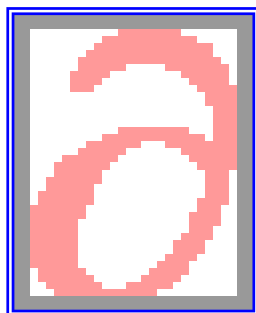




## **TRINUS Machine Safety Requirements for Safe Operation**



**TRINUS**  
**ENGINEERING**



---

---

### **(1) Use of reliable components**

The use of reliable components involves those components that are able to withstand all disturbances and stresses associated with the usage of the equipment in the conditions of intended use, for the period of time fixed for the use, without failures generating a hazardous malfunctioning of the machine.

### **(2) Use of automatic monitoring**

Automatic monitoring ensures that a protective measure is initiated if the ability of a component or an element to perform its function is diminished, or if the process conditions are changed in such a way that hazards are generated.

There are two categories of automatic monitoring:

- a) “continuous” automatic monitoring, whereby the protective measure is immediately initiated when a failure occurs; and
- b) “discontinuous” automatic monitoring, whereby the protective measure is delayed until a specific event occurs (e.g., the beginning of the next machine cycle) following a failure.

### **(3) Safeguarding**

Functions of guards:

Guards may have to perform the following functions:

- a) prevent access to the space enclosed by the guard; and/or
- b) contain/capture materials, workpieces, chips, liquids, radiation, hazardous substances (e.g., dust, fumes, gases), and noise that may be ejected, dropped, or emitted by the machine.

Additionally, they may need to have particular properties relating to electricity, temperature, fire, explosion, vibration, and visibility.

Requirements for fixed guards:

Fixed guards shall be securely held in place as follows:

- a) permanently (e.g., by welding); or
- b) by means of fasteners (screws, nuts) making removal/opening impossible without using tools; where possible, they should not remain closed without their fasteners.

Requirements for movable guards:

Movable guards that provide protection against hazards generated by moving transmission parts shall:

- a) remain fixed to the machinery or other structure (generally by means of hinges or guides) when open; and
- b) be interlocking guards with or without guard locking in order to prevent moving parts starting up as long as these parts can be reached and to give a stop command whenever they are no longer closed.

Movable guards that provide protection against hazards generated by non-transmission moving parts shall be designed and associated with the machine control system so that:

- a) moving parts cannot start up while they are within the operator's reach and the operator cannot reach moving parts once they have started up; this can be achieved by interlocking guards without guard locking;
- b) they can be adjusted only by means of an intentional action, such as the use of a tool, key, etc.;
- c) the absence or failure of one of their components prevents starting or stops the moving parts; this can be achieved by automatic monitoring; and
- d) protection against ejection hazard is ensured by appropriate means.

**Requirements for adjustable guards:**

Adjustable guards can be used in situations where the hazard zone cannot be completely enclosed. They shall:

- a) be adjustable in a manner that ensures that the adjustment remains fixed during a particular operation;
- b) be readily adjustable without the use of tools; and
- c) reduce as far as possible the risk from ejection.

**Requirements for interlocking guards with a start function (control guards):**

An interlocking guard with a start function shall be used sparingly and only if

- a) the risk assessment process yields a level of adequate risk reduction;
- b) all requirements for interlocking guards are satisfied;
- c) the cycle time of the machine is short (e.g., preset time of no more than 1 min if not specified in the appropriate type-C standard) so that when this time is exceeded, the hazardous movements cannot be initiated by the closing of the control guard;
- d) the dimensions or shape of the machine (as specified in the appropriate type-C standard) do not allow an operator or another person or a part of his or her body to stay in the hazard zone or between the hazard zone and the guard while the guard is closed;
- e) opening the interlocking guard with a start function or another interlocking guard is the only way to enter the hazard zone;
- f) the interlocking device associated with the interlocking guard with a start function is designed in such a way that its failure cannot lead to an unintended/unexpected start-up and it is control reliable; and
- g) the guard is securely held open (e.g., by a spring or counterweight) such that it cannot initiate a start while falling by its own weight.

**Hazards from guards:**

Care shall be taken to prevent hazards that might be generated by the

- a) guard construction (sharp edges or corners, material, etc.); and
- b) movements of the guard (shearing or crushing zones generated by energy-driven guards and by heavy guards that are liable to fall).

### **Technical characteristics of protective devices:**

A protective device intended to perform a critical safety function shall be designed according to the following principles:

- a) Protective devices shall be operated and connected with the control system so that they cannot be easily defeated.
- b) The characteristics of protective devices shall be consistent with the control system into which they are integrated.

## **(4) Use of active OPTO-electronic protective devices**

### **Basic requirements:**

An active opto-electronic protective device (AOPD) shall meet the following conditions:

- a) while the sensing field of the AOPD is interrupted, the machine cannot operate;
- b) the machine is stopped whenever the sensing field of the AOPD is interrupted during any part of the hazardous motion;
- c) wherever the sensing field of the AOPD is broken, the part of the body in question is detected; and
- d) failure of the AOPD does not lead to the possibility of a person entering the space between the sensing field of the AOPD and the hazard zone or to a reduction in the safety distance.

### **Additional requirements for AOPDs when used for cycle initiation:**

An AOPD shall be used sparingly for cycle initiation and only if

- a) the risk assessment process yields a level of adequate risk reduction;
- b) the requirements for an AOPD used as a presence-sensing device are satisfied (in particular, location, safety distance detection capability, reliability and monitoring of the control and braking system);
- c) the cycle time of the machine is short so that the opportunity to initiate the machine upon clearing of the sensing field is limited to a period commensurate with a single normal cycle;
- d) the pre-set time (e.g., 1 min if not specified in the appropriate type-C standard) has been exceeded, so that the AOPD is not capable of cycle initiation without using a reset procedure;
- e) the dimensions or shape of the hazard zone delimited by light curtains and guards does not allow an operator or another person(s) to enter this zone;
- f) the AOPD and interlocking guards are the only way to enter the hazard zone;
- g) only one AOPD is capable of cycle if there is more than one AOPD safeguarding the machine; and
- h) the AOPD meets the requirements of a Type 4, as specified in IEC 61496 Parts 1 and 2, and the interface of the AOPD to the control system is control reliable.

## **(5) Signals and warning devices:**

Visual signals, such as flashing lights, and audible signals, such as sirens, may be used to warn of an impending hazardous event such as machine start-up or over speed. Such signals may also be used to warn the operator before the triggering of automatic protective measures.

It is essential that these signals be

- a) emitted before the occurrence of the hazardous event;
- b) unambiguous;
- c) clearly perceived and differentiated from all other signals used; and
- d) clearly recognized by the users.

The warning devices shall be designed and located in such a manner that checking is easy. The instruction handbook shall prescribe regular checking of warning devices. The attention of designers is drawn to the risks of “sensorial saturation”, which results from too many visual and/or acoustic signals and which may also lead to defeating the warning devices.

## **(6) Markings, signs (pictograms), and written warnings**

Machinery shall bear all markings that are necessary

- a) for its unambiguous identification, including at the least:
  - the name and address of the manufacturer;
  - the designation of the series or type; and
  - the serial number, if any;
- b) to indicate its compliance with mandatory requirements, namely
  - markings; and
  - written warnings; and
- c) for its safe use; for example,
  - the maximum speed of rotating parts;
  - the maximum diameter of tools;
  - mass (of removable parts, etc.);
  - the necessity of wearing personal protective equipment;
  - guard adjustment data; and
  - the frequency of inspection.

Information printed directly on the machine should be permanent and remain legible throughout the expected life of the machine.

Signs or written warnings that only say “danger” shall not be used.

Markings, signs, and written warnings shall be readily understandable and unambiguous, especially as regards that part of the function(s) of the machine to which they are related. Readily understandable signs (pictograms) should be used in preference to written warnings. Signs and pictograms should only be used if they are understood in the culture in which the machinery is to be used. Written warnings shall be drawn up in English or French, or both, and, upon request, in the language(s) understood by operators.

## **(7) Emergency Stop**

### **General:**

The emergency stop shall be fully in accordance with NFPA 79 and ISO 13850, override all other machine controls, cause all moving parts to stop, and remove drive power from the machine actuators.

Each operator control station, including pendants, capable of initiating machine motion shall have a manually initiated emergency stop device.

### **Effects of emergency stop and reset commands:**

Once active operation of the emergency stop device has ceased following an emergency stop command, the effect of this command shall be sustained until the device is reset. This reset shall be possible only at that location where the emergency stop command has been initiated. The reset of the command shall not restart the machinery but shall only permit restarting.

### **Emergency stop device design:**

Push-buttons that activate an emergency stop circuit shall be

- a) red in colour with a yellow background;
- b) unguarded;
- c) Hard-wired;
- d) palm or mushroom head type;
- e) the type requiring manual resetting; and
- f) installed such that resetting the button shall not initiate a restart.

## **(8) Lighting**

Task lighting on the machine for the illumination of the work area shall be provided when the construction of the machine and/or its guards renders the normal lighting inadequate for the safe and efficient operation of the machine. Task lighting shall also be provided in areas of regular maintenance that are likely to be poorly lit (e.g., the inside of certain electrical compartments where electrical isolation is necessary for access). Electrical wiring, etc., for such lighting shall comply with the requirements of the *Canadian Electrical Code, Part I*.

Fluorescent-type lighting may be used, provided that any stroboscopic effects do not create a hazard.

If the position of the lighting has to be adjusted, its location shall be such that it does not present a hazard to the machine operator while making the adjustment.

## **(9) Coolant and swarf**

Machinery shall be designed, as far as is reasonably practicable, to contain coolant and/or swarf so as not to expose persons to additional hazards.

## **(10) Controls for machinery setting or adjustment and for feeding material where safeguards are displaced or removed**

### **General:**

Controls for starting or stopping a machine shall be clearly marked.

Where a safeguard has to be displaced or removed for setting or adjusting machinery, or feeding material and it is necessary for the purpose of these operations for the machinery to be in motion, the individual(s) shall be protected by one of the following types of controls:

- a) hold-to-run control(s):
  - two-hand controls;
  - enabling devices; and
  - pendant controls;
- b) limited movement device(s):
  - timed impulse device(s); and
  - controlled movement device(s); or
- c) handles and hand-wheels.

### **Hold-to-run control:**

A hold-to-run control shall only permit movement of the machinery as long as the control is held in a set position. The control shall return automatically to the stop position when released. Where the machinery runs at crawl speed, this speed shall be kept as low as practicable. A two-hand control may be used as a hold-to-run control.

A hold-to-run control for remote operation of machinery shall be used only where it is not practicable to provide effective guarding and where there is no risk of injury from overrun of the hazardous parts when the control has been released.

### **Enabling devices:**

An enabling device is an additional manually operated 2- or 3-position control device used in conjunction with a start control and which, when continuously actuated in one position only, allows a machine to function. In any other position, motion is stopped or a start is prevented.

Enabling devices shall have the following features:

- a) They shall be connected to a Category 0 or a Category 1 stop.
- b) They shall be designed in accordance with ergonomic principles:
  - position 1 is the off function of the switch (actuator is not operated);
  - position 2 is the enabling function (actuator is operated); and
  - position 3 (if used) is the off function of the switch (actuator is not operated past its mid position).
- c) Three-position enabling devices shall be designed to require manual operation in order to reach position 3.

- d) When returning from position 3 to position 2, the function shall not be enabled.
- e) An enabling device shall automatically return to its off function when its actuator is not manually held in the enabling position.

**Note:** *Tests have shown that human reaction to an emergency may be to release an object or to hold on tighter, thus compressing an enabling device. The ergonomic issues of sustained activation should be considered during design and installation of the enabling device.*

## **(11) Limited movement devices**

### **General:**

A limited movement device is a control system that physically constrains a moving machine part to a limited amount of travel on each occasion that the machinery control is operated. Further movement of the machinery is precluded until there is a subsequent and separate operation of the control.

The fitting of a limited movement device will inevitably result in a greater number of start/stop operations. Therefore, care shall be taken to ensure that the machine shall

- a) be mechanically robust enough to withstand the possible extra duty;
- b) have drive motors of adequate capacity such that they will not overheat;
- c) have rated contactors and relays adequate for this type of application;
- d) be fitted with a brake; if the load on the machinery varies during the process cycle, a brake will almost certainly be necessary if effective limited movement control is to be attained;
- e) have control operations readily distinguishable where reversal of motion is possible; and
- f) be installed such that the controls are not easily defeatable by the operator.

### **Types of limited movement devices:**

Installation should be such that the operator cannot readily tamper with the controls. There are two types of limited movement devices that may be used:

- a) Time impulse device. The method adopted is to close a contactor or relay supplying the drive motor or clutch for a predetermined time.
- b) Controlled movement device. Controlled movement devices are designed to give a reasonably accurate predetermined movement in which stopping is effected as soon as the required movement has taken place. Once properly set, such devices are affected only to a very limited, and probably negligible, extent by ambient temperature, varying load on the machine.

### **Handles and hand-wheels:**

Where hand-wheels have not been designed not to rotate when the energy drive is operating, they shall be either of the solid type without spokes or projections and/or provided with handholds of restricted size.

## **(12) Safeguard-operator interface principles**

All guards shall:

- a) prevent the entry of hands, fingers, or other parts of the body into a point of hazard;
- b) not create additional hazards between the guard and the moving parts;
- c) not cause undue obstruction to the view of the production process;
- d) be installed such that they do not cause undue interference with the activities of the worker during operation, maintenance, etc. A proper installation would reduce any incentive to circumvent or override the safeguard;
- e) be permanently affixed to the machine, or, when this is not possible, to the same surface to which the machine is fixed. The removal of a fixed guard should require the use of tools. Fasteners should be of the captive type and stay with the guard;
- f) be provided where openings intended to permit lubrication, adjustment, inspection, etc., cause an additional hazard; and
- g) protect an operator and others in the vicinity from materials, work pieces, chips, liquids, dust, fumes, gases, etc., that may be ejected, dropped, or emitted from a machine and that may present a hazard.

## **(13) Warning signals**

On installations where the main operating station or start control is in a position from which the hazardous parts of the machinery or people in the vicinity cannot be seen clearly, audible and visual warnings shall be provided. Such warnings shall be integrated through a suitable interlock for a predetermined time before the machinery starts to operate. Adjacent machines shall be provided with distinguishable audible signals.

These devices are not to be used in substitution for physical safeguards.

On installations where malfunction of the machinery creates a hazardous situation, suitable warning signals shall be provided. These signals shall be given automatically and shall be both audible and visual.

Where the machine does not have the capability of detection of a hazardous malfunction due to a hazardous situation, a manual signal that is both audible and visual shall be provided.

**Note:** *This provision is only applicable where a malfunction of the machinery creates a hazardous situation to any person.*

## **(14) Indicators**

Where necessary, a qualitative, quantitative, or check reading indicator shall have been provided to warn of a hazardous situation. Such indicators shall be designed to minimize the risk of failing to danger.

Explanations of these indicators are as follows:

- a) qualitative: shows a satisfactory or unsatisfactory state, e.g., a temperature gauge that indicates cold-normal-hot;
- b) quantitative: provides numerical data and as such requires precision in reading, e.g., a pressure gauge. A quantitative indicator shall not be used if a qualitative one would suffice; and
- c) check reading: gives information automatically or when demanded as to the state of the equipment, e.g., an indicator light and/or audible alarm.

## **(15) Braking systems**

### **General:**

This Clause applies whenever the braking system is integral for the protection of any person. Braking systems shall be so designed as to bring hazardous moving parts to rest within a consistent time interval.

As the braking capacity required is related to the momentum of the moving parts, their momentum shall be kept as low as the application permits, and, in particular, the possibility of inserting a clutch mechanism shall be considered as a means of limiting the momentum to be dealt with by the brake. Rotating parts and equipment fastened to rotating parts shall be so secured as to prevent dislodgement in consequence of the brake action. Precautions shall be taken to prevent disengagement of screwed components due to reversed torque following brake application.

Braking systems shall be designed to minimize the risk of failure to danger.

### **Mechanical (friction) braking systems:**

This Clause applies whenever the braking system is integral for the protection of any person. Application of mechanical (friction) braking systems shall be independent of the energy source.

Brakes shall be of such capacity as to perform satisfactorily under conditions of maximum sustained use.

The design shall provide for adequate dispersal of heat to prevent excessive temperature rise of the working parts.

The arrangements for guiding shall be such as to minimize the risk of binding.

Where the effectiveness of braking may be adversely affected by contamination and by the ingress of moisture or oil, consideration shall be given to

- a) selecting an appropriate friction material;
- b) providing an effective housing to prevent ingress; and
- c) monitoring braking efficiency and supplying control systems that prevent motion when efficiency is below the acceptable level (as specified by the brake manufacturer).

When springs are used, they shall be of the compression type, safety rated, and of sufficient strength to secure prompt and effective brake application. Any set of springs used on a brake shall be closely uniform in dimension, quality, and rating. A single spring shall not be relied upon unless equivalent safety is ensured by other means. The means for loading the springs shall be such that,

when correctly adjusted, the spring anchorages can be locked to prevent risk of slackening back.

Adequate instructions concerning the setting of the brake shall be available. These shall include the:

- a) length to which the spring(s) shall be compressed; and
- b) setting of the operating mechanism.

When hydraulic or pneumatic means are used to apply mechanical brakes, an accumulator/reservoir, connected as close as possible to the brake, shall be provided to ensure a sufficient supply of fluid in the event of failure of the main supply. The accumulator/reservoir shall have a low-pressure device to switch off the machinery if the pressure in the accumulator/reservoir falls below a safe limit, and the feed shall be fitted with a non-return valve.

#### **Electrodynamic braking systems:**

This Clause applies whenever the braking system is integral to the safety of any person. Electrodynamic braking systems shall be connected in such a way that their energy source is maintained when emergency stop controls are used.

One of the following methods shall be used for electrodynamic braking systems:

- a) reverse plugging;
- b) direct current injection;
- c) regenerative braking for alternating current motors; or
- d) regenerative braking for d.c. motors.

#### **Reverse plugging:**

This Clause applies whenever the braking system is integral to the safety of any person. Reverse plugging is a method of braking whereby the electrical connections to a motor are changed so that a reverse torque is applied and the machine is brought rapidly to rest. The change over contactor shall have been so controlled that it will open when the machinery stops, otherwise the machinery will restart in the reverse direction.

#### **Direct current injection:**

This Clause applies whenever the braking system is integral to the safety of any person. Direct current injection consists of disconnecting the motor stator windings from the a.c. supply and reconnecting them to a d.c. supply. This has a powerful braking effect and is better than reverse plugging because there is no tendency to restart in the reverse direction.

#### **Regenerative braking for alternating current motors (capacitor braking):**

This Clause applies whenever the braking system is integral to the safety of any person. Regenerative braking for a.c. motors consists of the following:

- a) Disconnecting the motor from the a.c. supply and reconnecting it to a capacitor bank. The capacitors help to maintain the self excitation of the motor and there is an induced braking effect.

- b) Improving the braking effect during the final stages of decelerating by short-circuiting the motor terminals.

**Regenerative braking for direct current motors:**

This Clause applies whenever the braking system is integral to the safety of any person. Regenerative braking for d.c. motors consists of reconnecting the motor so that it acts as a generator to supply a load.

The load may be a resistor or the main power supply.

**Emergency braking:**

Emergency braking shall be designed to fail in the safe mode and be suitably rated for the application (e.g., multiple spring-sets).

**(16) Clutches**

This Clause applies whenever the operation of the clutch is integral to the safety of any person. Where actuated by mechanical or other means, disengagement of the clutch should not depend on the maintenance of the energy source. This is commonly achieved by using compression-type springs. The springs shall be safety rated and of sufficient strength to secure prompt and effective clutch disengagement. Any set of springs used on a clutch shall be closely uniform in dimension, quality, and rating. A single spring shall not be relied upon unless equivalent safety is provided by other means. The means for loading the springs shall be such that, when correctly adjusted, the spring anchorages can be locked to prevent risk of slackening back.

**(17) Safety catches, overrun, runback, and fall-back protection devices**

Safety catches, overrun, runback, and fall-back protective devices shall be applied where there is a risk of personnel injury due to potential travel of machine components beyond their normal stopping position.

**(18) Counterweights and similar devices**

Counterweights that may fall upon or trap persons shall be suitably safeguarded. The movement of the counterweights should be safeguarded as far as necessary to provide complete protection against injury, in particular, in the event of an energy system failure.

Duplication of the flexible connections (chain or cable) between the mass and its balance weight(s) is good practice, provided that each connection is sufficiently strong to take the full load.

Similar precautions are necessary on other weights, e.g., those provided for tensioning ropes and belt conveyors, where such weights move when the machinery is operated. In these cases, provision shall be made to maintain safety in the event of rope or belt failure.

## **(19) Interlocking safeguarding devices**

### **General:**

Safeguarding devices that are used for interlocking shall

- a) have a key, plug, or actuating device that is not easily duplicated;
- b) be tamper-resistant and not be defeated intentionally without tools;
- c) provide a means for secure attachment; and
- d) be provided with documentation stating:
  - the standards with which the device is compliant;
  - the standards against which the device is independently certified; and
  - that the control system performance complies with the criteria for one of the four control systems types listed in Clause (20) below.

### **Mechanical devices:**

Mechanical devices (typically including, but not limited to, transfer or captive/trapped key interlocking) shall:

- a) have a physical link between the energy source of a hazard and the locking mechanism to allow the removal of the key or actuating device only when the hazard has been controlled. The removal of the key or actuating device shall prevent reinstatement of the hazard; and
- b) provide a mechanical lock for the guard at the point of access, which can only be unlocked by the key or actuating device described in Item (a). This lock shall trap or retain the key or actuating device when the guard is opened, and only release the key or actuating device when the guard is closed and locked.

## **(20) Safety control system performance criteria:**

Safety control systems (electric, hydraulic, pneumatic) shall meet one of the performance criteria listed below (Simple, Single channel or Single channel with monitoring):

### **I. Type (1) Simple:**

Simple safety control systems shall be designed and constructed using accepted single channel circuitry and may be programmable.

**Note:** *This type system should be used for signaling and annunciation purposes only.*

### **II. Type (2) Single channel:**

Single channel safety control systems shall:

- a) be hardware based or comply with “Safety-related software- and firmware-based controllers” listed below;
- b) include components, which should be safety rated; and
- c) be used in compliance with manufacturer’s recommendations and proven circuit designs (e.g., a single channel electro-mechanical positive break device that signals a stop in a de-energized state).

**Note:** *In this type of system, a single component failure can lead to the loss of the safety function.*

### **III. Type (3) Single channel with monitoring:**

Single channel safety control systems with monitoring shall:

- a) include the requirements for single channel;
- b) be safety rated; and
- c) be checked (preferably automatically) at suitable intervals.

The check of the safety function(s) shall be performed

- a) at machine start-up; and
- b) periodically during operation (preferably at each change in state).

The check shall either allow operation if no faults have been detected or generate a stop if a fault is detected. A warning shall be provided if a hazard remains after cessation of motion.

The check itself shall not cause a hazardous situation. Following detection of a fault, a safe state shall be maintained until the fault is cleared.

**Note:** *In this type of system, a single component failure may also lead to the loss of the safety function.*

### **IV. Type (4) Control reliable:**

Control reliable safety control systems shall be dual channel with monitoring. Such systems shall be designed, constructed, and applied such that any single component failure (including monitoring) shall not prevent the stopping action of the equipment.

These safety control systems shall be hardware based or comply with “Safety-related software- and firmware-based controllers” listed below and include automatic monitoring at the system level conforming to the following:

- a) The monitoring shall generate a stop if a fault is detected. A warning shall be provided if a hazard remains after cessation of motion.
- b) Following detection of a fault, a safe state shall be maintained until the fault is cleared.
- c) Common mode failures shall be taken into account when the probability of such a failure occurring is significant.
- d) The single fault should be detected at time of failure. If not practicable, the failure shall be detected at the next demand upon the safety function.
- e) These safety control systems shall be independent of the normal program control (function) and shall be designed to be not easily defeated nor easily bypassed without detection.

### **Safety-related software- and firmware-based controllers:**

Software- and firmware-based controllers used in place of hardware-based components with safety-related devices shall:

- a) be designed such that any single safety-related component or firmware failure shall:
  - lead to the shutdown of the system in a safe state; and
  - prevent subsequent automatic operation until the component failure has been corrected;

**Note:** *Firmware is that executive control program code provided by the manufacturer of the component in a non-volatile internal storage mode and is not changeable by the user.*

- b) supply the same degree of safety achieved by using hardwired/hardware components in accordance with “Control reliable” listed above. For example, this degree of safety may be achieved by using microprocessor redundancy, microprocessor diversity, and self-checking; and
- c) be certified by a Nationally Recognized Testing Laboratory (NRTL) or Standards Council of Canada (SCC)-accredited testing laboratory to an approved standard applicable for safety devices.

**Electrical devices:**

Electrical devices, with or without guard locking (including, but not limited to, safety switches, captive key systems, and magnetically actuated switches), shall:

- a) be provided with detailed information about the point in the travel of the actuating device where the switching action of the contacts occurs;  
**Note:** *Depending on the switch and the installation, the amount of travel before switching may differ significantly.  
For example, without the information, a hinge-mounted switch may be improperly installed such that the door could open and a person could enter before switching occurs.*
- b) either be in compliance with “Control reliable” listed above, and upon failure detection, successive automatic operation shall be prevented until the component failure has been corrected or shall be designed for positive opening (positive break) operation such that opening the contacts signals a stop; and **Note:** *Positive opening (positive break) operation is the full separation (opening) of a closed contact through a non-resilient linkage (e.g., not dependent on springs) due to movement from the home (engaged) position.*
- c) in the case of guard-locking devices, hold the guard closed and locked until the hazard has ceased. These devices, when provided, shall provide a method to
  - manually unlock the device in the event of power failure; and
  - monitor the state of the locking mechanism. The manufacturer shall separately state the safety controls performance, in accordance with Clause (20) listed above, of the locking portion of the guard-locking device.

## **(21) Safeguarding device safety distance**

The calculation for minimum safe distance between a safeguarding device and the danger zone of a machine shall be as follows:

$$Ds = [K \times (Ts + Tc + Tr + Tbm)] + Dpf$$

Where:

$Ds$  = minimum safe distance between the safeguarding device and the hazard

$K$  = speed constant: 1.6 m/s (63 in/s) minimum, based on the movement being the hand/arm only and the body being stationary.

**Note:** *A greater value may be required in specific applications and when body motion must also be considered.*

$Ts$  = worst stopping time of the machine/equipment

$Tc$  = worst stopping time of the control system

$Tr$  = response time of the safeguarding device, including its interface

**Note:**  *$Tr$  for interlocked barrier may include a delay due to actuation. This delay may result in  $Tr$  being a deduct (negative value).*

**Note:**  *$Ts + Tc + Tr$  are usually measured by a stop-time measuring device if unknown.*

$Tbm$  = additional stopping time allowed by the brake monitor before it detects stop-time deterioration beyond the end users' predetermined limits. (For part revolution presses only.)

$Dpf$  = maximum travel towards the hazard within the presence-sensing safeguarding device's (PSSD) field that may occur before a stop is signaled.

Depth penetration factors will change depending

## **(22) Ergonomics**

Machines shall be designed with consideration for ergonomics, including the movement and posture of the worker required to operate and maintain the machine, and the location and design of controls and displays. Machine design should also take into consideration the physiological and the cognitive/perceptive abilities of the user.

The body sizes and shapes of the probable machine operators shall be taken into account, as well as the efforts and postures, reach envelopes, and frequency of cyclic actions required to avoid cumulative strain

or fatigue. When reaches are required, the smaller user should be considered; when clearance is required, the larger user should be considered.

### **(23) Visual considerations**

Where vision is a critical component in the task,

- a) the worker should be able to view the areas of primary importance without adopting awkward postures;
- b) controls or guards shall be designed and located so as not to interfere with the operator viewing the task during work;
- c) adequate general or task lighting shall be provided to minimize eye-strain; and
- d) glare, shadows, contrast, and reflections shall be kept to a minimum.

### **(24) Installation, operation, and maintenance instructions**

The manufacturer shall provide sufficient information with each machine, including drawings, to enable the correct installation, safe operation, and maintenance for:

- a) transport;
- b) unloading and lifting, including the weight of the machine and its attachments, with indication where it should be lifted;
- c) commissioning and installation, i.e., the limits of travel of all moving elements should be shown;
- d) start-up, including preparation before start-up;
- e) operation, including description of controls and function;
- f) close-down;
- g) setting/process changeover/programming (particularly robots);
- h) adjustment;
- i) cleaning;
- j) lubrication; and
- k) repair, including information on foreseeable failures, and fault finding.