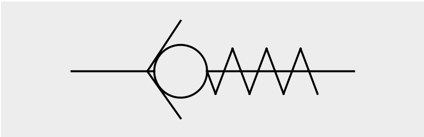
Graphic symbol/2-way pressure reducing valve (hydraulics)

For reducing the outlet pressure, pressure is directed to the front of the control piston (AK) where it is compared to the force (FF) of the regulating spring. Forces on the valve gate are always balanced.

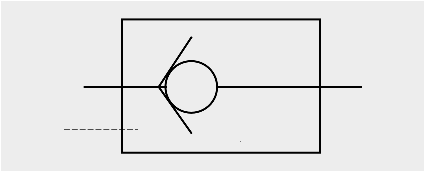
- **Check valves**
  Simple check valves allow the flow in one direction and block it off in the opposite direction. The seal element (spherical ball, diaphragm or conically shaped seal) is pressed into the seat simply by the pressure of the reverse flow.



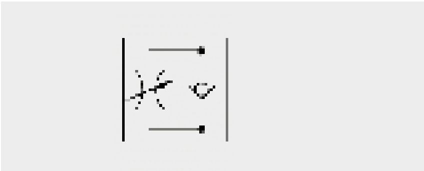
- **Spring-loaded check valves**
  On spring-loaded check valves, the seal element is pressed into the seat by spring loading. Valves only open under a defined pressure (spring pressure).



- **Stop-check valves**
  Stop-check valves provide the possibility to override blocking by a control command and allow streaming in both directions. Cylinders, for example, can be kept in an interim position. Blocking can be triggered by loss of pressure or by deliberate control signal.

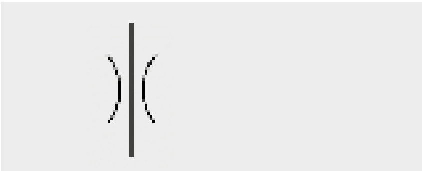


- **Throttle check valves**
  They combine the functions of check valves and those of a throttle. They are arranged in parallel and serve to reduce the speed of liquids in one flow direction.



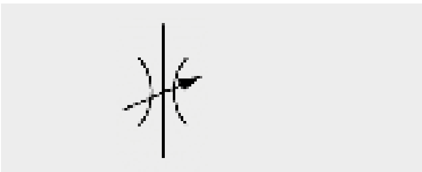
- **Throttle valves**
  - **Non-adjustable throttle valves**

  Non-adjustable throttle valves reduce volume flow by constant reduction of the flow diameter.



  - **Adjustable throttle valves**

  On adjustable throttle valves, the settings for reduction of the flow diameter and subsequent reduction of volume flow can be changed; adjustments can be made manually or by mechanical, pneumatic or electrical means.

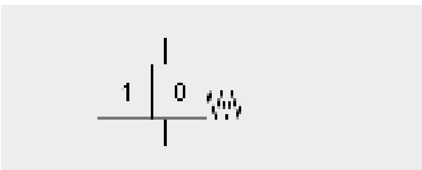


Directional control valves

Graphic symbols and designation of directional control valves.

- **Switching positions**

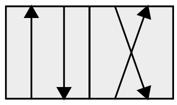
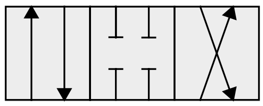
  Each individual switching position of a directional control valve is represented by a square. The individual switching positions can be identified by the numbers 0, 1 and 2. Position 0 is reserved for the quiescent position (blocking position), whereas the numbers 1 and 2 are used to denote actuated or flow positions.



e.g. two-way valve with spring

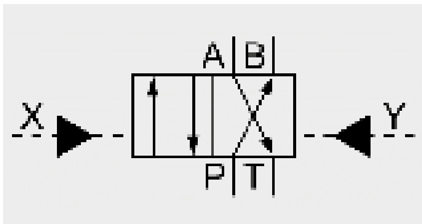
Connections and flow directions of directional control valves

REPRESENTATION OF CONNECTIONS IN GRAPHIC SYMBOLS

1	Within the **squares (switching positions), connections** are shown as **lines**
2	**The direction of flow** is indicated by **arrows** Example 
3	**Blockages** are indicated as **cross lines** inside the squares Example 

Valve connections can be indicated by defined identifiers

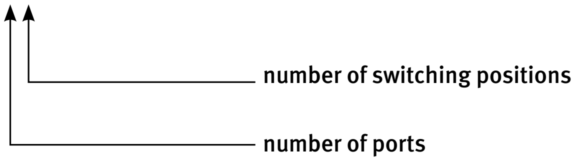
Connection	Hydraulics	Pneumatics
Working line	A, B, C, ...	2, 4 (even numbers)
Pressure line	P	1
Outlet (to tank)	T, R, S, ...	3, 5 (odd numbers)
Control line	X, Y, Z, ...	12, 14
Leakage oil line	L	



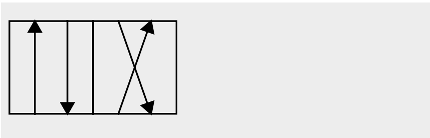
Example
Valve with Connection and Control

- **Representation of directional control valves**
  Directional control valves are identified by the number of connection ports on the one hand, on the other hand by the number of possible switching positions:

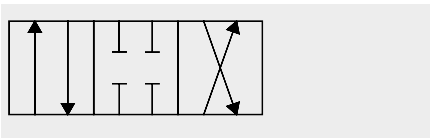
x/y-directional control valve



Examples



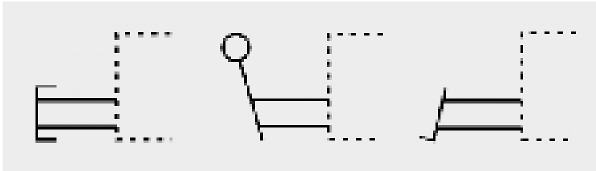
Number of ports: 4
Number of switching positions: 2
Representation of a directional control valve:
4/2 directional control valve



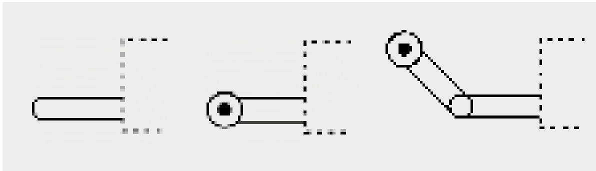
Number of ports: 4
Number of switching positions: 3
Representation of a directional control valve:
4/3 directional control valve

- **Operation of directional control valves**

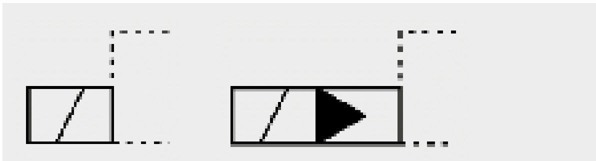
  – **Manually or pedal operated**



  – **Mechanically operated**



  – **Electromechanically operated**



Directives and standards

European Directives

- Noise Directive 2003/10/EC
- Machinery Directive 2006/42/EC
- Low-Voltage Directive 2014/35/EU
- Simple Pressure Vessels Directive 2014/29/EU
- ATEX Directive 2014/34/EU

Standards

EN 286-1
Simple unfired pressure vessels designed to contain air or nitrogen – Part 1: Pressure vessels for general purposes

EN ISO 13854
Safety of machinery – Minimum gaps to avoid crushing of parts of the human body

EN 482
Workplace exposure - Procedures for the determination of the concentration of chemical agents - Basic performance requirements

EN ISO 13851
Safety of machinery – Two-hand control devices, Functional aspects, Principles for design

EN 614-1
Safety of machinery – Ergonomic design principles – Part 1: Terminology and general principles

EN 614-2
Safety of machinery – Ergonomic design principles – Part 2: Interactions between the design of machinery and work tasks

EN ISO 14123-1
Safety of machinery – Reduction of risks to health resulting from hazardous substances emitted by machinery – Part 1: Principles and specifications for machinery manufacturers

EN ISO 14123-2
Safety of machinery – Reduction of risks to health from hazardous substances emitted by machinery – Part 2: Methodology leading to verification procedures

EN 689
Workplace exposure – Measurement of exposure by inhalation to chemical agents – Strategy for testing compliance with occupational exposure limit values

EN 894-1
Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 1: General principles for human interactions with displays and control actuators

EN 894-2
Safety of machinery – Ergonomics requirements for the design of displays and control actuators - Part 2: Displays

EN 894-3
Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 3: Control actuators

EN ISO 14120
Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards

EN 1005-2
Safety of machinery – Human physical performance – Part 2: Manual handling of machinery and component parts of machinery

EN 1005-3
Safety of machinery – Human physical performance – Part 3: Recommended force limits for machinery operation

EN 1010-1
Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 1: Common requirements

EN 1010-2
Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 2: Printing and varnishing machines including pre-press machinery

EN 1010-3
Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 3: Cutting machines

EN 1010-4
Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 4: Bookbinding, paper converting and finishing machines

EN 1010-5
Safety of machinery – Safety requirements for the design and construction of printing and paper converting machines – Part 5: Machines for the production of corrugated board and machines for the conversion of flat and corrugated board

- **EN ISO 14118**
Safety of machinery – Prevention of unexpected start-up

- **EN ISO 14119**
Safety of machinery - Interlocking devices associated with guards – Principles for design and selection

- **EN 1093-1**
Safety of machinery – Evaluation of the emission of airborne hazardous substances – Part 1: Selection of test methods

- **EN 1127-1**
Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology

- **ISO 1219-1**
Fluid power systems and components – Graphic symbols and circuit diagrams – Part 1: Graphic symbols for conventional use and data-processing applications

- **ISO 1219-2**
Fluid power systems and components – Graphic symbols and circuit diagrams – Part 2: Circuit diagrams

- **EN 1539**
Dryers and ovens, in which flammable substances are released – Safety requirements

- **EN ISO 4413**
Hydraulic fluid power – General rules and safety requirements for systems and their components

- **EN ISO 4414**
Pneumatic fluid power – General rules and safety requirements for systems and their components

- **ISO 7000**
Graphical symbols for use on equipment – Index and synopsis

- **EN 11688-1**
Acoustics – Recommended practice for the design of lownoise machinery and equipment – Part 1: Planning

- **EN ISO 12100**
Safety of machinery – General principles for design – Risk assessment and risk reduction

- **EN 12198-1**
Safety of machinery – Assessment and reduction of risks arising from radiation emitted by machinery – Part 1: General principles

- **EN 12753**
Thermal cleaning systems for exhaust gas from surface treatment equipment – Safety requirements

- **EN 13023**
Noise measurement methods for printing, paper converting, paper making machines and auxiliary equipment – Accuracy grades 2 and 3

- **EN ISO 13732-1**
Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1: Hot surfaces

- **EN ISO 13849-1**
Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design

- **EN ISO 13849-2**
Safety of machinery – Safety-related parts of control systems – Part 2: Validation

- **EN ISO 13850**
Safety of machinery – Emergency stop – Principles for design

- **EN ISO 13855**
Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body

- **EN ISO 13856-1**
Safety of machinery - Pressure-sensitive protective devices – Part 1: General principles for design and testing of pressuresensitive mats and pressure-sensitive floors

- **EN ISO 13856-2**
Safety of machinery - Pressure-sensitive protective devices – Part 2: General principles for design and testing of pressuresensitive edges and pressure-sensitive bars

- **EN ISO 13857**
Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs

- **EN ISO 14122-1**
Safety of machinery – Permanent means of access to machinery – Part 1: Choice of fixed means and general requirements of access

- **EN ISO 14122-2**
Safety of machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways

- **EN ISO 14122-3**
Safety of machinery – Permanent means of access to machinery – Part 3: Stairs, stepladders and guard-rails

EN ISO 14122-4
Safety of machinery – Permanent means of access to machinery – Part 4: Fixed ladders

EN 14986
Design of fans working in potentially explosive atmospheres

EN 60079-0
Explosive atmospheres – Part 0: Equipment – General requirements

EN 60079-1
Explosive atmospheres – Part 1: Equipment protection by flameproof enclosures "d"

EN 60204-1
Safety of machinery – Electrical equipment of machines – Part 1: General requirements

EN 60825-1
Safety of laser products – Part 1: Equipment classification and requirements

EN 60947-5-1
Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices

EN 61310-1
Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, acoustic and tactile signals

EN 61310-2
Safety of machinery – Indication, marking and actuation – Part 2: Requirements for marking

EN 61496-1
Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests

Standards are available from:

Beuth Verlag GmbH
Burggrafenstraße 6
10787 Berlin
www.beuth.de

Legal Basis, Brochures, DGUV Rules and Information Sheets

Ordinances

- GefStoffV – German "Ordinance on the Protection against Hazardous Substances" (Hazardous Substances Ordinance – GefStoffV)
- German "Ordinance on the Protection against Damage and Injuries Caused by Ionising Radiation" (Radiation Protection Ordinance – StrlSchV)

Technical Rules for Hazardous Substances (TRGS)

- TRGS 402: Identification and assessment of the risks from activities involving hazardous substances: inhalation exposure
- TRGS 420: Process- and substance-specific criteria (VSK) for identifying and assessing inhalation exposure
- TRGS 430: Isocyanates – Risk assessment and protective measures
- TRGS 723: Hazardous explosive mixtures – prevention of ignition of dangerous explosive mixtures
- TRGS 900: Occupational exposure limits
- TRGS 905: Index of substances which can cause cancer, genetic changes, or limit reproductive capability

DGUV Rules and DGUV Information

- DGUV Rule 109-002: Workplace ventilation – Technical ventilation measures
- DGUV Rule 113-002: Safety rules for continuous dryers of printing and paper converting machines
- DGUV Information 203-079: Selection and installation of electromechanical position switches in safety applications
- DGUV Information 213-715: Use of reactive PU hotmelt adhesives in the processing of wood, paper and leather

VDI Guidelines

- VDI 2262 Sheets 1–4: Workplace air – reduction of exposure to air pollutants
- VDI 2263: Dust fires and dust explosions; hazards, assessment, protective measures

BG Brochures and Inspection Body Information Sheets

- Brochure No. MB034, BG ETEM: "UV Drying"
- Brochure No. MB049, BG ETEM: Requirements for placing machinery on the market in the European Economic Area
- DP Information sheet 904: Requirements for PU hotmelt adhesive application systems in adhesive binding machines and for PU premelters
- DP Information sheet 917: Determination of emission sound pressure levels of printing and paper converting machines

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