भारतीय मानक

Indian Standard

IS 17277 (Part 2) : 2023
ISO 16092-2 : 2019

मशीन के औज़ारों की सुरक्षा — दाबयंत्र

भाग 2 यांत्रिक दाबयंत्रों के लिए सुरक्षा अपेक्षाएँ

Machine Tools Safety — Presses

Part 2 Safety Requirement for Mechanical Presses

ICS 25.080.01

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

May 2023 **Price Group 15**

Metal Forming Machines Sectional Committee, PGD 04

NATIONAL FOREWORD

This Indian Standard (Part 2) which is identical with ISO 16092-2 : 2019 ‘Machine tools safety — Presses — Part 2: Safety requirement for mechanical presses’, issued by the International Organization for Standardization (ISO), was adopted by the Bureau of Indian Standards, after the draft finalized on the recommendation of the Metal Forming Machines Sectional Committee had been approved and approval of the Production and General Engineering Division Council. This standard specifies technical safety requirements and measures to be adopted by persons undertaking the design, manufacture, and supply of the following groups of mechanical presses and mechanical press production systems:

a) Group 1: Presses with a part revolution clutch(es); and
b) Group 2: Presses with a servo drive system (Mechanical servo presses).

The presses covered by this standard range in size from small high-speed machines with a single operator producing small work, pieces to large relatively slow-speed machines with several operators and large complex work pieces. This standard deals with all significant hazards relevant to mechanical presses and ancillary devices (e.g., moving to die cushions, work-piece ejectors, feeding and transfer systems) which are integral to the machine, when they are used as intended and under the conditions of misuse which are reasonably foreseeable by the manufacturer.

Other parts in this series are:

Part 1 General safety requirements
Part 3 Safety requirements for hydraulic presses
Part 4 Safety requirements for pneumatic presses

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appear referring to this standard, they should be read as ‘Indian Standard; and
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated.

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 12100 Safety of machinery — General principles for design — Risk assessment and risk reduction	IS 16819 : 2018 Safety of machinery — General principles for design — Risk assessment and risk reduction	Identical with ISO 12100 : 2010

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Introduction

This document is a type-C standard as stated in ISO 12100.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance etc.)

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e. g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Indian Standard

MACHINE TOOLS SAFETY — PRESSES

PART 2 SAFETY REQUIREMENT FOR MECHANICAL PRESSES

1 Scope

This document, in addition to ISO 16092-1, specifies technical safety requirements and measures to be adopted by persons undertaking the design, manufacture and supply of the following groups of mechanical presses and mechanical press production systems:

— Group 1: Presses with a part revolution clutch(es);

— Group 2: Presses with a servo drive system (Mechanical servo presses).

NOTE 1 Requirements in this document are essentially applicable to both groups of the mechanical press. If a requirement applies to only one group, then the group is specified.

NOTE 2 Other types of motorized drive systems provide similar functionalities to what is commonly called “servo drives” or "servo motors”, and as such their use is considered the same within the terms used in this document (e.g. variable frequency drive systems).

The presses covered by this document range in size from small high-speed machines with a single operator producing small workpieces to large relatively slow-speed machines with several operators and large complex workpieces.

This document deals with all significant hazards relevant to mechanical presses and ancillary devices (e.g. moving die cushions, work-piece ejectors, feeding and transfer systems) which are integral to the machine, when they are used as intended and under the conditions of misuse which are reasonably foreseeable by the manufacturer (see Clause 4). All phases of the machine life cycle as described in ISO 12100:2010, 5.4 have been taken into consideration.

NOTE 2 All significant hazards means those identified or associated with presses at the time of the publication of this document.

In addition to machines not covered by ISO 16092-1:2017, this document does not cover machines which:

a) transmit energy to impart press slide motion by using hydraulic or pneumatic means;

b) have two or more slides moving in different angular orientations from each other;

NOTE 3 This document applies to presses which have two or more slides moving in the same angular orientations, e.g. a press which has inner and outer slides.

c) transmit energy to impart press slide motion by using a linear motor mechanism(s).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1:2015, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2:2012, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

ISO 13855:2010, *Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body*

ISO 16092-1:2017, *Machine tools safety — Presses — Part 1: General safety requirements*

ISO 16092-3:2017, *Machine tools safety — Presses — Part 3: Safety requirements for hydraulic presses*

IEC 60204-1:2016, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 61800-5-1:2007+A1:2016, *Adjustable speed electrical power drive systems — Part 5-1: Safety requirements — Electrical, thermal and energy*

IEC 61800-5-2:2016, *Adjustable speed electrical power drive systems — Part 5-2: Safety requirements — Functional*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100:2010, ISO 13849-1:2015, ISO 16092-1:2017 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
brake
mechanism for slowing, stopping and holding the slide/ram

3.2
mechanical brake
friction brake
brake (3.1) using dry or fluid friction

3.3
clutch
part revolution clutch
friction clutch
mechanism which engages or disengages the power transmission from the flywheel to the slide by means of friction at any point in the cycle

3.4
moving direction monitoring
monitoring function which monitors the slide moving direction, directly or indirectly

3.5
standstill monitoring
monitoring function which monitors the slide position, directly or indirectly

3.6
stopping-performance (overrun) monitoring
monitoring function which monitors the slide stopping time, angle or braking distance

3.7
servo drive system
system which replaces the need for a clutch by directly connecting a servo motor to the transmission system such as gear (motor reducer), timing belt drive mechanism, crank mechanism, mechanical link, ball screw, harmonic drive reducer, etc.

3.8
protective stop
<function> stop initiated by a protective measure

3.9
safe energized standstill
safety function preventing an unexpected movement of the slide of more than a defined amount from the stopped position, with energy supplied to the servomotor(s) to resist to external forces, and without actuation of the mechanical brake(s)

3.10
safe de-energized standstill
safety function preventing an unexpected movement of the slide by removing the energy supply to the clutch, servomotor(s) and the mechanical brake(s)

3.11
safe stop
<function> stop initiated by a monitoring function

3.12
safe torque off
STO
function which prevents force-producing power from being provided to the motor

3.13
worst case
condition of the press when it would be under foreseeably unfavourable situations e.g., the press slide is in its most disadvantageous position, with a tool of maximum weight being used, etc.

4 List of significant hazards

This clause contains all the significant hazards, hazardous situations and events identified by risk assessment as significant for the machines defined in the scope and which require a specific action to eliminate or reduce the risk.

These hazards are listed in ISO 16092-1:2017, Annex A, and additional hazards are listed in Table A.1.

5 Safety requirements and/or measures

5.1 General

Mechanical presses shall comply with the safety requirements and/or protective/risk reduction measures of this clause. In addition, the machine shall be designed according to the principles of ISO 12100 for relevant but not significant hazards which are not dealt with by this document.

5.2 Basic design considerations

5.2.1 Hydraulic and pneumatic systems — Common features

ISO 16092-1:2017, 5.2.1, shall apply.

5.2.2 Pneumatic systems

ISO 16092-1:2017, 5.2.2, shall apply.

5.2.3 Hydraulic systems

ISO 16092-1:2017, 5.2.3, shall apply.

5.2.4 Electric systems

ISO 16092-1:2017, 5.2.4, shall apply.

5.2.5 Mechanical brake

5.2.5.1 All mechanical presses shall be equipped with at least one mechanical brake, which conforms to the requirements from 5.2.5.2 to 5.2.5.4. The mechanical brake and its control system shall be designed so that, in the event of failure of the pneumatic, hydraulic or electrical supply, the mechanical brake engages immediately.

5.2.5.2 The mechanical brake shall be self-engaging by means of multiple spring assemblies of a compression-type that requires power or force from an external source for disengagement. The mechanical brake shall have sufficient capacity to stop and hold the slide and its attachments at any point in the full stroke range of the press and function when the clutch is disengaged or the servomotor is de-energized even if 50 % of the spring assemblies have failed.

5.2.5.3 The mechanical brake(s) shall be designed and constructed to ensure that:

a) all the springs are closely uniform in dimension, quality and rating;

b) the means of loading the springs are such that, when adjusted, the spring anchorages can be locked to prevent slackening back;

c) the arrangements for spring housing and of guide pins are such as to minimize binding;

d) any heat generated which can cause a hazardous event is dissipated;

e) effective arrangements are adopted to prevent penetration of lubricants to the brake friction surfaces, when this is not intended by the brake design;

f) any moisture, dust or lubricating oil, which breaks or corrodes packing material (e.g. gaskets and seals), cannot influence the required function adversely, e.g. by obstructing a fluid channel or otherwise affecting its efficiency;

g) the accumulation of dust, fluid or debris is minimized in areas likely to give rise to inefficient brake performance and that broken or loose components does not cause brake fault.

In addition, where provision is necessary for redundancy and monitoring of the brake control system/function (see Tables 1 and 2), in order to prevent any single fault from leading to the loss of the braking function:

h) springs are provided as defined in ISO 13849-2:2012, Tables A.2, A.3 and A.5, so that any fault which can occur in pressure coil springs is excluded;

i) all mechanical parts or elements are capable of providing the required rationales according to ISO 13849-2:2012, Table A.4, so that any fault which can occur in mechanical elements is excluded;

j) the engagement and disengagement of the brake do not affect its safe function;

k) the brake is designed so that failure of a component (e.g. for power transmission or screws) does not stress other components in such a way that rapid consequential dangerous failure is possible.

5.2.5.4 Band brake(s) shall not be used as a mechanical brake for this purpose of stopping the slide.

NOTE A band brake is a brake where a flexible band lined with friction material is arranged around the circumference of a drum.

5.2.6 Slide adjustment

5.2.6.1 A means that is capable of supervisory control shall be provided to prevent the press from cycling while the slide adjustment circuit is enabled and to prevent operating the slide adjustment motor while the clutch is engaged for Group 1 presses or the servo motor is energized for Group 2 presses. This requirement does not apply when the slide adjustment motor is operable only in automatic cycle and with programmable control systems that compensate, e.g. tool wear during press operation.

5.2.6.2 The means of controlling the slide adjustment shall be clearly identified.

5.2.6.3 The up and down travel of the slide adjustment shall be limited; e.g. by limit switches, proximity switches or encoders.

5.2.7 Slide counterbalance systems

5.2.7.1 If provided, mechanical spring counterbalance systems shall incorporate means to retain system parts in the event of breakage and shall have the capability of holding the slide and its attachments at mid-stroke without the brake applied.

5.2.7.2 If provided, pneumatic counterbalance cylinders shall incorporate means to retain the piston and rod in case of breakage or loosening and shall have the capability of holding the slide and its attachments at any point in the cycle without the brake applied.

5.2.8 Operating valves and exhaust systems

5.2.8.1 Operating valves and exhaust systems used with fluid valves for mechanical brake(s), clutch(es) or combined clutch/brake unit(s) shall be designed to prevent deterioration of stopping performance in the event of failure.

5.2.8.2 Operating valves shall be designed to ensure that, when in the non-operating position, leakage past the inlet valve will escape sufficiently to prevent the build-up of pressure in mechanical brake(s), clutch(es) or combined clutch/brake unit(s) operating cylinder.

5.2.8.3 Exhaust ports, piping between mechanical brake(s), clutch(es) or combined clutch/brake unit(s), operating cylinders and valves, and exhaust systems used with clutch fluid valves shall be designed to prevent the deterioration of stopping performance of the press. Precautions shall be taken to ensure that the exhaust ports of operating valves are of adequate size to prevent residual pressure in the cylinder. The valve shall be selected so that the pressure ratio between the mechanical brake(s), clutch(es) or combined clutch/brake unit(s) is such that the residual pressure in the cylinder will not become excessive in the event of a valve fault.

NOTE Normally, a ratio of at least 3,5 to 1 between the spring pressure in the brake and the residual pressure in the cylinder is satisfactory.

5.2.8.4 If provided, manual override devices incorporated into operating valves shall be designed to include a captive lid or cover which requires the use of a tool or key to open it.

NOTE A manual override device is intended to be used to actuate the valves when required (e.g. maintenance).

5.2.8.5 If provided, electrical manual override devices shall be key-operated and their operation shall only be possible with the slide in BDC position, the motor off, and the flywheel stopped.

5.2.9 Additional requirements for Group 1 presses

The engagement and disengagement of the part revolution clutch (friction clutch) and the mechanical brake shall not affect their safety function.

NOTE Combined clutch and brake units is a means to reduce the possibility of overlapping engagement.

The clutch and its control system shall be designed so that, in the event of the failure of a pneumatic, hydraulic or electrical supply, the clutch is disengaged immediately.

The clutch shall be designed and constructed to ensure that:

a) any moisture, dust or lubricating oil, which breaks or corrodes packing material (e.g. gaskets and seals), cannot influence the required function adversely, e.g. by obstructing a fluid channel or otherwise affecting their efficiency;

b) any heat generated which can cause a hazard is dissipated. Clutches are of a capacity capable of engaging and disengaging the stroke in the correct position, without excessive temperature rise, under conditions of maximum use of the clutch;

c) sufficient working clearances are provided to ensure that, the clutch will disengage upon removal of the external engaging force;

d) arrangements are made to prevent the accumulation of, and for the effective dispersal, debris evolved from friction surfaces in places where it can degrade (decrease) clutch performance;

e) the clutch is disengaged when the external clutch–engaging means is removed, deactivated, or de–energized;

f) if diaphragms are used in a clutch system, measures are taken to avoid damage by the cutting effect of sharp edges or wearing by rough surfaces. Evacuation of fluid shall not be prevented due to slackening of the diaphragm, e.g. due to material fatigue.

5.2.10 Additional requirements for Group 2 presses

5.2.10.1 Where a belt drive mechanism is utilized to transmit force or torque to decelerate or hold the slide, any single fault of the belt drive such as belt breakage, belt elongation, unfastening, looseness, belt pulley idling, tooth skipping, shall not lead to the loss of the braking function. If a fault, which would affect the stopping performance occurs, it shall be detected immediately, then the safe stop stated in 5.4.1.7 shall be initiated. No new cycle initiation shall be possible until the fault is eliminated.

5.2.10.2 Where Group 2 presses are capable of converting the kinetic energy of the slide into electrical energy and storing the electrical energy in devices e.g. capacitors, unintended slide movement resulting from electrical discharges from the devices shall be prevented.

5.2.10.3 The mechanical brake(s) shall always be engaged when the servomotor is de-energized.

5.3 Mechanical hazards in the tools area

5.3.1 Major danger zone

ISO 16092-1:2017, 5.3.1, shall apply.

5.3.2 Safeguarding measures

In addition to the requirements given in ISO 16092-1:2017, 5.3.2, the following shall apply.

The minimum distance shall be calculated according to Annex B.

5.3.3 Other safety requirements

In addition to the requirements given in ISO 16092-1:2017, 5.3.3, the following shall apply.

For Group 1 presses, reverse running shall only be possible in the setting mode. It shall not be possible to start the motor if the press clutch is engaged. It shall not be possible to engage the clutch if the motor is switched off, except under-setting conditions.

5.3.4 Release of trapped persons in the tools area

ISO 16092-1:2017, 5.3.4, shall apply.

5.3.5 Release of persons trapped inside enclosed areas

ISO 16092-1:2017, 5.3.5, shall apply.

5.3.6 Prevention of gravity fall during maintenance or repair

In addition to the requirements given in ISO 16092-1:2017, 5.3.6, the following shall apply.

5.3.6.1 Mechanical slide restraint devices shall be designed and constructed to ensure that:

a) the primary action of the mechanical slide restraint device to prevent hazardous slide movements is performed by the removal or reduction of voltage or fluid pressure or, if binary logic elements are considered, by passage from state 1 to state 0 (where state 1 represents the highest energy state);

b) for Group 1 presses, where the mechanical slide restraint device is interlocked, the interlocking function shall remove the energy supply to the clutch control circuits, the brake system and the main drive motor;

c) for Group 2 presses, where the mechanical slide restraint device is interlocked, the interlocking function shall remove the energy supply to the servo motors control circuits and the brake system;

d) the mechanical slide restraint devices are of adequate strength to support the total weight of the slide, the tool holder and the upper tool. The device shall have a minimum safety factor of 2 based on the maximum anticipated load;

NOTE The maximum anticipated load is normally the static weight of the slide(s), upper die(s), tooling, and all attachments that apply downward force due to gravity. The effects of the counter balance system cannot be considered in calculating the maximum anticipated load.

e) hazardous events caused by a momentary malfunction (e.g. the falling of the slide due to being subjected to impact) shall be analysed and eliminated;

f) when the mechanical slide restraint device is actuated, two independent means of indication verifying its engagement shall be provided.

A mechanical brake fulfilling the requirements a) to f) and designed according to 5.2.5 can also realise the function of a mechanical slide restraint device. In this case, stopping-performance (overrun) monitoring according to 5.4.9 shall be implemented. For Group 2 presses (see also 5.4.11).

5.3.6.2 Safety blocks or scotches shall be designed and constructed to ensure that:

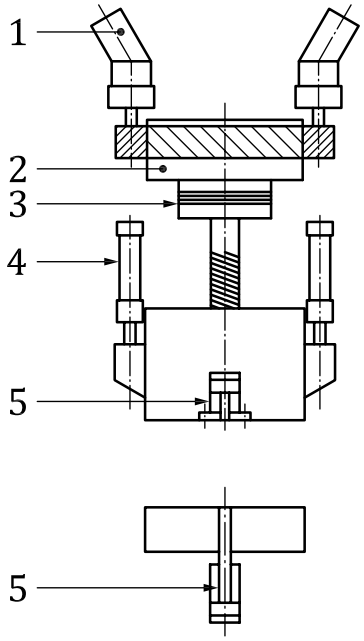
a) where the safety blocks are interlocked, the interlocking function shall remove the energy supply to the clutch control circuits, the brake system and the main drive motor for Group 1 presses or initiate a safe de-energized standstill for Group 2 presses;

b) it is of adequate strength to support the total weight of the slide, the tool holder and the upper tool. The blocks shall have a minimum safety factor of 2 based on the maximum anticipated load;

c) its shape and its length are appropriate for insertion and use between the slide (or the tool) and the bolster (or the die).

NOTE Some safety blocks are adjustable in length.

5.3.6.3 The hydraulic restraint device of screw presses shall comply with the requirements of ISO 16092-3:2017, 5.3.7.2 and 5.3.7.4. Where the hydraulic restraint device is interlocked, the interlocking function shall initiate a safe de-energized standstill (see Figure 1)



Key

1 motors
2 flywheel
3 clutch
4 hydraulic cylinders used as a restraint device
5 ejectors

Figure 1 — Example of a hydraulic restraint device of a screw press

5.4 Control and monitoring system

5.4.1 Control and monitoring functions

In addition to the requirements given in ISO 16092-1:2017, 5.4.1, the following shall apply.

5.4.1.1 In the event of an intervention of an adopted protective measure (interlocking guard without guard locking, ESPE using the AOPD, two-hand control device and hold-to-run control device with a slow closing speed), a protective stop shall be initiated.

When interlocking guard with guard locking is used, opening of the guard shall only be possible with safe de-energized standstill (safe de-energized standstill shall remain active until the guard is closed and locked).

5.4.1.2 For Group 2 presses, stop functions shall be designed and installed in accordance with 5.4.1.2.1 to 5.4.1.2.3.

5.4.1.2.1 Type 0 stop function shall consist in immediately removing the electrical power to the servomotors using a stop category 0 of IEC 60204-1:2016, 9.2.2 (e.g. using a STO sub-function as defined in IEC 61800-5-2:2016, 4.2.3.2) and immediately removing power (e.g. pneumatic) to the mechanical brake(s) to stop and hold-the slide.

5.4.1.2.2 Type 1 stop function shall consist in:

— decelerating with power available to the servomotors to achieve the stop of the slide and then, when the stop is achieved, removing the electrical power to the servomotors, using a SS1 sub-function as defined in IEC 61800-5-2:2016, 4.2.3.3b) (SS1-r) or 4.2.3.3 c) (SS1-t); and

— removing the power (e.g. pneumatic) to the mechanical brake(s) to hold the slide.

The monitoring of Type 1 stop function shall initiate a safe stop when a fault is detected, (except presses comprised of multiple independent servo drive systems for which the stopping performances are still achieved in the event of a fault).

5.4.1.2.3 Type 2 stop function shall consist in a deceleration with power available to the servomotors to achieve the stop of the slide and, when the stop is achieved, hold the slide using a safe energized standstill function, using a SS2–r sub-function as defined in IEC 61800-5-2: 2016, 4.2.3.4 b).

The monitoring of Type 2 stop function shall initiate a safe stop when a fault is detected, (except presses comprised of multiple independent servo drive systems for which the stopping performances are still achieved in the event of a fault).

5.4.1.3 Safe standstill functions shall be designed and installed in accordance with 5.4.1.3.1 and 5.4.1.3.2.

5.4.1.3.1 For Group 2 presses, safe energized standstill shall be achieved by using a SOS sub-function as defined in IEC 61800-5-2:2016, 4.2.4.2.

During a safe energized standstill, standstill monitoring shall initiate a safe stop in case of any unintended dangerous closing stroke of the slide. The maximum unintended closing stroke from the initial energized standstill position to the safe de-energized standstill position achieved after safe stop shall not exceed 2 mm.

5.4.1.3.2 Safe de-energized standstill shall stop and hold the slide.

— For Group 1 presses, power shall be removed to the clutch and the mechanical brake.

— For Group 2 presses, electrical power shall be removed to the servomotors (e.g. using a STO sub-function as defined in IEC 61800-5-2:2016, 4.2.3.2) and power (e.g. pneumatic) removed to the mechanical brake(s).

5.4.1.4 For Group 1 presses, emergency stop function and protective stop function shall disengage the clutch and engage the mechanical brake(s) to stop and hold the slide. Electrical safety related parts of this function shall act as a stop category 0 of IEC 60204-1:2016, 9.2.2.

For Group 2 presses, emergency stop function and protective stop function shall operate as a type 0 or type 1 stop function.

5.4.1.5 If presses are equipped with pneumatic counterbalance cylinders, low pressure cut-off arrangements shall be provided to monitor failure of the counterbalance capability (e.g. a sudden loss of pressure, an air supply failure). If the low pressure cut-off arrangements detect such a failure, then the

protective stop function shall be initiated immediately. Reactivation of the motor (s) or the clutch shall require restoration of a normal air supply.

5.4.1.6 Monitoring functions shall initiate a safe stop in case of fault detection.

5.4.1.7 For Group 1 presses, safe stop shall disengage the clutch and engage the mechanical brake(s) to stop and hold the slide. Electrical safety related parts of this function shall act as a stop category 0 of IEC 60204-1:2016, 9.2.2. No new cycle initiation shall be possible until the fault is eliminated

For Group 2 presses, safe stop shall operate as a type 0 stop function. No new cycle initiation shall be possible until the fault is eliminated.

5.4.2 Muting

In addition to the requirements given in ISO 16092-1:2017, 5.4.2, the following shall apply.

5.4.2.1 For Group 2 presses, during muting, the possibility of inconsistency between the motions of the slide and the motor shaft due to any fault in the mechanical linkage (e.g. chain or belt drive, position sensor coupling) or any fault of servo drive system shall be taken into account when designing and implementing these muting functions.

If muting is active during the opening stroke, safe stop shall be immediately initiated if:

— an unintended decrease of the opening speed of the slide has occurred before the programmed stop position has been achieved;

— the moving direction monitoring has detected inversion of the movement of the slide; or

— an unintended loss of power supply happens.

When muting is activated, monitoring functions for the above parameters shall be initiated at same time.

If muting is active during type 2 stop function, the standstill monitoring stated in 5.4.1.3.1 shall be activated.

5.4.2.2 No muting shall be executed during automatic cycle (see ISO 16092-1:2017, 5.4.2).

5.4.3 Selection devices

ISO 16092-1:2017, 5.4.3, shall apply.

5.4.4 Position sensors

In addition to the requirements given in ISO 16092-1:2017, 5.4.4, the following shall apply.

5.4.4.1 The position sensors (e.g. position switches, proximity switches), slide motion/position feedback sensors (e.g. encoders, resolvers) and the means of their operation (e.g. cams) shall be designed to comply with ISO 16092-1:2017, 5.4.4.

5.4.4.2 The position sensors and the slide motion/position feedback sensors shall be so arranged that they will not be damaged in the event of over-travel of moving parts. Where mechanical means are used (e.g. a cam and a follower), the means shall be so designed that reverse rotation is possible without damage.

5.4.4.3 The position sensors and the slide motion/position feedback sensors, if used as parts which provide a safety function [e.g. muting, stopping-performance (overrun) monitoring, etc.], shall have direct opening action (see IEC 60947-5-1:2016, Annex K) or provide similar reliability to achieve the required performance level.

5.4.4.4 Where mechanical cams are used, they shall be positively secured to the shaft. All cams and relevant switches shall be in a locked enclosure.

5.4.4.5 If the camshaft is connected to the crankshaft by a clutch, the clutch engagement shall be positive, e.g. by gearing.

5.4.4.6 The maximum alteration of the rotary cam arrangement shall be mechanically limited to an angle of maximum 60° (see Annex C).

NOTE The maximum alteration is commonly limited to an angle of 45°.

5.4.4.7 Cam discs shall be so applied that a wrong or unintended fitting cannot cause accidents, and:

a) the limit switches and cams used to control of the press shall be fixed to each other and adequately secured. Unsecured nuts or bolts are not permissible;

b) the position of the limit switches and cam plates in relation to each other shall be marked;

c) the possibility of re-adjusting limit switches or cams shall be limited by fixed end stops, so that the muting time during the closing movement of the press cannot exceed the press overall response time with any combination of speed and stroke length.

5.4.4.8 Where position sensors are used for safety functions, e.g. for muting or for the stopping-performance (overrun) monitoring device, and are actuated by a camshaft which is indirectly driven by a crankshaft (e.g. a duplex chain drive between the camshaft and the crankshaft), indirect drive shall be monitored in such a way that, if it fails, a safe stop shall be initiated and no new cycle initiation shall be possible until the fault is eliminated.

5.4.5 Control devices

ISO 16092-1:2017, 5.4.5, shall apply.

5.4.6 Valves

Where it is necessary to provide for redundancy and monitoring of the control system for mechanical brake(s), clutch or combined clutch/brake unit(s) (see Tables 1 and 2), the valves for fluid release shall fulfil the following requirements.

a) The deterioration of stopping performance of the press due to any single fault in the operating valve(s), including the valve solenoid(s), shall be prevented by using valves which directly control the fluid to the operated mechanical brake(s), clutch or combined clutch/brake unit(s), or the equivalent in the case of other drive mechanisms.

b) If a single fault occurs, the control system for mechanical brake(s), clutch or combined clutch/brake unit(s) shall prevent further operation. Resuming normal operation shall only be possible by a restricted means, such as a tool, a key or an electronic password.

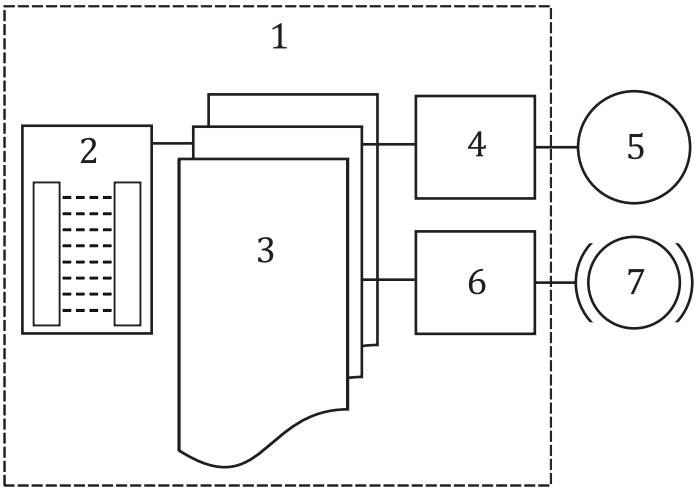
c) When valve monitoring is required, the valve(s) shall have an inherent monitoring system in which valve failure is self-revealing, or sensors detecting the valve state shall be an integral part of the valves.

d) Measures (e.g. separate wiring) shall be provided so that a single fault in the wiring cannot activate both solenoids.

e) A short circuit between valve connections (e.g. solenoid to solenoid, solenoid to self-monitoring assembly) shall be avoided or detected automatically and shall not lead to additional or unexpected slide motion.

5.4.7 Performance level of safety functions

Safety functions of mechanical press shall meet the requirements stated in the Tables 1 and 2. Figure 2 shows an example of all relevant parts of control system of a Group 2 press with a safety function to stop the closing stroke of the slide by ESPE using AOPD.



Key

1 overall SRP/CS of safety function (stopping slide down stroke by ESPE using AOPD)
2 “Input”: ESPE using AOPD
3 “Logic”: control parts (plausibility check of selection, logic of AOPD
4 “Output”: servo drive or current converter
5 servo motor
6 “Output”: electromagnetic valve or contactor
7 mechanical brake (see 5.2.5)

Figure 2 — Example of a safety function with all relevant safety related parts for Group 2 presses

The performance levels in Tables 1 and 2 are the minimum required performance levels and already take the probability of occurrence into account.

Table 1 — Summary of requirements for the operator safeguarding of the danger zones at the tools, die cushions, work-piece ejectors and transfer systems areas (See ISO 16092-1:2017, 5.3.1) for different modes of operation — Mode of production: Single cycle, manual feed or removal

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Closed tools used as the only means of protection [see ISO 16092-1, 5.3.2.1 a)]	Movement (e.g. closing stroke) of the slide, die cushions, workpiece ejectors	Cycle initiation/stop	PL a	Cat B	Any[g]	Any	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Single stroke function			Cam switch, encoder or suitable alternative		
Closed tools used in a press with other operating modes with different main safety systems [see ISO 16092-1, 5.3.2.1 a)]	Movement of the slide, die cushions, workpiece ejectors	Cycle initiation/stop	PL a	Cat B	Any[g]	Any	
		Single stroke function			Cam switch, encoder or suitable alternative		
Fixed enclosing guard used as the only means of protection [see ISO 16092-1, 5.3.2.1 b)]	Movements of the slide, die cushions, workpiece ejectors and transfer systems	Cycle initiation/stop	PL a	Cat B	Any[g]	Any	
		Single stroke function			Cam switch, encoder or suitable alternative		
Interlocking guard with or without guard locking (with or without early opening feature) or control guard (with or without early opening feature) [see ISO 16092-1 5.3.2.1.c), d) and e)]	Movements (e.g. closing stroke) of the slide and die cushions	Cycle initiation by other control device than the guard	PL a	Cat B	Any but not actuated by the guard itself[g]	Any	Logic control shall act on the appropriate part of the electrical control system
		Cycle initiation by control guard			Interlocking device of the guard		

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Interlocking guard with or without guard locking (with or without early opening feature) or control guard (with or without early opening feature) [see ISO 16092-1 5.3.2.1.c), d) and e)]	Movements (e.g. closing stroke) of the slide and die cushions	Stop by interlocking device of guard without guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 b)]	PL e[b,c]	Cat 4	Interlocking device (2 sensors or equivalent solution)[e,f]	Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Stop by interlocking device of guard with guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 a)]			Interlocking device with guard locking (2 sensors or equivalent solution)[e,f]		
		Conditional unlocking of guard	PL d	Cat 3 for input and logic, Cat 2[j] for output	Sensor or other suitable detection device to confirm safe de-energized standstill is achieved		Pre-actuator of the guard locking
		Muting in in case of early opening guard and control guard without guard locking (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	Same as of the safety function on which muting is acting[q]	—	Position sensor or suitable alternative (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	—	—
		For Group 2, speed monitoring (during muting)[l] (see 5.4.2.1)			Encoder or suitable alternative	Same as of the safety function on which muting is acting	Servo drive and brake control system (e.g. air valves)
		For Group 2, standstill monitoring (during muting)[l] (see 5.4.1.3.1)					

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Interlocking guard with or without guard locking (with or without early opening feature) or control guard (with or without early opening feature) [see ISO 16092-1 5.3.2.1.c), d) and e)]	Movements (e.g. closing stroke) of the slide and die cushions	For Group 2, moving direction monitoring (during muting)[l] (see 5.4.2.1)	Same as of the safety function on which muting is acting[q]	—	Encoder or suitable alternative	Same as of the safety function on which muting is acting	Servo drive and brake control system (e.g. air valves)
		Single stroke function in case of early opening[r] (see 5.4.8)	PL e[b,c]	Cat 4	Cam switch, encoder or suitable alternative	Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Stopping-performance (overrun) monitoring in case of guard without guard locking (see 5.4.9)	PL c	Cat 2[j]			
	Movements of work-piece ejectors and transfer systems	Stop by interlocking device of guard without guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 b)]	PL d[b,d]	Cat 3	Interlocking device (2 sensors or equivalent solution)[e,f]		Electrical, hydraulic or pneumatic system
		Stop by interlocking device of guard with guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 a)]			Interlocking device with guard locking (2 sensors or equivalent solution)[e,f]		
		Conditional unlocking of guard	PL c	Cat 3 for input and logic, Cat 2[j] for output	Sensor or other suitable detection device to confirm safe de-energized standstill is achieved		Pre-actuator of the guard locking

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Interlocking guard with or without guard locking (with or without early opening feature) or control guard (with or without early opening feature) [see ISO 16092-1 5.3.2.1.c), d) and e)]	Movements of work-piece ejectors and transfer systems	Muting in case of early opening guard and control guard without guard locking (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	Same as of the safety function on which muting is acting[q]	—	Position sensor or suitable alternative (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	—	—
		Prevention of restart by an additional safeguarding of a control guard by AOPD (see ISO 16092-1:2017, 5.3.2.9)	PL e [o]	Cat 4	AOPD	Safety related logic	Logic control shall act on the appropriate part of the electrical control system
		Prevention of restart by an additional safeguarding of a control guard by interlocking guard (see ISO 16092-1:2017, 5.3.2.9)	PL c[o,p]	Cat 1 for input, Cat 3 for logic and output	Interlocking device		Logic control shall act on the appropriate part of the electrical control system
Interlocking guard with or without guard locking (see ISO 16092-1, 5.6.1)	Drive and transmission (see ISO 16092-1, 5.6.1)	Stop by interlocking device of guard without guard locking	PL c	Cat 1			Electric, hydraulic or pneumatic system
		Stop by interlocking device of guard with guard locking					
		Conditional unlocking of guard	PL c	Cat 3 for input and logic, Cat 2[j] for output	Sensor or other suitable detection device to confirm safe de-energized standstill is achieved		Pre-actuator of the guard locking
Interlocking guard opened for tool setting only [see ISO 16092-1:2017, 5.3.2.1.c) and 5.5.6]	Movements of the slide, die cushions, workpiece ejectors and transfer systems	Stop by interlocking device of guard	PL c	Cat 1 for input, Cat 3 for logic and output	Interlocking device	Safety related logic	Same output than those used for safeguarding measures used in production mode

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
ESPE using AOPD [see ISO 16092-1:2017, 5.3.2.1.f) and 5.3.2.11]	Movements (e.g. closing stroke) of the slide and die cushions	Cycle initiation by other control device than the AOPD	PL a	Cat B	Any but not actuated by the AOPD itself[g]	Any	Logic control shall act on the appropriate part of the electrical control system
		Cycle initiation by AOPD			AOPD		
		Stop by AOPD	PL e[c]	Cat 4		Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Muting (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	Same as of the safety function on which muting is acting[q]	—	Position sensor or suitable alternative (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	—	—
		For Group 2, speed monitoring (during muting)[l] (see 5.4.2.1)			Encoder or suitable alternative	Same as of the safety function on which muting is acting	Servo drive and brake control system (e.g. air valves)
		For Group 2, standstill monitoring (during muting)[l] (see 5.4.1.3.1)					
		For Group 2, moving direction monitoring (during muting)[l] (see 5.4.2.1)					

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
ESPE using AOPD [see ISO 16092-1:2017, 5.3.2.1.f) and 5.3.2.11]	Movements (e.g. closing stroke) of the slide and die cushions	Single stroke function in case of muting during opening stroke[r] (see 5.4.8)	PL e[b,c]	Cat 4	Cam switch, encoder or suitable alternative	Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Stopping-performance (overrun) monitoring (see 5.4.9)	PL c	Cat 2[j]			
	Movements of work-piece ejectors and transfer systems	Stop by AOPD	PL d[d]	Cat 3	AOPD		Electrical, hydraulic or pneumatic system
		Muting (see 5.4.2 and ISO 16092-1:2017, 5.4.2) Not allowed for transfer system	Same as of the safety function on which muting is acting[q]	—	Position signal or suitable alternative (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	—	—
	Movements of the slide, die cushions, workpiece ejectors and transfer systems	Prevention of restart by an additional safeguarding by AOPD [see ISO 16092-1:2017, 5.3.2.11 c)]	PL d	Cat 3	AOPD	Safety related logic	Logic control shall act on the appropriate part of the electrical control system
		Prevention of restart by an additional safeguarding by interlocking guard [see ISO 16092-1:2017, 5.3.2.11 c)]	PL c[o,p]	Cat 1 for input, Cat 3 for logic and output	Interlocking device		
Two-hand control device [see ISO 16092-1, 5.3.2.1 g) and 5.3.2.12]	Movements (e.g. closing stroke) of the slide and die cushions	Stop and cycle initiation by two-hand control device	PL e[b,c]	Cat 4	Push buttons of two-hand control device[g,h]		Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Two-hand control device [see ISO 16092-1, 5.3.2.1 g) and 5.3.2.12]	Movements (e.g. closing stroke) of the slide and die cushions	Muting (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	Same as of the safety function on which muting is acting [q]	—	Position sensor or suitable alternative (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	—	—
		For Group 2, speed monitoring (during muting)[k] (see 5.4.2.1)			Encoder or suitable alternative	Same as of the safety function on which muting is acting	Servo drive and brake control system (e.g. air valves)
		For Group 2, standstill monitoring (during muting)[k] (see 5.4.1.3.1)					
		For Group 2, moving direction monitoring (during muting)[k] (see 5.4.2.1)					
		Single stroke function in case of muting during opening stroke[r] (see 5.4.8)	PL e[b,c]	Cat 4	Cam switch, encoder or suitable alternative	Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Stopping-performance (overrun) monitoring (see 5.4.9)	PL c	Cat 2[j]			
	Movements of work-piece ejectors and transfer systems	Stop and cycle initiation by two-hand control device	PL d[b,d]	Cat 3	Push buttons of two-hand control device[g,h]	Safety related logic	Electrical, hydraulic or pneumatic system
		Muting (see 5.4.2 and ISO 16092-1:2017, 5.4.2) Not allowed for transfer system	Same as of the safety function on which muting is acting[q]	—	Position signal or suitable alternative (see 5.4.2 and ISO 16092-1:2017, 5.4.2)	—	—

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Two-hand control device [see ISO 16092-1, 5.3.2.1 g) and 5.3.2.12]	Movements of the slide, die cushions, workpiece ejectors and transfer systems	Additional means to restrict access (see ISO 16092-1:2017, 5.3.2.12) Stop by interlocking device of guard	PL d[b,d]	Cat 3	Interlocking device (2 sensors or equivalent solution)	Safety related logic	Electrical, hydraulic or pneumatic system
		Additional means to restrict access (see ISO 16092-1:2017, 5.3.2.12) Stop by ESPE using AOPD or AOPDDR	PL d[d]		AOPD or AOPDDR		
Common features							
Safety systems which need reset	Movements of the slide, die cushions, workpiece ejectors and transfer systems	Manual reset (see ISO 16092-1:2017, 5.4.1.1.3)	Same as of the safety function on which it is acting[m]	Any Cat for input[l], Same category as of the selected safety functions for logic and output	Push button	Safety related logic[l]	Logic control shall act on the appropriate part of the electrical control system
Safety systems which need selection means		Means of selection (see ISO 16092-1:2017, 5.4.3.1)	Same as the highest PLr among the selected functions		Selection means, e.g. selector switch, electronic key system	Safety related logic to check plausibility of inputs[i]	
Low pressure cut-off arrangements[k]	Movements of the slide	Monitoring a failure of pneumatic counterbalance	PL a	Cat B	Pressure switch or suitable alternative	Any	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
Emergency stop device	Movement (e.g. closing stroke) of the slide, die cushions, workpiece ejectors and transfer systems	Emergency stop function (see 5.4.1.4, ISO 16092-1:2017, 5.4.1.1.6, 5.4.5.2 and 5.4.5.3)	PL c (see ISO 13850:2015, 4.1.5.1)	Cat 1	Emergency stop push button [h]	Safety related logic	

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)

[a] In the table, "Requirement for category of Input, Logic and Output" means the following relationships between the requirements of categories for Input, Logic or Output part:

— Cat. 4, 3 or 2 may apply instead of Cat. 1;

— Cat. 4 or 3 may apply instead of Cat. 2;

— Cat. 4 may apply instead of Cat. 3.

[b] Fault exclusion, e.g. mechanical break of a sensor is not acceptable.

[c] Functional safety described in ISO 16092-1:2017, 5.4.1.1.4 a) to e) shall apply.

[d] Functional safety described in ISO 16092-1:2017, 5.4.1.1.4 a) to c), and if reasonably practicable 5.4.1.1.4 d) to e) shall apply.

[e] Plausibility check required or equivalent solution e.g. 1 system fulfilling the required PL by itself.

[f] See ISO 14119 for the design of interlocking device of guard with guard locking.

[g] In case of mobile control device (e.g. foot pedal) provision shall be made to ensure that unintended start-up due to a short circuit in the cable connecting the control device to the control system is prevented.

[h] In case of mobile control device, provision shall be made to ensure that the stop function remains operational in case of a short circuit in the connecting cable to the control system.

[i] Plausibility check of inputs shall be provided and shall insure that one selected position and the relevant safety measures are still operative without any mal-function or dangerous movements are stopped.

[j] This part can be considered of category 2 if, either demand rate ≤1/100 test rate; or testing occurs immediately upon demand of the safety function and a detected fault leads immediately to a stop of the machine (stop by the output of the testing part of the category 2 system – See ISO 13849-1:2015, 6.2.5 NOTE 4 and Figure 10). Restart of the machine shall only be possible after repair.

[k] If required. It depends on the design and structure of the machine.

[l] No specific category is required for input, because logic part will only act after actuation or de-actuation of the input, and any blocking of the input will not lead to any new reset (See ISO 16092-1, 5.4.1.1.3).

[m] Manual reset function, which is related to a protective device placed where there is no possibility of access of the whole body of a person into the danger zone, may not be subjected to the requirements of PL on this table as a safety function. Only ISO 16092-1, 5.4.1.1.3 is applied.

Table 1 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output [a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
[n] PL e is based on the assumption of F2 (see ISO 13849-1:2015, A.2.2) that the additional safeguarding by AOPD is provided to cover the space between the control guard and the danger zone where a person enters frequently, e.g.at every cycle.							
[o] The additional safeguarding by interlocking guard shall not be opened frequently during production (e.g. it is opened only for tool setting, trial or maintenance). Where this is not practicable, other means shall be used.							
[p] In the case of additional safeguarding by interlocking guard, P1 (see ISO 13849-1:2015, A.2.3) is assigned because the guard is in place as a physical obstacle. Even if the interlocking device fails, it is possible that an operator recognizes the guard is removed or opened before initiating a stroke (if additional safeguarding is by AOPD: in case of a failure, an operator can stand undetected between the control guard/primary AOPD and the danger zone).							
[q] No specific PL is required for this sub function which shall be considered as an internal part of the safety functions on which it is acting. This internal part shall be taken into account in the evaluation of the PL of the relevant safety functions.							
[r] For Group 2 presses unable to achieve PL e, Cat 4, the muting is not acceptable.							

Table 2 — Summary of requirements for the operator safeguarding of the danger zones at the tools, die cushions, work-piece ejectors and transfer systems areas (See ISO 16092-1:2017, 5.3.1) for different modes of operation — Mode of production: Automatic cycle, Solely automatic feed and removal

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output[a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Closed tools used as the only means of protection [see ISO 16092-1:2017, 5.3.2.1.a)]	Movement (e.g. closing stroke) of the slide, die cushions, workpiece ejectors	Cycle initiation/stop	PL a	Cat B	Any[g]	Any	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
Closed tools used in a press with other operating modes with different main safety systems [see ISO 16092-1:2017, 5.3.2.1.a)]							
Fixed enclosing guard used as the only means of protection [see ISO 16092-1:2017, 5.3.2.1.b)]	Movements of the slide, die cushions, workpiece ejectors and transfer systems	Cycle initiation/stop	PL a				
Interlocking guard with or without guard locking [see ISO 16092-1:2017, 5.3.2.1.c)]	Movements (e.g. closing stroke) of the slide and die cushions	Cycle initiation by other control device than the guard	PL a	Cat B	Any but not actuated by the guard itself[g]	Any	Logic control shall act on the appropriate part of the electrical control system
		Stop by interlocking device of guard without guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 b)]	PL d[b,d]	Cat 3	Interlocking device (2 sensors or equivalent solution)[e,f]	Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Stop by interlocking device of guard with guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 a)]	PL d[b]	Cat 2[k]	Interlocking device with guard locking (2 sensors or equivalent solution)[e,f]		

Table 2 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output[a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Interlocking guard with or without guard locking [see ISO 16092-1:2017, 5.3.2.1.c)]	Movements (e.g. closing stroke) of the slide and die cushions	Conditional unlocking of guard	PL c	Cat 3 for input and logic, Cat 2[j] for output	Sensor or other suitable detection device to confirm safe de-energized standstill is achieved	Safety related logic	Pre-actuator of the guard locking
		Stopping-performance (overrun) monitoring in case of guard without guard locking (see 5.4.9)	PL c	Cat 2[k]	Cam switch, encoder or suitable alternative		Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
	Movements of work-piece ejectors and transfer systems	Stop by interlocking device of guard without guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 b)]	PL d[b,d]	Cat 3	Interlocking device (2 sensors or equivalent solution)[e,f]		Electrical, hydraulic or pneumatic system
		Stop by interlocking device of guard with guard locking [see ISO 16092-1:2017, 5.3.2.7 and 5.3.2.10 a)]	PL d[b]	Cat 2[j]			
		Conditional unlocking of guard	PL c	Cat 3 for input and logic, Cat 2[j] for output	Sensor or other suitable detection device to confirm safe de-energized standstill is achieved		Pre-actuator of the guard locking
	Drive and transmission (see ISO 16092-1, 5.6.1)	Stop by interlocking device of guard with or without guard locking	PL c	Cat 1	Interlocking device		Electrical, hydraulic or pneumatic system
		Conditional unlocking of guard	PL c	Cat 3 for input and logic, Cat 2[j] for output	Sensor or other suitable detection device to confirm safe de-energized standstill is achieved		Pre-actuator of the guard locking
Interlocking guard opened for tool setting only [see ISO 16092-1, 5.3.2.1 c) and 5.5.6]	Movements of the slide, die cushions, work-piece ejectors and transfer systems	Stop by interlocking device of guard	PL c	Cat 1 for input, Cat 3 for logic and output	Interlocking device	Safety related logic	Same output than those used for safeguarding measures used in production mode

Table 2 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output[a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
ESPE using AOPD [see ISO 16092-1, 5.3.2.1 f) and 5.3.2.11]	Movements (e.g. closing stroke) of the slide and die cushions	Cycle initiation by other control device than the AOPD	PL a	Cat B	Any but not actuated by the AOPD itself[g]	Any	Logic control shall act on the appropriate part of the electrical control system
		Stop by AOPD	PL d[d]	Cat 3	AOPD	Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)
		Stopping-performance (overrun) monitoring (see 5.4.9)	PL c	Cat 2[j]	Cam switch, encoder or suitable alternative		
	Movements of work-piece ejectors and transfer systems	Stop by AOPD	PL d[d]	Cat 3	AOPD		Electrical, hydraulic or pneumatic system
Common features							
Safety systems which need reset	Movements of the slide, die cushions, work-piece ejectors and transfer systems	Manual reset (see ISO 16092-1:2017, 5.4.1.1.3)	Same as of the safety function on which it is acting[m]	Any Cat for input[l], Same category as of the selected safety functions for logic and output	Push button	Safety related logic[l]	Logic control shall act on the appropriate part of the electrical control system
Safety systems which need selection means		Means of selection (see ISO 16092-1:2017, 5.4.3.1)	Same as the highest PLr among the selected functions		Selection means, e.g. selector switch, electronic key system	Safety related logic to check plausibility of inputs[i]	
Low pressure cut-off arrangements[k]	Movements of the slide	Monitoring a failure of pneumatic counterbalance	PL a	Cat B	Pressure switch or suitable alternative	Any	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)

Table 2 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output[a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
Slow speed and hold-to-run control device (See ISO 16092-1, 5.3.3.4)	Movements of handling device	Slow speed	PL c	Cat 2[k]	Encoder or suitable alternative	Safety related logic	Electrical, hydraulic or pneumatic system
		Hold-to-run control			2 electro-mechanical contacts (1 for initiation, 1 for diagnostic)[g,h]		
Inching device		Start and automatic stop of a limited movement		Cat 1 for Start Input Cat 3 for Logic and Output	Any for start[g]	Safety related logic utilizing e.g. fault resistant position detection or time depending on machine speed	
Emergency stop device	Movement (e.g. closing stroke) of the slide, die cushions, workpiece ejectors and transfer systems	Emergency stop function (see 5.4.1.4, ISO 16092-1:2017, 5.4.1.1.6, 5.4.5.2 and 5.4.5.3)	PL c (see ISO 13850:2015, 4.1.5.1)	Cat 1	Emergency stop push button[h]	Safety related logic	Clutch/brake operating valves or servo drive and brake control system (e.g. air valves)

[a] In the table, "Requirement for category of Input, Logic and Output" means the following relationships between the requirements of categories for Input, Logic or Output part:

— Cat. 4, 3 or 2 may apply instead of Cat. 1;

— Cat. 4 or 3 may apply instead of Cat. 2;

— Cat. 4 may apply instead of Cat. 3.

[b] Fault exclusion, e.g. mechanical break of a sensor is not acceptable.

[c] Functional safety described in ISO 16092-1:2017, 5.4.1.1.4 a) to e) shall apply.

[d] Functional safety described in ISO 16092-1:2017, 5.4.1.1.4 a) to c), and if reasonably practicable 5.4.1.1.4 d) to e) shall apply.

[e] Plausibility check required or equivalent solution e.g. 1 system fulfilling the required PL by itself.

[f] See ISO 14119 for the design of interlocking device of guard with guard locking.

[g] In case of mobile control device (e.g. foot pedal) provision shall be made to ensure that unintended start-up due to a short circuit in the cable connecting the control device to the control system is prevented.

[h] In case of mobile control device, provision shall be made to ensure that the stop function remains operational in case of a short circuit in the connecting cable to the control system.

[i] Plausibility check of inputs shall be provided and shall insure that one selected position and the relevant safety measures are still operative without any mal-function or dangerous movements are stopped.

Table 2 *(continued)*

Main safety system	Hazardous movement	Safety function	Minimum required PL (PL_r) for safety function and I, L and O	Basis for the design of input, logic, output of safety function			
				Requirement for category of Input, Logic and Output[a]	I – Input (sensor area)	L – Logic (control)	O – Output (pre-actuator)
[j] This part can be considered of category 2 if, either demand rate ≤1/100 test rate; or testing occurs immediately upon demand of the safety function and a detected fault leads immediately to a stop of the machine (stop by the output of the testing part of the category 2 system – See ISO 13849-1:2015, 6.2.5 NOTE 4 and Figure 10). Restart of the machine shall only be possible after repair. [k] If required. It depends on the design and structure of the machine. [l] No specific category is required for input, because logic part will only act after actuation or de-actuation of the input, and any blocking of the input will not lead to any new reset (See ISO 16092-1, 5.4.1.1.3). [m] Manual reset function, which is related to a protective device placed where there is no possibility of access of the whole body of a person into the danger zone, may not be subjected to the requirements of PL on this table as a safety function. Only ISO 16092-1, 5.4.1.1.3 is applied.							

5.4.8 Single stroke function/device

Where a press is used in single cycle, a single stroke function or device shall be implemented or fitted to prevent a subsequent stroke even if the control device is continuously actuated. A further stroke shall require the release of the control device and a new initiation (see Table 1).

5.4.9 Stopping-performance (overrun) monitoring function/device

Presses fitted with protective devices or guards of the following types, namely:

— ESPE using AOPDs;

— interlocking guard without guard locking;

— control guard without guard locking;

— early opening interlocking guard;

— two-hand control device used in production mode;

shall include a stopping-performance (overrun; distance or time) monitoring function or device to ensure that:

a) monitoring shall be performed at the end of every cycle, a stopping angle of the crankshaft shall not exceed 15° from the intended or programmed cycle stop position (e.g. TDC);

NOTE The maximum stopping angle is commonly limited to 10°.

b) for Group 2 presses, monitoring shall be performed after each protective stop initiated by the protective device or the guard mentioned above. The stopping time shall not exceed the predetermined time used for the calculation of the minimum distance.

If the stopping performance as indicated in a) or b) is exceeded, a safe stop shall be immediately initiated and no new cycle initiation shall be possible. It shall only be possible to resume further operation of the press by a restricted means, e.g. a tool, key or electronic password. No mode of operation other than INCH mode shall be possible until the slide is returned to its programmed initial start position or TDC.

The manufacturer shall provide means to restrict the capability to modify the predetermined limits to the authorized persons (e.g. locked enclosure, pass code, etc.).

The safety-related parts providing the stopping-performance (overrun) monitoring shall conform to the performance level (PL) specified in Tables 1 and 2 depending on the adopted protective measures.

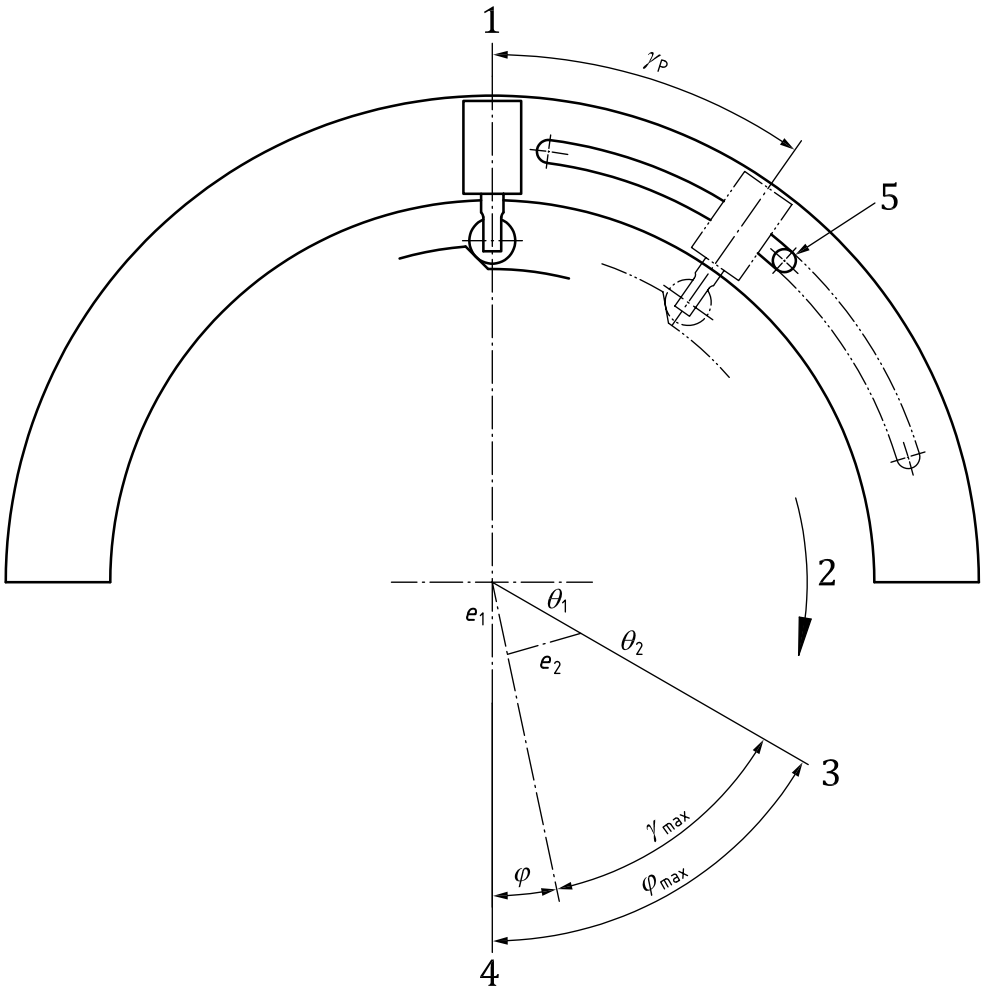
5.4.10 Additional requirements for Group 1 presses

5.4.10.1 The monitoring of the clutch/brake control system shall be performed at least once per cycle and shall ensure that, in the case of a failure within the valve(s), the clutch is disengaged and the brake is activated.

5.4.10.2 The position sensors for stopping-performance (overrun) monitoring, single stroke function and muting shall be linked together in a positive way so that the relative position between the cams and the relative position between the switches cannot be altered. However, on presses fitted with a variable speed arrangement, the single stroke function switch may be capable of separate adjustment.

5.4.10.3 In cases where the stroke length can be varied, position sensors used for cycle control shall be arranged so that their relative position cannot be altered in order to minimize the probability of incorrect

setting by the user, for example to compensate for braking performance degradation which should be remedied by maintenance of the mechanical brake (see Figure 3 and Annex C).



Key

1	TDC
2	direction of rotation
3	muting signal
4	BDC
5	mechanical stop for the limitation of the adjustment of the rotary cam arrangement
γ_P	largest angle by which the rotary cam arrangement can be rotated between mechanical stops
ϕ	part of the muting angle before BDC
ϕ_{max}	maximum permissible part of the muting angle before BDC in degrees, calculated form the overall system stopping performance and the lowest speed

Figure 3 — Example of sensor positions for presses with variable stroke length

5.4.11 Additional requirements for Group 2 presses

5.4.11.1 Where a mechanical brake(s) is (are) only used during a protective stop or as a mechanical restraint device, the brake(s) shall be submitted to a periodic brake test. Both following measures shall be provided.

a) Static brake test

Test shall be made so that the brake shall support during longer than or equal to 1 s, at least 1,5 of the torque which is generated by the mass of the press slide and its attachments in the worst case (see 3.17). Initiating the servomotor(s) while the brake is active, the slide shall remain in a stopped (holding) position. Test has failed when the slide has moved more than 2 % of the maximum stroke during the test.

For presses operated in single cycle, at the beginning of each shift (normally 8 h) the control system shall require that the test shall be performed. If the test is not performed the control system does not allow further production.

For all other presses, the control system shall require that the test shall be performed once every 24 h. If the test is not performed the control system does not allow further production.

The manufacturer shall provide means to restrict the capability to modify the test torque value and other test parameters to the authorized persons (e.g. locked enclosure, pass code, etc.)

If the press is operated in automatic mode and it is equipped with interlocking guards with guard locking, the 24-hour brake test may be suspended until one of the guards is to be opened. If the brake test fails the unlocking of the guard shall be impossible.

b) Active brake test

Manufacturers shall give necessary provisions (technical means) for the active brake test to be performed.

The test shall be performed during the closing stroke, when the slide is moving at maximum speed (at the speed of which the stopping performance is practicably evaluated) by initiating a type 0 stop.

Test has failed when stopping time exceeds the predetermined time used for the calculation of the minimum distance (see Annex B).

The control system shall require that the active brake test shall be performed at least once a year. If the test is not performed the control system does not allow further production.

If a static or active test fails, a new cycle initiation shall be impossible until the fault is eliminated and it shall only be possible to resume further operation of the press by a restricted means, e.g. by tool, key or electronic password.

5.4.11.2 A periodic brake test shall only be possible with guards and protective devices in position and operational.

5.5 Tool-setting, trial strokes, maintenance and lubrication

In addition to the requirements given in ISO 16092-1:2017, 5.5, the following shall apply.

5.5.1 INCH mode

INCH mode shall be provided to ensure that, where the safeguarding measures used in production mode are not practicable, risks associated with the slide movement are adequately reduced by implementing the risk reduction measures of 5.5.2.1 for Group 1 presses and 5.5.3.1 for Group 2 presses.

5.5.2 Additional requirements for Group 1 presses

5.5.2.1 Facilities shall be provided to allow slide movement during tool-setting, maintenance and lubrication with guards and protective devices in position and operational (see ISO 16092-1:2017, 5.3.2.1).

Where this is not practicable, at least one of the following facilities shall be provided (i.e. INCH mode, see 5.5.1):

a) rotation of the crankshaft by hand, with power isolated;

b) slow closing speed (equal or less than 10 mm/s) and hold-to-run control device;

c) two-hand control device in accordance to ISO 16092-1:2017, 5.5.7 and 5.5.8, which is located outside the minimum distance;

d) the slide movement produced by the inching device which is so small as to prevent a hazardous situation and limited by a time control or by a distance control. The slide movement shall not exceed 6 mm per inching step with the crankshaft at 90°.

Stop functions of slide during tool-setting, maintenance and lubrication shall be performed by a protective stop function.

5.5.2.2 If a bar or other device is used to rotate the crankshaft by hand:

a) after the main motor is switched off, a device shall prevent re-engagement of the clutch before the flywheel has come to full stop. This device may be a timer that cannot be adjusted by the user or a motion detector, and shall be monitored;

b) it shall not be possible to inadvertently leave the bar in position during normal operation;

c) it shall be possible to see at least part of the flywheel to ensure that it is stationary.

5.5.3 Additional requirements for Group 2 presses

5.5.3.1 Means shall be provided to allow slide movement during tool-setting, maintenance and lubrication with guards and protective devices in position and operational (see ISO 16092-1:2017, 5.3.2.1).

Where this is not practicable, at least one of the following means shall be provided (i.e. INCH mode, see 5.5.1):

a) incremental manual motion control device used with a hold-to-run control device and slow closing speed (equal or less 10 mm/s);

b) two-hand control device in accordance to ISO 16092-1: 2017, 5.5.7 and 5.5.8, which is located outside the minimum distance;

c) intermittent movement (6 mm or less) produced by a safely-limited increment (SLI) sub-function (see IEC 61800-5-2:2016, 4.2.4.10).

Standstill of the slide during tool-setting, maintenance and lubrication shall be performed by safe de-energized standstill function that conforms to 5.4.1.3. Stop functions of slide during tool-setting, maintenance and lubrication shall be performed by a protective stop function.

5.5.3.2 If the slow closing speed is a function of the servo drive system [i.e. by a safely-limited speed (SLS) sub-function (see IEC 61800-5-2:2016, 4.2.4.5)], either:

— the speed control function shall comply with PL d, Cat 3; or

— the slow closing speed of the slide shall be monitored by a function which complies with PL d, Cat 3. If the speed exceeds a predetermined limit, then the safe stop shall be initiated.

5.5.3.3 If the intermittent movement is a function of the servo drive system, safely-limited increment (SLI) function shall comply with PL d, Cat 3 or the intermittent movements of the slide shall be monitored by a function which complies with PL d, Cat 3. When the intermittent movement exceeds a predetermined limit then the safe stop shall be initiated.

5.5.3.4 An incremental manual motion control device (e.g. electronic hand-wheel which initiates and maintains a slide movement by pulse generation input to the servo drive system during its rotation) and its safety-related control system shall be designed and constructed to ensure that:

— unintended pulse generation will not occur due to the effects of its own weight or minor vibrations;

— any slide movement is prevented while the incremental manual motion control device is not being used.

5.5.3.5 Means to indicate the operating state (power-supply condition) of the servo drive system and the brake system during setting and maintenance shall be provided.

5.6 Mechanical hazards — Other

ISO 16092-1:2017, 5.6, shall apply.

5.7 Slips, trips and falls

ISO 16092-1:2017, 5.7, shall apply.

5.8 Protection against other hazards

In addition to the requirements given in ISO 16092-1:2017, 5.8, the following shall apply.

5.8.1 Hazards related to servo drive system

For Group 2 presses, servo drive system shall conform to IEC 61800-5-1:2007+A1:2016, Clause 4.

6 Verification of the safety requirements and/or measures

Table 3 shall be used together with in ISO 16092-1:2017, Table 1.

The crosses in Table 3 indicate the method(s) by which the safety requirements and protective measures described in Clause 5, Clause 7 and Annex B shall be verified, together with a reference to the corresponding subclauses in this document.

Table 3 — Means of verification of the safety requirements and/or measures for type testing

Subclause	Safety requirements and/or measures	Visual inspection[a]	Performance check/test[b]	Measure-ment[c]	Drawings/ Calculations/ Technical data[d]
5.2	Basic design considerations				
5.2.5	Mechanical brake				
5.2.5.1	Mechanical brake and its control system	X	X		X
5.2.5.2	Multiple spring assemblies	X		X	X
5.2.5.3 a)	Uniform springs	X		X	X
5.2.5.3 b)	Prevention of slackening back	X			X
5.2.5.3 c)	Spring housing and guiding	X			X
5.2.5.3 d)	Dissipation of heat	X		X	X
5.2.5.3 e)	Prevention of lubricant penetration	X			X
5.2.5.3 f)	Foreign matters		X		X
5.2.5.3 g)	Accumulation of unwanted material		X		X
5.2.5.3 h)	Fault exclusions of springs				X
5.2.5.3 i)	Exclusion of mechanical faults				X
5.2.5.3 j)	Safe function		X		X
5.2.5.3 k)	Consequential failure				X
5.2.6	Slide adjustment				
5.2.6.1	Supervisory control		X		X
5.2.6.2	Slide adjustment means identification	X			X
5.2.6.3	Limiting means		X	X	X
5.2.7	Slide counterbalance systems				
5.2.7.1	Mechanical spring counterbalance system		X	X	X
5.2.7.2	Pneumatic counterbalance cylinder		X	X	X
5.2.8	Operating valve and exhaust system	X	X		X
5.2.8.1	Deterioration of stopping performance				X
5.2.8.2	Escape of leakage				
5.2.8.3	Exhaust from cylinders		X		X
	Valve exhaust ports		X		X
5.2.9 a)	Foreign matters		X		X
5.2.9 b)	Dissipation of heat	X		X	X
5.2.9 c)	Working clearances		X	X	X

[a] Visual inspection is used to verify the features necessary for the requirement by visual examination of the components supplied.

[b] A performance check/test verifies that the features provided perform their function in such a way that the requirement is met.

[c] Measurement verifies by the use of instruments that requirements are met, to the specified limits.

[d] Drawings/calculations/technical data verifies that the design characteristics of the components provided meet the requirements.

Table 3 *(continued)*

Subclause	Safety requirements and/or measures	Visual inspection[a]	Performance check/test[b]	Measure-ment[c]	Drawings/ Calculations/ Technical data[d]
5.2.9 d)	Accumulation and dispersal of debris		X		X
5.2.9 e)	External clutch–engaging means		X		X
5.2.9 f)	Diaphragms	X	X		X
	Evacuation of fluid		X		X
5.2.10	Additional requirements for Group 2 press				
5.2.10.1	Safety relevant belt drive mech-anism	X		X	X
	Fault detection function		X		X
5.2.10.2	Converting the kinetic energy of the slide		X		X
5.2.10.3	Engagement of mechanical brake		X		X
5.3	Mechanical hazards in the tools area				
5.3.2	Safeguarding measures				
	Minimum distance			X	X
5.3.3	Other safety requirements				
	Motor and clutch interlocking		X		X
5.3.6	Prevention of gravity fall during maintenance or repair				
5.3.6.1 a) to c)	Interlock of mechanical slide restraint device		X		X
5.3.6.1 d)	Adequate strength				X
5.3.6.1 e)	Events caused by momentary malfunction				X
5.3.6.1 f)	Indication function of restraint device engagement	X	X		X
5.3.6.2 a)	Interlock of safety block		X		X
5.3.6.2 b) and c)	Strength, shape and length				X
5.3.6.3	Interlock of hydraulic restraint device		X		X
5.4	Control and monitoring system				
5.4.1	Control and monitoring functions				
5.4.1.1	Intervention of protective measures		X		X
5.4.1.2	Stop functions for Group 2 press		X		X
5.4.1.3	Safe standstill function		X	X	X
5.4.1.4	Protective stop function		X		X

[a] Visual inspection is used to verify the features necessary for the requirement by visual examination of the components supplied.

[b] A performance check/test verifies that the features provided perform their function in such a way that the requirement is met.

[c] Measurement verifies by the use of instruments that requirements are met, to the specified limits.

[d] Drawings/calculations/technical data verifies that the design characteristics of the components provided meet the requirements.

Table 3 *(continued)*

Subclause	Safety requirements and/or measures	Visual inspection[a]	Performance check/test[b]	Measure-ment[c]	Drawings/ Calculations/ Technical data[d]
5.4.1.5	Low pressure cut-off arrangements		X		X
5.4.1.6	Monitoring		X		X
5.4.2	Muting				
5.4.2.1	Muting for Group 2 presses		X		X
5.4.4	Position sensors				
5.4.4.2	No damage due to over-travel or reverse rotation		X		X
5.4.4.3	Direct opening action	X			X
5.4.4.4	Mechanical cams	X			X
5.4.4.5	Positive clutch engagement	X			X
5.4.4.6	Cam arrangement alteration			X	X
5.4.4.7 including a) and b)	Cam disc fitting and marking	X			X
5.4.4.7 c)	Fixed end stops			X	X
5.4.4.8	Monitoring of Indirect cam drive		X		X
5.4.6	Valves				
5.4.6 a)	Direct control of the fluid				X
5.4.6 b)	Occurrence of single fault and resuming normal operation		X		X
5.4.6 c)	Sensors integrated to the valve				X
5.4.6 d)	Separate wiring		X		X
5.4.6 e)	Short circuit		X		X
5.4.7	Performance level of safety functions				
	Requirements of Tables 1 and 2	X	X	X	X
5.4.8	Single stroke function/device				
	Prevention of a subsequent stroke		X		X
5.4.9	Stopping-performance (overrun) monitoring function/device				
5.4.9 a)	Max overrun: 15°		X	X	X
5.4.9 b)	Stopping time performance		X	X	X
5.4.9	Safe stop		X		X
5.4.9	Resume		X		X
5.4.9	Restriction of the modification of predetermined limit		X		X
5.4.10	Additional requirements for Group 1 press				

[a] Visual inspection is used to verify the features necessary for the requirement by visual examination of the components supplied.

[b] A performance check/test verifies that the features provided perform their function in such a way that the requirement is met.

[c] Measurement verifies by the use of instruments that requirements are met, to the specified limits.

[d] Drawings/calculations/technical data verifies that the design characteristics of the components provided meet the requirements.

Table 3 *(continued)*

Subclause	Safety requirements and/or measures	Visual inspection[a]	Performance check/test[b]	Measure-ment[c]	Drawings/ Calculations/ Technical data[d]
5.4.10.1	Dynamic monitoring of the clutch/brake control system		X		X
5.4.10.2	Positive linking	X			X
5.4.10.3	Relative position of sensors for stroke adjustment		X		X
5.4.11	Additional requirements for Group 2 press				
5.4.11.1 a)	Static brake test		X	X	X
5.4.11.1 b)	Active brake test		X	X	X
5.4.11.1	Prevent resumption of further operation		X		X
5.4.11.2	Guards and protective devices		X		X
5.5	Tool-setting, trial strokes, maintenance, lubrication				
5.5.1	INCH mode		X		X
5.5.2	Additional requirements for Group 1 press				
5.5.2.1	Movement of the slide with safeguards operational	X	X		X
5.5.2.1 a)	Rotation by hand		X		X
5.5.2.1 b)	Slow speed and hold-to-run control device		X	X	X
5.5.2.1 c)	Two-hand control device		X	X	X
5.5.2.1 d)	Inching device		X	X	X
5.5.2.1	Protective stop function		X		X
5.5.2.2 a)	Prevention of clutch re-engagement		X		X
	Timer/motion detector, monitored		X		X
5.5.2.2 b)	Bar removal		X		X
5.5.2.2 c)	View of the fly wheel	X			X
5.5.3	Additional requirements for Group 2 press				
5.5.3.1	Movement of the slide with safeguards operational	X	X		X
5.5.3.1 a)	Incremental manual motion control device		X	X	X
5.5.3.1 b)	Two-hand control device		X	X	X
5.5.3.1 c)	Intermittent movement		X	X	X
5.5.3.1	Safe de-energized standstill and protective stop function		X		X
5.5.3.2	Slow closing speed function		X		X
5.5.3.3	Intermittent movement function		X		X

[a] Visual inspection is used to verify the features necessary for the requirement by visual examination of the components supplied.

[b] A performance check/test verifies that the features provided perform their function in such a way that the requirement is met.

[c] Measurement verifies by the use of instruments that requirements are met, to the specified limits.

[d] Drawings/calculations/technical data verifies that the design characteristics of the components provided meet the requirements.

Table 3 *(continued)*

Subclause	Safety requirements and/or measures	Visual inspection[a]	Performance check/test[b]	Measure-ment[c]	Drawings/ Calculations/ Technical data[d]
5.5.3.4	Incremental manual motion control device		X		X
5.5.3.5	Operating state indicator	X	X		X
5.8	Protection against other hazards				
5.8.1	Hazards related to servo drive system				X
7	Information for use				
7.2	Marking	X			X
7.4	Instruction handbook				
7.4 a)	Instructions for the use of restraint device	X			X
7.4 b)	Necessary provisions for periodic brake tests	X			X
7.5	Stroke indication means: current slide position	X	X		X
Annex B	Calculation of minimum distance and stopping time measurement			X	X

[a] Visual inspection is used to verify the features necessary for the requirement by visual examination of the components supplied.

[b] A performance check/test verifies that the features provided perform their function in such a way that the requirement is met.

[c] Measurement verifies by the use of instruments that requirements are met, to the specified limits.

[d] Drawings/calculations/technical data verifies that the design characteristics of the components provided meet the requirements.

7 Information for use

7.1 General

ISO 16092-1:2017, 7.1, shall apply.

7.2 Marking

In addition to the requirements given in ISO 16092-1:2017, 7.2, the following shall be marked:

a) its designation as a “mechanical press” and the press group (Group 1 or Group 2) it conforms to;

b) the minimum and maximum stroke lengths;

c) the slide adjustment and shut height;

d) the continuous stroke rate, in strokes per minute; showing minimum and maximum, if there is a variable speed range;

e) a chart indicating the appropriate air pressure in the pneumatic counterbalance cylinders for the mass of the tool, if provided;

f) lifting points for transportation and installation.

Furthermore, Group 1 presses shall be marked with the following:

g) the normal stop position of the crankshaft, e.g. TDC;

h) the maximum permissible flywheel speed in rpm, and the normal direction of rotation;

i) the maximum permissible number of clutch engagements per minute.

7.3 Warnings

ISO 16092-1:2017, 7.3, shall apply.

7.4 Instruction handbook

In addition to the requirements given in ISO 16092-1:2017, 7.4, the instruction handbook shall include the following:

a) instructions for the use of the restraint device provided in accordance with 5.3.6;

b) for Group 2 presses, necessary provisions for static and active brake tests.

7.5 Stroke indication means

For Group 2 presses, a means to indicate the current slide position in the programmed stroke shall be provided.

If reasonably practicable, the followings should be indicated:

a) the direction of slide motion (up-stroke or down-stroke);

b) the position of the upper and lower limits of the programmed stroke or the position of the position sensors which are used to set these limits;

c) the parameter settings of the stopping-performance (overrun) monitoring function (e.g. the allowable braking distance) and the monitoring results.

Annex A
(informative)

Significant hazards, hazardous situations and protective measures

This annex contains the significant hazards, hazardous situations and events identified by risk assessment as significant for this type of machinery and which require action to eliminate or reduce the risk (see Table A.1).

Table A.1 — Significant hazards, hazardous situations and protective measures

ISO 12100:2010, Annex B	Origin of hazards	Hazardous situations on presses	Relevant subclause in this document
1 Mechanical hazards			
Table B.1	Gravity	Maintenance or repair	5.2.5, 5.3.6
Table B.1	Moving elements	All modes of production	5.2.5, 5.2.6, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.3.2, 5.3.3, 5.4.1, 5.4.2, 5.4.4, 5.4.6, 5.4.7, 5.4.8. 5.4.9, 5.4.10, 5.4.11
		Tool-setting, trial strokes, maintenance and lubrication	5.5.1, 5.5.2, 5.5.3
2 Electrical hazards			
Table B.1	Servo drive system	All modes of operation and maintenance situation (for Group 2 presses)	5.8.1
3 Thermal hazards			
Table B.1	Servo drive system	All modes of operation and maintenance situation (for Group 2 presses)	5.8.1

Annex B
(normative)

Calculation of minimum distances

B.1 General

This annex replaces ISO 16092-1:2017, Annex D.

The minimum distance, *S*, at which:

— interlocking guards without guard locking;

— control guards without guard locking;

— early opening interlocking guards without guard locking;

— ESPE using AOPDs;

— two-hand control devices;

shall be placed from the hazard zone is to be calculated according to the general formula laid down in ISO 13855:2010, Formula (2), and Formula (B.1):

$$S = (K \times T) + C \tag{B.1}$$

where

S is the minimum distance in millimetres, from the danger zone to the detection point, line or plane (see ISO 16092-1:2017, Figure C.1, borderline of the danger zone);

K is a parameter in millimetres per second;

T is the overall system stopping performance (overall response time) in seconds;

C is the intrusion distance in millimetres, based on the intrusion towards the danger zone prior to actuation of the protective device (for ESPE using vertically arranged AOPDs and AOPDDRs, see ISO 16092-1:2017, D.3, for its determination).

The overall system stopping performance, *T*, shall comprise the following two phases as per Formula (B.2):

$$T = t_1 + t_2 \tag{B.2}$$

where

T is the overall system stopping performance (overall response time) in seconds;

t_1 is the maximum time between the actuation of the sensing function and the point until the protective device has switched the output signal in the OFF state;

t_2 is the stopping time, which is the maximum time between the point when the output signal from the protective device achieves the OFF state and the point until all of the following three conditions have been achieved:

a) the slide is decelerated at 10 mm/s or less;

b) the mechanical brake is activated (i.e. de-energized or de-pressurized); and,

c) the servo motor(s) is de-energized or clutch(es) is disengaged.

The approach speed, *K*, and the intrusion distance, *C*, for each protective device shall be determined in conformity to each applicable clause of ISO 13855:2010. However,

— the intrusion distance, *C*, for early opening interlocking guards without guard locking may be zero;

— the intrusion distance, *C*, for vertically arranged AOPDs and AOPDDRs shall be determined in accordance with ISO 16092-1:2017, D.3.

Where an AOPD is used for cycle re-initiation of a press, the device shall be placed in accordance with ISO 13855:2010, 6.2.3.2.

When the position of safeguards which are mechanically linked to the press can be altered, the safeguards shall, in order to maintain the minimum distance, be interlocked or capable of being locked in a designated position, so that they can only be moved with the use of a tool, key or electronic password.

B.2 Overall system stopping performance

B.2.1 General

When measuring or estimating the overall system stopping performance *T*, the following aspects shall be taken into account under the most severe normal conditions:

a) the wear of the relevant parts of the stopping function;

b) the influence of temperature of the relevant parts of the system;

c) the maximum tool mass according to the intended use of the press;

d) maximum slide speed of the press (e.g. maximum slide speed at 90° after TDC for eccentric presses, highest angular speed of the drive system);

e) the effect of any exhaust valve and its silencer of an air-release type of brake;

f) the counterbalance system (e.g. minimum balance air pressure indicated in the instruction handbook);

g) the delay in control systems from the time a stop command is inputted to or initiated by the system logic until the system's output achieves the OFF state;

h) the delay of the interface between the protective device and the control system;

i) the maximum stroke length.

B.2.2 Additional considerations for Group 1 presses

When measuring or estimating the overall system stopping performance T of Group 1 presses, in addition to B.2.1, the following aspects shall be taken into account under the most severe normal conditions:

a) the maximum number of strokes per minute;

b) the maximum fluid pressure in the clutch/brake system;

c) the minimum air pressure allowed by the low pressure cut-off arrangement of the counterbalance cylinders.

NOTE For detailed information on determination of the stopping time, t_2, see Annex D.

B.2.3 Additional considerations for Group 2 presses

B.2.3.1 General

When measuring or estimating the overall system stopping performance, T, of Group 2 presses, in addition to B.2.1, the following aspects shall be taken into account:

B.2.3.2 Overall system stopping performance in a fault condition

For Group 2 presses, the overall system stopping performance T shall not exceed the value marked in accordance with ISO 16092-1:2017, 7.2 m), due to any single fault occurring in the safety related control system including servo system and auxiliary electrical braking units. When the safety-related parts involving the protective stop function and the mechanical brake control function are designed as the redundant and monitored system then a single fault in any of these safety-related parts will not lead to the loss of the function. However, the amount of time required for the stopping function to occur could vary depending on the faulty item and the timing when the single fault occurs.

Therefore, the manufacturer shall identify the fault condition that gives the longest overall system stopping performance and shall adopt the minimum distance calculated from it. An analysis will be required based on the design strategy of system configuration to decelerate the slide, to activate the mechanical brake and to de-energize the servo motor.

NOTE 1 Fault lists and fault exclusions for the servo system can be found in IEC 61800-5-2:2016, Annex D.

NOTE 2 Overall system stopping performance in a fault condition includes the monitoring response time (time for fault detection and time for fault reaction, e.g. safe stop).

B.2.3.3 Consideration of power loss

Unintended loss of, or disruption to the power supply to the control system including servo system shall be regarded as a single fault in the analysis.

In this case, the electronic braking functions performed by the servo system shall be assumed as being disabled, and the stopping function shall be performed by other means (e.g. mechanical brake, dynamic brake unit consisting of passive elements such as resistors, etc.).

B.2.3.4 Determination of the highest slide speed for presses using a speed monitoring function

When measuring the time required to decelerate the slide to less than 10 mm/s as a factor of the stopping time t_2, the highest slide speed during the closing stroke shall be taken into account.

Where speed monitoring is implemented, its effect may be taken into consideration only if it conforms to PL (see ISO 13849-1:2015) required for the protective stop function or PL d. In this case, the highest slide speed is calculated by Formula (B.3):

$$v = v_{\text{limit}} + \alpha_{\text{max}} \times t_{\text{delay}} \quad \text{(B.3)}$$

where

v is the highest slide speed to be set in this measurement;

v_{limit} is a preset speed limit of the monitoring function;

α_{max} is a maximum acceleration of the slide on the closing stroke produced by the maximum motor torque;

t_{delay} is a maximal time lag from the time when an over-speed occurs to the time until the speed monitoring initiates the safe torque off (STO).

If the speed monitoring does not conform to same PL as required for the protective stop function or PL d, it shall be deemed to be ineffective in restricting the highest slide speed.

B.3 Interlocking guards without guard locking, control guards without guard locking and early opening interlocking guards without guard locking

ISO 16092-1:2017, D.2, shall apply using the overall system stopping performance *T* calculated according to this annex.

B.4 ESPE using vertically arranged AOPDs and AOPDDRs

ISO 16092-1:2017, D.3, shall apply using the overall system stopping performance *T* calculated according to this annex.

B.5 ESPE using horizontally arranged AOPDs when used as the sole means of safeguarding

ISO 16092-1:2017, D.4, shall apply using the overall system stopping performance *T* calculated according to this annex.

B.6 Two-hand control devices

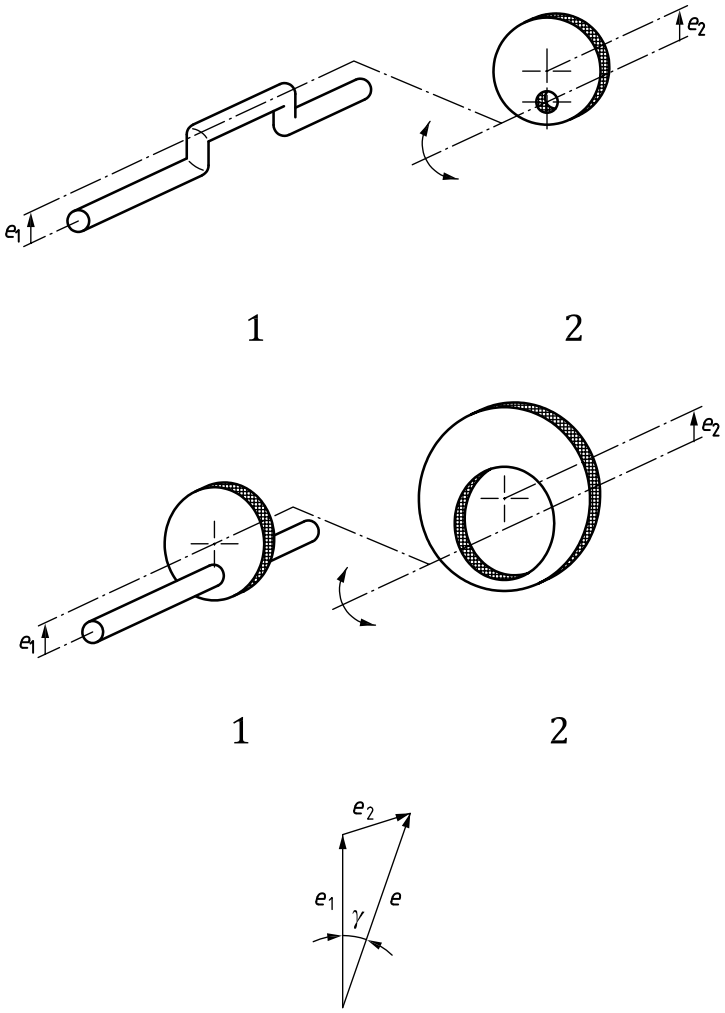
ISO 16092-1:2017, D.5 shall apply using the overall system stopping performance *T* calculated according to this annex.

Annex C
(informative)

The setting of the rotary cam arrangement

C.1 Basic features of the eccentric adjustment and rotary cam arrangement

Fixing the angle during adjustment of different lengths of stroke. Figure C.1 shows the eccentric adjustment.



Key

1 crankshaft

2 eccentric bush

e_1 eccentric distance of the crankshaft or eccentric shaft

e_2 eccentric distance of the eccentric bush

e (half stroke length) vector sum of e_1 and e_2

γ angle between e_1 and e (i.e. change in angle between e_1 and e on the basis of the change in stroke length)

NOTE This is the angle that the crankshaft needs to be turned in order to reposition the slide to the same angle position as before the stroke adjustment.

Figure C.1 — Eccentric adjustment

Assuming starting from the maximum stroke length and the slide in TDC, e_1 and e_2 are then in line, and the rotary cam arrangement indicates that the slide is positioned in TDC (see Figure C.2 a).

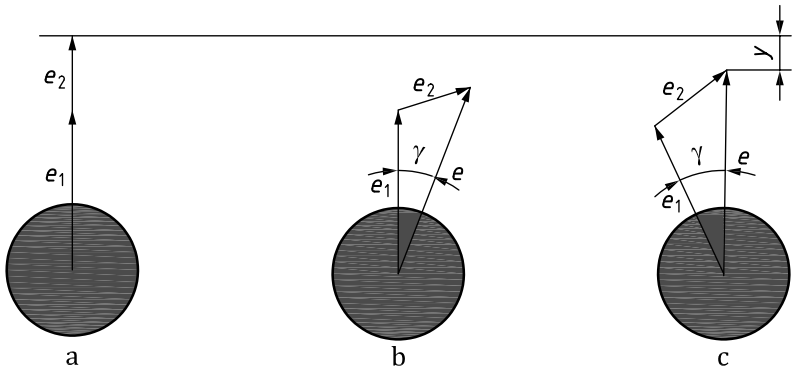


Figure C.2 — Position of eccentric bush on crankshaft

By turning the eccentric bush, e_2, a new and shorter stroke length equal to e_2 is achieved (see Figure C.2 b).

To reposition the slide to TDC, the crankshaft (and thus the rotary cam arrangement) is turned by an angle γ in the opposite direction to the turning of the eccentric bush. The stroke length is now reduced 2 y [see Figure C.2 c)]. The rotary cam arrangement indicates a slide position deviating an angle, γ, from TDC. This is the reason why the rotary cam arrangement needs to be adjusted.

The angle γ_{max} can thus achieve values between 0° and a value of γ_{max}, which is dependent on the ratio between e_1 and e_2.

γ_{max} is achieved if e_2 is turned in such a way that the angle between e_2 and e is 90° (see Figure C.3).

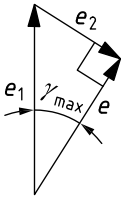


Figure C.3 — Maximum angle of rotary cam arrangement, γ_{max}

γ_{max} is obtained from $\sin \gamma_{max} = e_2/e_1$, with $e_1 \geq e_2$. It means that γ_{max} cannot be greater than 90° ($\gamma_{max} = 90°$ can occur for $e_1 \leq e_2$).

If the eccentric bush is adjustable by 180°, γ_{max} can also be calculated by using the maximum and minimum stroke lengths S_{max} and S_{min} (see Table C.1).

Table C.1 — Recommended values of maximum angle of rotary cam arrangement in relation to stroke lengths and power

Stroke length in mm	**max**	63	71	80	90	100	112	125	140	160	180	200
	min	12			16		20			25		
$\frac{s_{max}-s_{min}}{s_{max}+s_{min}}$		$\frac{51}{75}$	$\frac{59}{83}$	$\frac{68}{92}$	$\frac{74}{106}$	$\frac{84}{116}$	$\frac{92}{132}$	$\frac{105}{145}$	$\frac{120}{160}$	$\frac{135}{185}$	$\frac{155}{205}$	$\frac{175}{225}$
sin γ_{max}		0,68	0,711	0,739	0,698	0,724	0,697	0,724	0,75	0,73	0,756	0,778
γ_{max} in°		42,9	45,4	47,7	44,4	46,5	44,3	46,5	48,7	47,0	49,3	51,2
Pressing force in kN		100	160	250	400	630	(800)	1 000	(1 250)	1 600	(2 000)	2 500

$\gamma_p + \varepsilon_2$ shall not exceed, preferably $\gamma_p + \varepsilon_2 \leq 45°$.

NOTE The table is based on EPPMP (European Power Press Manufacturers' Panel) recommendation on stroke lengths enlarged with angle γ_{max} and stopping displacement position $\lambda \approx$stopping performance (overrun) margin ε_2.

Using Formula (C.1):

$$\sin\gamma_{max} = \frac{S_{max} - S_{min}}{S_{max} + S_{min}} = \frac{e_2}{e_1} \quad \text{(C.1)}$$

If the press stopping position coincides with TDC at the maximum and minimum stroke lengths ($\gamma = 0°$), the stopping position is displaced according to the angle from TDC at every other set stroke length.

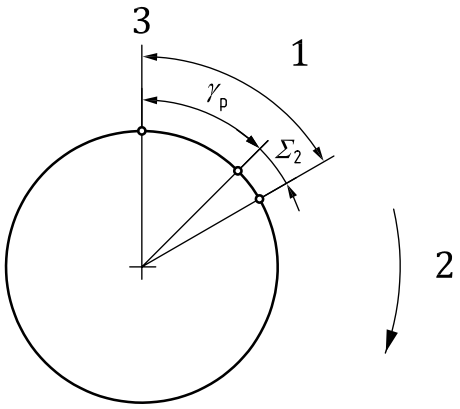
To compensate for this and to maintain the stopping position at TDC, it needs to be possible to adjust the rotary cam arrangement to a corresponding angle. This adjustment can be made by rotating the limit switches, or cams, in relation to the crankshaft.

The largest angle by which the rotary cam arrangement can be rotated between mechanical stops is designated γ_p which is the maximum permissible adjustment of the rotary cam arrangement.

It is not permissible for the average stopping position of the slide to exceed TDC by more than 60° (45° is recommended) at any combination of speed, stroke length and/or adjustment of the rotary cam arrangement (see 5.4.4.6). Therefore, the angle γ_p needs to be limited between the mechanical stops.

The safety margin of stopping-performance (overrun) monitor, in degrees, ε_2 defined in Annex D also needs to be included in the permissible overrun (60° or preferably 45°).

Therefore, the sum of γ_p and ε_2 needs to be less than 60° (preferably 45°) at the maximum stroke rate of the press (see Figure C.4).



Key

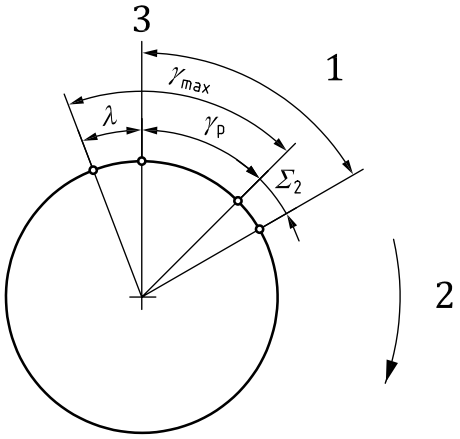
1 maximum overrun ($=\gamma_p+\varepsilon_2$)
2 direction of rotation
3 TDC

Figure C.4 — Overrun in relation to rotary cam arrangement

γ_p is normally equal to γ_{max}, so that the stopping position of the slide will always be at TDC at different stroke lengths.

If the angle γ_{max} is large, however, γ_p needs to be limited so that the permissible overrun is not exceeded.

Consequently, the stopping time of the slide at certain stroke lengths (these are dealt with below) cannot be nearer to TDC than within the angle λ (see Figure C.5).



Key

1 maximum overrun ($=\gamma_p + \varepsilon_2$)
2 direction of rotation
3 TDC

NOTE λ is the displacement of the stopping position.

Figure C.5 — Stopping position in relation to rotary cam arrangement

Figure C.5 shows $\gamma_p = \gamma_{max} - \lambda$

The size of γ_{max} is dependent on the maximum or minimum stroke length of the press. The minimum stroke length is the factor which has most effect on the size of the angle. For this reason, maximum and minimum stroke lengths should be used as shown in Table C.1.

If γ_p cannot equal γ_{max}, thus a stop of TDC cannot be achieved ($\lambda > 0$). This can alternatively arise at:

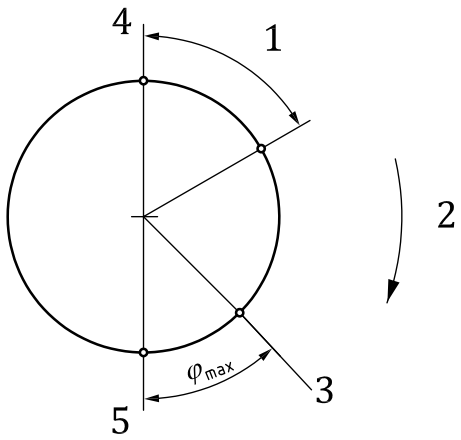
— the maximum and minimum stroke length;

— the stroke length created at $\gamma = \gamma_{max}$.

The adjustment limits of the rotary cam arrangement are determined:

— with crankshaft direction of rotation: by the maximum overrun $\gamma_p + \varepsilon_2$;

— against crankshaft direction of rotation: the maximum permissible part of the muting angle before BDC, which is designated ϕ_{max} (see Figure C.6).



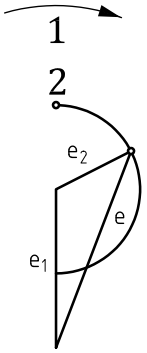
Key

1 maximum overrun ($=\gamma_p + \varepsilon_2$)
2 direction of rotation
3 start of muting
4 TDC
5 BDC

Figure C.6 — Position of maximum muting angle

In order to not exceed the maximum permissible overrun, one of the rotary cam arrangement end stops needs to be fixed in relation to the eccentric shaft when the slide is in TDC either by alternative a) or b) in Figure C.2. That is $\gamma = 0$ or $\gamma = \gamma_{max}$.

It should be noted that the eccentric bush, e_2, can be turned clockwise or counter-clockwise by e_1 (see Figures C.7 and C.8). However, the necessary limitation of the adjustability of the rotary cam arrangement allows only one half of a full revolution of the eccentric bush to be used. For this reason, the stroke adjustment needs to be designed so that only the correct half can be used.

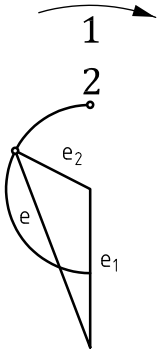


Key

1 direction of rotation

2 TDC

Figure C.7 — e_2 turned clockwise



Key

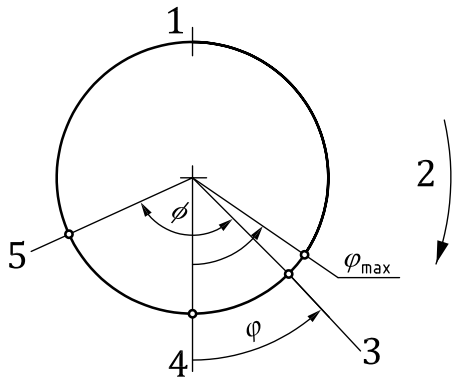
1 direction of rotation

2 TDC

Figure C.8 — e_2 turned counter-clockwise

C.2 Determination of the position where muting begins

The movement of the press is shown schematically in Figure C.9.



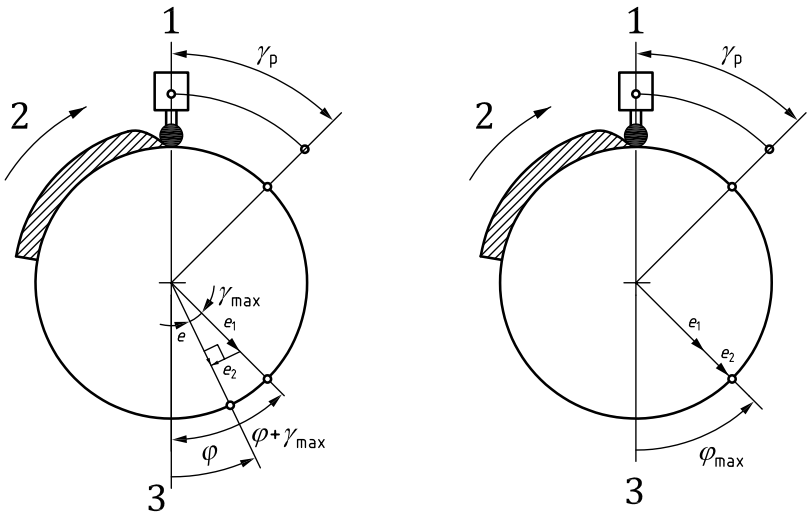
Key

1	TDC
2	direction of rotation
3	muting signal
4	BDC
5	stopping signal
Φ	muting angle (angle between the muting signal and the stopping signal)
φ	part of the muting angle before BDC, which varies with stroke length and the rotary cam arrangement and is calculated as a negative after BDC
φ_{max}	maximum permissible part of the muting angle before BDC, in degrees, calculated from the overall system stopping performance and the speed as described below

Figure C.9 — Position of muting point

The time from the moment the press receives the muting signal until BDC is traversed (corresponds to angle φ_{max}) needs to be less than the overall system stopping performance of the press with any combination of speed and stroke lengths and/or settings of the rotary cam arrangement [see 5.4.4.7 c)].

Figure C.10 shows $\varphi_{max} \geq \varphi + \gamma_{max}$ so that the muting cannot occur before the angle resulting from Formula (C.1).



Key

1 TDC

2 direction of rotation

3 BDC

Figure C.10 — Position of muting point in relation to overall system stopping performance

This means that it is not permissible for ϕ to exceed a specific value.

φ can be calculated with Formula (C.2):

$$\varphi = \omega \times T \tag{C.2}$$

where

ω is the angular velocity, in degrees per second;

T is the overall system stopping performance, in seconds (see Annex D).

The maximum permissible value φ_{max}, in degrees, is calculate with Formula (C.3):

$$\varphi_{max} = 6Tn \tag{C.3}$$

where n is the number of strokes per minute. φ_{max} needs to be calculated at the lowest number of strokes n_{min} of the press, if adjustable.

The value obtained for φ_{max} by the above formula applies basically to presses with a fixed stroke length and a fixed rotary cam arrangement. Hence the point where muting begins needs to be occurred later than angle φ_{max} before BDC as a result of a change in the stroke length and/or setting of the rotary cam arrangement (see Figure C.10).

This means that the rotary cam arrangement needs to have a fixed (mechanical) stop in one end position, so that $\varphi + \gamma_{max}$ (or γ_p) does not exceed φ_{max} when the stroke length (or rotary cam arrangement) is adjusted (the angle φ can be negative at a certain setting).

The following settings then give the two end positions of the rotary cam arrangement (between which the angle is γ_p):

a) with direction of crankshaft rotation: the end position is determined from γ_p (or γ_{max}) + $\varepsilon_2 \leq 60°$ (preferably 45°) after TDC (see Figure C.1);

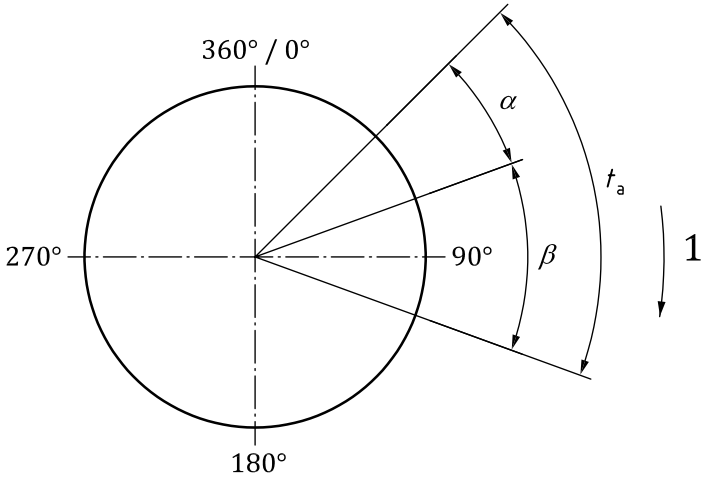
b) in the opposite direction of crankshaft rotation: the end position is determined by $\varphi + \gamma_{max}$ (or γ_p) $\leq \varphi_{max}$ before BDC.

This applies to the least favourable setting.

Annex D
(informative)

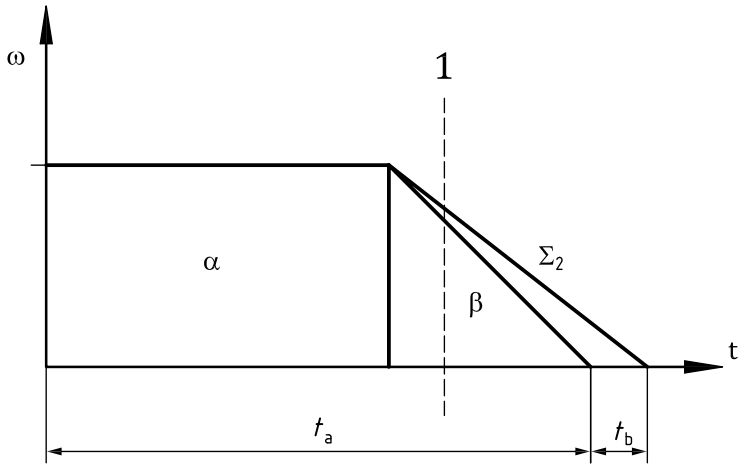
Determination of the stopping time t_2 for Group 1 presses

The following angles and times are described in Figures D.1 to D.4:



Key
1 direction of rotation

Figure D.1 — Relation between response time t_a, angle of free rotation α and braking time β



Key
1 slide passes 90°

Figure D.2 — Angular velocity variation during stopping

α is the angle of free rotation, in degrees

β is the braking angle (assumed to be linear), in degrees

ε_2 is the safety margin of stopping-performance (overrun) monitor, in degrees

ω is the angular velocity, in degrees per seconds

t_a is the response time measured at working pressure and under the conditions specified in B.2 and B.3, in seconds

t_b is the safety margin of stopping-performance (overrun) monitor, in seconds, referred to time $t_b = \varepsilon_2/\omega$

t_c is the pressure differential response time, in seconds

Δt is the uncertainty in the measuring method, in seconds

$\alpha + \beta$ is the measured stopping angle of a press with a brake in good condition, in degrees

$\alpha + \beta + \varepsilon_2$ is the measured stopping angle of the same press with a worn brake, in degrees

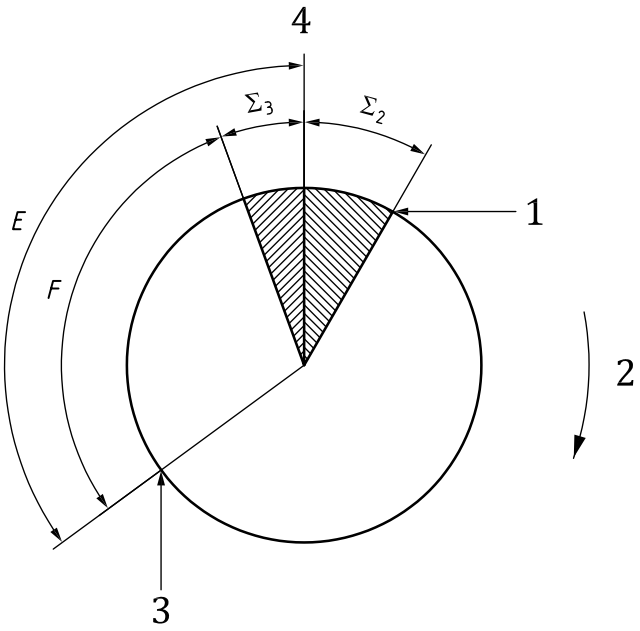
ε_2 is normally $\Delta\alpha + \Delta\beta$, but can consist only of $\Delta\beta$ in the worst case

The stopping time t_2 for Group 1 presses is determined as described below:

a) the time t_a should be measured under the conditions specified in B.2.1 and B.2.2.

NOTE 1 The stopping time, t_2, can only be determined for individual presses.

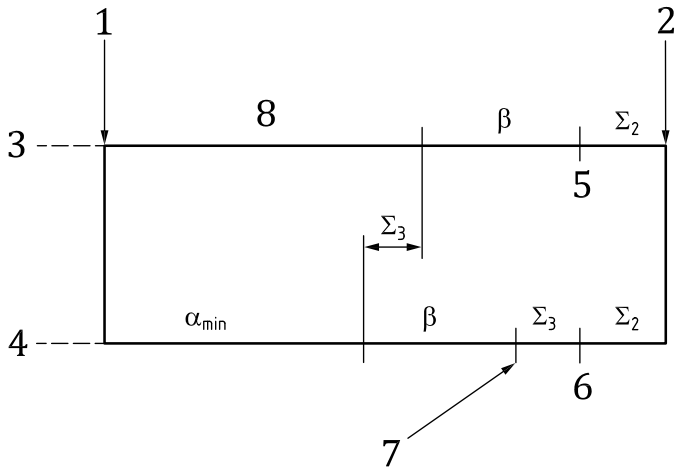
b) the time t_c, which corresponds to ε_3, and t_b, which corresponds to ε_2 (i.e. the pressure differential time plus the safety margin of the brake monitor), should now be added to t_a (see Figures D.3 and D.4).



Key

1 stopping-performance monitor
2 direction of rotation
3 stopping signal
4 TDC
E angle at working pressure
F angle at minimum pressure

Figure D.3 — Stopping position in relation to pressure differential time t_c and safety margin of stopping-performance monitor t_b



Key

1 stopping signal
2 stopping-performance monitor
3 working pressure
4 minimum pressure
5 TDC
6 BDC
7 stopping point at minimum pressure
8 α at working pressure

Figure D.4 — Sequence diagram of stopping

Figures D.3 and D.4 show that when the stopping signal and the position of the stopping-performance (overrun) monitor are fixed, the angles between these two points are constant although the size of the partial angles can vary.

In Figure D.3, *E* is the stopping angle that occurs at normal working pneumatic pressure when the cam arrangement is adjusted so that the average stop position is as close to TDC as possible, and *F* is the new average stopping position that occurs at the same setting of the rotary cam arrangement, but at the minimum pneumatic pressure determined by the pressure monitor switch setting.

Figure D.4 shows that a smaller braking angle occurs with minimum pressure in the slide drive than with normal working pressure, as air at the lower pressure exhausts more rapidly. If the brake deteriorates while working at minimum pressure, the stopping time t_2 can be exceeded although the stopping-performance (overrun) monitor angle has not been exceeded. This occurs because the crankshaft rotates at full speed during α (the response angle) but on average at half speed during β (the mechanical braking angle).

Theoretically, t_c can be measured directly (t_a at working pressure minus t_a at minimum pressure equals to t_c as pressure differential time), but a more practical way is to measure ε_3 manually and convert it to t_c with Formula (D.1)

$$t_c = \frac{\varepsilon_3}{\omega} = \frac{\varepsilon_3}{6\,n_{\max}} \tag{D.1}$$

This assumes free rotation of the crankshaft with:

ε_3 in degrees;

$n_{\max}$ in strokes per minute (the maximum stroke rate).

The safety margin of stopping-performance (overrun) monitor ε_2 is converted to the time t_b with Formula (D.2):

$$t_b = \frac{2\varepsilon_2}{\omega} = \frac{\varepsilon_2}{3 n_{\max}} \max \quad \text{(D.2)}$$

This assumes rotation of the crankshaft under braking with:

ε_2 in degrees;

$n_{\max}$ in strokes per minute (the maximum stroke rate).

c) possible additions for uncertainties in the measuring method is taken into account by Δt;

d) the stopping time, t_2, used to calculate the minimum distance for Group 1 presses is given in Formula (D.3):

$$t_2 = t_a + t_b + t_c + \Delta t \quad \text{(D.3)}$$

Bibliography

[1] ISO 13850:2015, *Safety of machinery — Emergency stop function — Principles for design*

[2] ISO 14119:2013, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

[3] IEC 60947-5-1:2016, *Low-voltage switchgear and control gear—Part 5-1: Control circuit devices and switching elements—Electromechanical control circuit device*

(Continued from second cover)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 13849-1 Safety of machinery — Safety related parts of control systems — Part 1: General principles for design	IS 16810 (Part 1) : 2018 Safety of machinery Safety related parts of control systems: Part 1 General principles for design	Identical with ISO 13849-1 : 2015
ISO 13849-2 Safety of machinery — Safety-related parts of control systems — Part 2: Validation	IS 16810 (Part 2) : 2018 Safety of machinery — Safety related parts of control systems: Part 2 Validation	Identical with ISO 13849-2 : 2012
ISO 13855 Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body	IS 16815 : 2019 Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body	Identical with ISO 13855 : 2010
ISO 16092-1 Machine tools safety — Presses — Part 1: General safety requirements	17277 (Part 1) : 2019 Machine tools safety — Presses: Part 1 General safety requirements	Identical with ISO 16092-1 : 2017
ISO 16092-3 Machine tools safety — Presses — Part 3: Safety requirements for hydraulic presses	IS 17277 (Part 3) : 2021 Machine tools safety — Presses: Part 3 Safety requirements for hydraulic presses	Identical with ISO 16092-3 : 2017
IEC 60204-1 Safety of machinery — Electrical equipment of machines — Part 1: General requirements	IS 16504 (Part 1) : 2019 Safety of machinery — Electrical equipment of machines: Part 1 General requirements (*first revision*)	Identical with IEC 60204-1 : 2016

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 61800-5-1 : 2007 +A1:2016	Adjustable speed electrical power drive systems — Part 5-1: Safety requirements — Electrical, thermal and energy
IEC 61800-5-2 : 2016	Adjustable speed electrical power drive systems — Part 5-2: Safety requirements — Functional

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values *(second revision)'.* The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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This Indian Standard has been developed from Doc No.: PGD 04 (19794).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Headquarters:

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Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

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Eastern	: 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	2367 0012 2320 9474
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Published by BIS, New Delhi