Risk Reduction Measures/Methods In Manufacturing

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3. Design & Verification

ISO, IEC, ANSI, RIA, etc. Functional Safety Life Cycle







Risk Estimation/Score in three states

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PLC and stops non-safety rated actuators					both rollers												PLC and stops non-safety rated actuators						canner is interlocked with the coil																	





SAFETY is.... Freedom from unacceptable RISK RISK is... a combination of SEVERITY and PROBABILITY

ACCEPTABLE RISK is... UP TO YOU!





Risk Estimation & Risk Reduction Methods

A clear and consistent means to determine a risk level

		Risk Level		
VERY HIGH	HIGH	MEDIUM	LOW	NEGLIGIBLE



Risk Estimation is the <u>combination</u> of the;

- Severity of harm Probability of occurrence
- Probability is frequency of exposure avoid-ability





Redesign the machine or change the process

Guarding, gates, sensors, controls

Lights, signs, rules, training, LOTO, PPE

AMERICAN NATIONAL STANDARD

B11.0 - 2020 (Annex - A)

Possible Effect on Risk Possibly **Risk Reduction Measures** susceptible to: Factors Probability (even when properly applied) Hierarchy Severity Occur-rence Avoid-ance Error / Examples Expo. sure Failure Misuse Classification Type Limiting Interaction modify the process to eliminate/reduce human interaction ٠ ٠ ٠ replace task, increase clearance Most ٠ ٠ Elimination Preferred Inherently Safe energy magnitude reduction ٠ • ٠ by Design automated material handling (Redesign) ٠ ٠ ٠ ٠ . ٠ Substitution use less hazardous chemicals ٠ • ٠ reduce force, speed, etc. through selection of inherently safe components ٠ ٠ fixed guards, shields Separation ٠ ٠ . ٠ Detect / Control Access Interlock devices, presence sensing devices • ٠ . ٠ Engineering two-hand / single actuating controls Controls ٠ ٠ ٠ • ٠ Control Hazardous Motion (Guards. enabling devices, jog controls . ٠ ٠ ٠ Devices and Control controlled selection of operating modes **Restricting Operation** ٠ . Functions) Monitor / Limit Hazards speed / force monitoring and limiting ٠ ٠ ٠ ٠ **Emergency Action** emergency stop devices ٠ . • ٠ awareness barriers ٠ . ٠ ٠ Awareness Means (Warnings & awareness signals (audible and/or visible) ٠ ٠ ٠ ٠ Instructions) awareness signs / markings . ٠ ٠ Information for Use safe work procedures, training . . ٠ (Training & Procedures) Administrative Administrative Methods safe-holding safeguarding method ٠ ٠ ٠ Controls supervisory control of configurable elements Supervision . ٠ . Control of hazardous energy isolation of hazardous energy ٠ • ٠ ٠ Tools hand tools ٠ ٠ ٠ ٠ ٠ Least Preferred PPE safety glasses, hearing protection, gloves ٠ . ٠ • .

Table 6 — Potential Effects/Additional Characteristics of Risk Reduction Measures



Risk estimation/rating determines the recommended primary risk reduction measure

RIA TR R15.306-2016

Risk Reduction		7	Risk Level		
Measure	VERY HIGH	HIGH	MEDIUM	LOW	NEGLIGIBLE
Elimination					
Substitution	Use of one or	a combina			
Limit Interaction	risk reduction	measures means to re			
Safeguarding/ SRP/CS	uo a printary i		duce none.	Any of t reduction	he risk on measures
Complementary Protective Measures Warnings and Awareness Means Administrative Controls	Use of one or risk reduction in conjunction reduction mea used as the p	a combina measures with the al asures but rimary risk	tion of these may be used bove risk shall not be reduction	that wor risks to accepta be used	uld reduce an Ible level may I.
PPE	incuouro.				

	Ris	sk Reduction Measures
	Hierarchy	Examples
Classification	Туре	
	Limiting Interaction	modify the process to eliminate/reduce human interaction
	Elimination	replace task, increase clearance
Inherently Safe	Elimination	energy magnitude reduction
(Redesign)		automated material handling
	Substitution	use less hazardous chemicals
		reduce force, speed, etc. through selection of inherently safe comport
	Separation	fixed guards, shields
Engineering	Detect / Control Access	Interlock devices, presence sensing devices
Controls	Control Hozordous Motion	two-hand / single actuating controls
(Guards, Devices and	Control Hazardous Motion	enabling devices, jog controls
Control	Restricting Operation	controlled selection of operating modes
Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting
	Emergency Action	emergency stop devices
		awareness barriers
	Awareness Means (Warnings & Instructions)	awareness signals (audible and/or visible)
		awareness signs / markings
Administrative	Information for Use (Training & Procedures)	safe work procedures, training
Controls	Administrative Methods	safe-holding safeguarding method
	Supervision	supervisory control of configurable elements
	Control of hazardous energy	isolation of hazardous energy
	Tools	hand tools
	PPE	safety glasses, hearing protection, gloves



Redesign the machine or change the process

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		Ris	sk Reduction Measures	Pos	sible Ef Fac	fect on I tors robabilit	Risk	Possibly susceptible to: (even when properly applied)		
	Classification	Hierarchy	Examples	everity	- txpo-	void-)ccur-	Failure	Error / Misuse	
	Classification	туре		0	шs	9 P	02			
		Limiting Interaction	modify the process to eliminate/reduce human interaction		•		•		•	
Most		Elimination	replace task, increase clearance	•	•					
Preferred	Inherently Safe		energy magnitude reduction	•			•	•		
	(Redesign)		automated material handling	•	•	•	•	•	•	
		Substitution	use less hazardous chemicals	•			•		•	
			reduce force, speed, etc. through selection of inherently safe components	•		•				
		Separation	fixed guards, shields		•		٠	•	•	
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•	Probability (even whe \overline{Probability} Probability Failure \overline{Probability} \overline{Probability} Failure \overline{Probability} \overline{Probability} Failure \overline{Probability} \overline{Probability} Probability \overline{Probability} \overline{Probability} Probability \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} \overline{Probability} <td>•</td> <td>•</td>	•	•		
	Controls		two-hand / single actuating controls		•	•	•	•	•	
	(Guards,	Control Hazardous Motion	enabling devices, jog controls			•	•	•	•	
	Control	Restricting Operation	controlled selection of operating modes				•		•	
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•		
		Emergency Action	emergency stop devices	•		•	٠	•		
			awareness barriers		•	•	•		•	
		Awareness Means (Warnings &	awareness signals (audible and/or visible)			•	•	•	•	
			awareness signs / markings			•	•		•	
	Administrativo	Information for Use (Training & Procedures)	safe work procedures, training			•	•		•	
77	Controls	Administrative Methods	safe-holding safeguarding method			•	•		•	
\setminus /		Supervision	supervisory control of configurable elements			•	•		•	
\backslash		Control of hazardous energy	isolation of hazardous energy	•	•		•		•	
V Least		Tools	hand tools	•		•	•	•	•	
Preferred		PPE	safety glasses, hearing protection, gloves	•		•	•	•	•	

Table 6 — Potential Effects/Additional Characteristics of Risk Reduction Measures



Inherently Safe by Design or Redesign Elimination of the hazard

- Eliminate human interaction or exposure
 - Eliminate the task
 - Relocate the operator
- Mechanical or process alteration
 - Automate material handling, robotics
- Modify the machine
 - Elimination of shear points or offset edges
- Product substitution
 - raw material or "support product" like lubricant
- Reducing the energy available/accumulated
 - Kinetic, potential, electrical







For new machines

Inherently Safe by Design

- Suggest that this is in contractual layout (Ts & Cs)
 - Infuse risk assessments and mitigation into the process/contract
 - Collaboration of Supplier/User of Equipment/Machine
 - Risk assessed & mitigated at each stage
 - Specify standards
 - ANSI B11.0-2020 (Risk Assessment)
 - ANSI B11.19-2019 (Mitigation)







Inherently Safety by Design ANSI B11.19-2019

- Inherently safe by design: A design measure that reduces risk, which is not susceptible to a malfunction that will increase the risk of harm.
- Prevention though design
 - Safe-opening safeguarding method
 - When work piece is in place, no room for human (in part or whole)
 - Typically includes an engineered control (guard)
 - Safe-location safeguarding method
 - Put hazard out of normal reach (horizontal/vertical)
 - Separate area/room/vault
 - Maximum gaps to avoid exposure to hazards
 - ANSI US = 1/4" (~6mm)
 - ISO EU = 4mm (~5/32")
 - Minimum gaps to avoid crushing of parts of the human body
 - ANSI B11.19-2019 Table 1









Redesign the machine or change the process

Guarding, gates, sensors, controls

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B11.0 – 2020 (Annex – A)

		Table 6 —	Potential Effects/Additional Characteristics of Risk Reduction	on Mea	sures	5			
		Ris	k Reduction Measures	Pos	sible Eff Fac	fect on tors	Risk	Pos: suscep	sibly tible to:
		Hierarchy	Examples	erity		robabili	ty -in: ce	(even when pr	operly applied) Error /
	Classification	Туре		Sev	Exp sur	Avdanc	Oco ren	Fallule	Misuse
		Limiting Interaction	modify the process to eliminate/reduce human interaction		•		٠		•
Most		Elimination	replace task, increase clearance	•	•				
Preferred	Inherently Safe		energy magnitude reduction	•			•	•	
	(Redesign)		automated material handling	•	•	•	•	•	•
		Substitution	use less hazardous chemicals	•			•		•
			reduce force, speed, etc. through selection of inherently safe components	•		•			
		Separation	fixed guards, shields		•		٠	•	•
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•
	Controls	Control Hazardova Mation	two-hand / single actuating controls		•	•	•	•	•
	(Guards, Devices and		enabling devices, jog controls			•	•	•	•
	Control	Restricting Operation	controlled selection of operating modes				•		•
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•	
		Emergency Action	emergency stop devices	•		•	•	•	
			awareness barriers		•	•	•		•
		Awareness Means (Warnings & Instructions)	awareness signals (audible and/or visible)			•	•	•	•
			awareness signs / markings			•	•		•
	Administrative	Information for Use (Training & Procedures)	safe work procedures, training			•	•		•
7 7	Controls	Administrative Methods	safe-holding safeguarding method			•	•		•
\setminus /		Supervision	supervisory control of configurable elements			•	•		•
\setminus		Control of hazardous energy	isolation of hazardous energy	•	•		•		•
۷ Least		Tools	hand tools	•		•	•	•	•
Preferred		PPE	safety glasses, hearing protection, gloves	•		•	•	•	•



Engineering Controls

	Risk F		k Reduction Measures	Pos	sible Ef Fac	fect on tors	Risk	Pos: suscep	sibly tible to:				
					P	robabili	ty	(even when pro	operly applied)				
		Hierarchy	Examples	verity	po- re	oid- ce	cur- Ice	PointError / Misuse					
	Classification	Туре		Se	Ex	Avano	Oc rer		WISUSE				
Machine Guarding		Separation	fixed guards, shields		٠		•	•	•				
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•				
	Controls	Control Hozordova Mation	two-hand / single actuating controls		•	•	•	•	•				
	(Guards, Devices and	Control Hazardous Motion	enabling devices, jog controls			•	•	•	•				
	Control	Restricting Operation	controlled selection of operating modes				•		•				
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•					
		Emergency Action	emergency stop devices	•		•	•	•					

US Law = Requirements



<u>1910.212(a)</u>*Machine guarding.*

<u>1910.212(a)(1)</u> *Types of guarding.* One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are-barrier guards, two-hand tripping devices, electronic safety devices, etc.

<u>1910.212(a)(2)</u> General requirements for machine guards. Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself.





Machine Guarding Requirements

- ANSI B11.19 2019 -Performance Requirements for Risk Reduction Measures
 - **ISO 14120-2015** *General requirements for the design and construction of fixed and movable guards*







- On-machine or perimeter
- Welded or fasteners that require a tool
- Withstand impact forces
- Reasonably foreseeable misuse
- Maintain visibility
- AUTO test, Around, Under, Through or Over the guard to access a hazard

OMROF

• Depth of Penetration Test (gotcha stick)









- On machine or perimeter
 - Gates and Panels
- Most of the same requirements as fixed guards
- Switches & Interlocking Devices & Control Functions
- Safety Distance & Stop Time Calculations







American National Standard

B11.19-2019

Table E.2 – Horizontal reaching distance when accessing over a protective structure

	Vertical distance of 3 Height of upper edge of protective structure ¹										
1	$\frac{H_{gt}}{H_{gt}}$										
-	zone from	1 000 mm	1 200 mm	1 400 mm	1 600 mm	1 800 mm	2 000 mm	2 200 mm	2 400 mm	2 500 mm	2 700 mm
	plane ³	(39.37") 2	(47.24")2	(55.12")	(62.99")	(70.87")	(78.74")	(86.61")	(94.49")	(98.43")	(106.30")
	H _h	2 Ho	rizontal re	eaching d	istance to	oward haz	ard zone	over a pr	otective s	structure o	l _{go}
	2 700 mm (106.30")	0	0	0	0	0	0	0	0	0	0
	2 600 mm (102.36")	900 mm (35.43")	800 mm (31.50")	700 mm (27.56")	600 mm (23.26")	600 mm (23.62")	500 mm (19.69")	400 mm (15.75")	300 mm (11.81")	100 mm (3.94")	0
	2 400 mm (94.49")	1 100 mm (43.31")	1 000 mm (39.37")	900 mm (35.43")	800 mm (31.50")	700 mm (27.56")	600 mm (23.62*)	400 mm (15.75")	300 mm (11.81")	100 mm (3.94")	0
	2 200 mm (86.61")	1 300 mm (51.18")	1 200 mm (47.24")	1 000 mm (39.37")	900 mm (35.43")	800 mm (31.50")	600 mm (23.62*)	400 mm (15.75")	300 mm (11.81")	0	0
	2 000 mm (78.74")	1 400 mm (55.12")	1 300 mm (51.18")	1 100 mm (43.31")	900 mm (35.43")	800 mm (31.50")	600 mm (23.62")	400 mm (15.75")	0	0	0
	1 800 mm (70.87")	1 500 mm (59.06")	1 400 mm (55.12")	1 100 mm (43.31")	900 mm (35.43")	800 mm (31.50")	600 mm (23.62")	0	0	0	0
	1 600 mm (62.99")	1 500 mm (59.06")	1 400 mm (55.12")	1 100 mm (43.31")	900 mm (35.43")	800 mm (31.50")	500 mm (19.69")	0	0	0	0
	1 400 mm (55.12")	1 500 mm (59.06")	1 400 mm (55.12")	1 100 mm (43.31")	900 mm (35.43")	800 mm (31.50")	0	0	0	0	0
	1 200 mm (47.24")	1 500 mm (59.06")	1 400 mm (55.12")	1 100 mm (43.31")	900 mm (35.43")	700 mm (27.56")	0	0	0	0	0
	1 000 mm (39.37")	1 500 mm (59.06")	1 400 mm (55.12")	1 000 mm (39.37")	800 mm (31.50")	0	0	0	0	0	0
	800 mm (31.50")	1 500 mm (59.06")	1 300 mm (51.18")	900 mm (35.43")	600 mm (23.62")	0	0	0	0	0	0
	600 mm (23.62")	1 400 mm (55.12")	1 300 mm (51.18")	800 mm (31.50")	0	0	0	0	0	0	0
	400 mm (15.75")	1 400 mm (55.12")	1 200 mm (47.24")	400 mm (15.75")	0	0	0	0	0	0	0
	200 mm (7.87")	1 200 mm (47.24")	900 mm (35.43")	0	0	0	0	0	0	0	0
	0	1 100 mm (43.31")	500 mm (19.69")	0	0	0	0	0	0	0	0
	¹ Protective s movement	tructures lo	wer than 1	000 mm (3	9.37") in he	eight are no	t included b	ecause the	y do not si	ufficiently re	strict
\star	² Protective s	structures lo	wer than 1	400 mm (5	5.12") shou	uld not be u	sed without	additional	engineerin	g controls.	
	For safe-location-safeguarding method (7.4), the hazard should be 2 700 mm (106.30") or greater vertical distance above the reference plane (e.g., floor).										

American National Standard







Detect/Control Access

		Ris	k Reduction Measures	Possible Effect on R Factors				Poss suscept	sibly tible to:
				`	Pi	obabilit	y	(even when properly applied	
		Hierarchy	Examples	verity	-od-	oid- ce	cur-	Failure	Error /
	Classification	Туре		Se	Ex	Avan	Oc rer		Misuse
Machine Guarding Separation		Separation	fixed guards, shields		•		٠	•	•
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•
Minor Servicing	Controls	Control Hozardous Motion	two-hand / single actuating controls		•	•	•	•	٠
	(Guards, Devices and		enabling devices, jog controls			•	•	•	•
Exception	Control	Restricting Operation	controlled selection of operating modes				•		•
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•	
		Emergency Action	emergency stop devices	•		•	•	•	



Tasks - Minor Servicing Exception



https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.147

Note: Exception to paragraph (a)(2)(ii): Minor tool changes and adjustments, and other minor servicing activities, which take place during normal production operations, are not covered by this standard if they are routine, repetitive, and integral to the use of the equipment for production, provided that the work is performed using alternative measures which provide effective protection (See Subpart O of this Part).

- 1. The task is performed during normal operations
- 2. Is routine, repetitive and integral to the use of the equipment for production
- 3. Alternative measures are just as effective does not increase risk
- 4. * Shall provide justification and a team/task-based risk assessment (documentation).









- Functional Safety of machinery are those parts of the machine control system that are specifically used to reduce risk, particularly with regard to human safety
 - An example of Functional Safety is a simple interlock circuit.



- The **Safety Function** could be described as follows:
 - The Safety Gate is opened, causing the gate monitoring sensor to turn off (input). The Monitoring Safety Relay (logic) detects this change of state and de-energizes the contactors (output), thus stopping the associated motor and hazardous motion.



- Functional Safety of machinery are those parts of the machine control system that are specifically used to reduce risk, particularly with regard to human safety
 - An example of Functional Safety is a simple interlock circuit.



 The Safety Gate is opened, causing the gate monitoring sensor to turn off (input). The Monitoring Safety Relay (logic) detects this change of state and commanding the safety valve to the block and dump position (output), thus stopping the hydraulic actuator and hazardous motion.



- Normal stop The stopping of a machine, initiated by the control system, at the completion of a cycle.
- Emergency stop The stopping of a machine, manually initiated, for emergency purposes.
- Protective or safety stop The stopping of a machine initiated by an engineering controls device for risk reduction purposes.
- These definitions are harmonized across all of the standards

9.4.4 Comparison of Stop Functions

Table 2 offers an explanatory comparison of the different types of stop functions.

B11.19-2019

Table 2 — Comparison of stop, emergency stop, and protective stop
(Informativo)

		(
	Normal Stop	Emergency Stop	Protective Stop			
ANSI B11.19 reference	3.101.3; <u>9.4.1</u>	3.101.2; <u>9.4.2;</u> <u>10.12</u>	3.101.4; <u>9.4.3</u>			
Location	Personnel have quick, unobstructed access. Required on all operator stations	Personnel have quick, unobstructed access. Required on all operator stations and other locations as determined by a risk assessment	Located such that an individual cannot access the hazard. Determined by the safety distance formula (see also, <u>9.6</u> and <u>Annex H</u>).			
Initiation of stop signal	Manual or automatic	Manual only	Manual or automatic			
Stop category**	0, 1 or 2	0 or 1 only	0, 1, or 2			
	As determined by a docum	ented risk assessment				
Circuit performance	Typically single channel (non safety-rated)	Minimum single channel safety rated controls. Greater performance may be required	Typically control reliable, see also, <u>9.2</u>			
Circuit reset	Manual only	Manual only	Manual or automatic (hardware or software)			
Manual suspension and mute	Allowed (for cycle completion, etc.)	Not allowed	Allowed (for muting, modes of operation, set up, etc.)			
Use frequency	Variable; frequent (every cycle) to infrequent	Infrequently; only in emergency situations or for other immediate stop purposes	Variable; frequent (every cycle) to infrequent. Typically a stop command is only issued when a safe condition is not present			
Effect	De-energize the relevant circuit and override related start functions	Remove all energy sources to hazards in the span of control and override all other functions and operations in all modes	Remove or control energy sources to the hazard in the span of control and override all other functions and operations in all modes associated with the hazard in the span of control			
Final removal of power	Electromechanical or solid-state components	Electromechanical components or solid-state components designed for safety functions	Electromechanical or solid- state components designed for safety functions			



- **Category 0** an uncontrolled stop by immediately removing power to the machine actuators. (Additional braking can be necessary)
- **Category 1** a controlled stop with power to the machine actuators available to achieve the stop then power is removed when the stop is achieved.
- **Category 2** a controlled stop with power left available to the machine actuators.
- These definitions are harmonized across all of the standards.
- Applies to all controllable power sources electric, hydraulic and pneumatic that produce motion.
- Type and category applied is determined by the risk assessment.



- Reset rearms the estop or protective stop function – allows the potential to return to normal production
- **Restart** return to normal operation/production









Detect/Control Access

		Risl	k Reduction Measures	Pos	Possible Effect on Risk Factors			Possibly susceptible to:		
		Hierarchy	Evenules	rity	Pi	robabilit	nr- a	(even when pro	operly applied)	
	Classification	Туре	Examples			Avoi ance	Occu	Failure	Misuse	
		Separation	fixed guards, shields		٠		٠	•	٠	
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•	
Minor Servicing	Controls		two-hand / single actuating controls		•	•	•	•	•	
	(Guards, Devices and	Control Hazardous Motion	enabling devices, jog controls			•	•	•	even when properly applied) Failure Error / Misuse	
Exception	Control	Restricting Operation	controlled selection of operating modes				•		•	
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•		
		Emergency Action	emergency stop devices	•		•	•	•		





Detect - interlocked (formally "non-separating safeguarding")

• Detection device must:

- Prevent contact with the hazard
- Secure tamper-proof, not easily by-passed
- Create no new hazard
- Not impede worker's task
- Allow safe operation of the machine without the need to:
 - Remove
 - Modify
 - Bypass







Access Control (formally "separating safeguarding")

- Movable physical gates, panels or shields
- Switches & interlocking control functions
 - Interlock or guard lock
- Safety Distance & Stop Time Calculations









Interlocked access control

- Opening/removing the guard triggers the safety function
- Unique RFID code and/or uncommon key







- Hinge switch
 - Electric or pneumatic





pneumatic



Guard locked (also interlocked)

- Guard door remains locked until safe state is attained
- Controlled by the safety logic device (PLC or relay)
 - Actual safe state via feedback or timer (assumption)
- Mechanical or magnetic locks









Guard locked (also interlocked)

- Multifunction Gate Access Control
 - Typically networked vs hard wired











Band Saw – interlock or guard lock?







Safety Distance Calculation ex. ANSI B11.19-2019, Annex H

Ds = [K x (Ts + Tc + Tr)] + Dpf + Z

- **Ds** = the minimum safe distance between safeguarding device and the hazard
- K= speed constant; 1.6 m/sec (63"/sec) walking 2m/sec (78 ³/₄"/sec) hand, reaching
- **Ts** = machine/equipment stopping time
- Tc = control system stopping time
- **Tr** = detecting device response time
- Dpf = maximum travel towards the hazard within the presence sensing safeguarding devices (PSSD) field that may occur before a stop is signaled
- Z = Supplemental distance factor







ex. [K x (Ts + Tc + Tr)] + Dpf + Z = Ds [1600mm x (.3sec + .01sec + .080sec)] + 23.8mm + 10mm = 657.8mm





Detect/Control Access

		Ris	k Reduction Measures	Poss	Possible Effect on Risk Factors			Possibly susceptible to:		
					Pi	obabilit	у	(even when properly applied)		
		Hierarchy	Examples	verity	-od	oid- ce	cur- ice	Failure	Error /	
	Classification	Туре		Se	Ex su	Avana	Oc ren		Misuse	
		Separation	fixed guards, shields		•		•	•	•	
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•	
Minor Servicing	Controls	Control Hozordovo Motion	two-hand / single actuating controls		•	•	•	•	•	
	(Guards, Devices and		enabling devices, jog controls			•	•	•	•	
Exception	Control	Restricting Operation	controlled selection of operating modes				•		٠	
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	٠		
		Emergency Action	emergency stop devices	•		•	•	•		

Alternative Methods/Measures routine, repetitive and integral to the operation of the machine



Control Hazardous Motion

Two hand/single actuating

- Simultaneous actuation
- Repositions the operator
 - All or part (hands)
- Stop time/safe distance
 - Ds = [K x (Ts + Tc + Tr)] + Dpf + Z
- Anti tie down buttons





Control Hazardous Motion

Enabling Device – Jog Controls

- 3-position center on
- Exclusive control of hazardous motion
- Enable the machine to operate while within parameters
 - safety speed/torque/direction
 - typically within the hazard area
- In proximity to the hazard





Detect/Control Access

		Ris	k Reduction Measures	Pos	Possible Effect on Risk Factors			Possibly susceptible to:	
		Hierarchy	Examples		Pr o o	obabilit	cur- č	(even when pro	operly applied) Error /
	Classification	Туре		Sev	Exp sur	Avc anc	Occ ren	i alluic	Misuse
		Separation	fixed guards, shields		•		٠	•	•
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•
Minor Servicing	Controls	Control Homondous Motion	two-hand / single actuating controls		•	•	•	•	•
Exception	(Guards, Devices and	Control Hazardous Motion	enabling devices, jog controls			•	•	•	•
	Control	Restricting Operation	controlled selection of operating modes				•		٠
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•	
		Emergency Action	emergency stop devices	•		•	•	•	

Alternative Methods/Measures routine, repetitive and integral to the operation of the machine



Restricting Operation (typically associated with access control – interlocked or guard locking)



Illustrated Principles of Trapped Key Interlocking









ETU Isolator with timed delay key release AA AB AB KEX Trapped key 'AA' Locking off ETU, Release access door lock, key 'AB'.

SBL 'AB' key in to retract bolt from guard door.



Trapped-key

- Access Key triggers the safety function
- Safety and/or
 Enabling Key
 - "Exclusive control"







Speed/force limiting (monitored)

		Ris	k Reduction Measures	Pos	Possible Effect on Risk Factors			Possibly susceptible to:	
		Hierarchy	Examples			obabilit	ur- K	(even when pro	roperly applied) Error /
	Classification	Туре				Avo anc	Occ	Fallure	Misuse
		Separation	fixed guards, shields		•		٠	•	٠
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•
Minor Servicing	Controls	Control Homondous Motion	two-hand / single actuating controls		•	•	•	•	•
	(Guards, Devices and		enabling devices, jog controls			•	•	• • • • • •	
Exception	Control	Restricting Operation	controlled selection of operating modes				•		•
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•	
		Emergency Action	emergency stop devices	•		•	•	•	





Speed/Force Monitoring and Limiting (+ access control and control of hazardous motion)

- Usually not actually stopped
 - Category 2 "stop"
- Reduce the severity
- Sophisticated controls/safety function
 - Minimum PLd
- Many variations
 - Threading as slow speed
 - Suspended load
 - Safe direction





11.19–2019 Annex L – Safety Functions for Power Drive Systems - Speed/Force Monitoring and Limiting



Figure L.10 – Safely Speed Range (SSR) Figure L.17 – Safe Braking and Holding System (SBS) (V = velocity; t = time) Figure L.12 – Safely-Limited Increment (SLI) (V = velocity; S = position; t = time)



Speed/Force Monitoring and Limiting (+ access control and control of hazardous motion)

Direction / Speed of Rolls

- Input Speed / Direction Sensors
- Input Enable switch
- Logic Speed / direction
- Output Advanced Drive







Figure L.2 – Safe Stop 1 Deceleration Controlled (SS1-d) (V = velocity; t = time)

Figure L.10 – Safely Speed Range (SSR) (V = velocity; t = time) igure L.13 – Safe Direction (SDi) (V = velocity; t = time)



Speed/force limiting (monitored)

		Risl	Reduction Measures	Pos	Possible Effect on Risk Factors			Possibly susceptible to:	
					PI	obabilit	y	(even when pro	operly applied)
	Hierarchy		Examples	verity	po-	oid- ce	cur-	Failure	Error /
	Classification	Туре		Se	Ex	Avan	Oc rer		Misuse
		Separation	fixed guards, shields		•		•	•	•
	Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•
Minor Servicing	Controls	Control Llazardava Mation	two-hand / single actuating controls		•	•	•	•	•
Exception	(Guards, Devices and		enabling devices, jog controls			•	•	•	•
	Control	Restricting Operation	controlled selection of operating modes				•		•
	Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	٠	
E-stop		Emergency Action	emergency stop devices	•		•	•	•	

Alternative Methods/Measures routine, repetitive and integral to the operation of the machine



Emergency Stop Function – General Requirements ISO 13850:2015(E) 4.1.1

- Immediate succession of hazard (motion)
- Is to be initiated by a single human action
- Shall be available and operational at all times
- It shall be maintained until it is manually reset
- Hazardous movements and operations of the machine are stopped in an appropriate manner
 - Cat 0, 1
 - Reversal or limitation of motion, rate of braking, etc.
- Actuation shall not create any new hazards





- At each operator control station
- At other locations, as determined by the risk assessment, e.g.:
 - at entrance and exit locations;
 - at locations where intervention to the machinery is needed, e.g. operations with a hold-to-run control function;
 - at all places where a man / machine interaction is expected by design (loading / unloading zone for example).
 - could also be portable and wireless a device on a person

























E-stop

Speed/force limiting (monitored)

	R	Risk Reduction Measures		Pos	sible Ef Fac	fect on tors	Risk	Possibly susceptible to:	
	Hierarchy	Examples		erity	P	robabili e oid-	ty -in: eo	(even when p	operly applied) Error /
Classification Type		Sev				Fallure	Misuse		
	Separation fixed guards, shields				•		•	•	•
Engineering	Detect / Control Access	Interlock devices, presence sensing devices			•		•	•	•
Controls	Osustas I I I and and Mating	two-hand / single actuating controls			•	•	•	•	•
(Guards, Devices and	Control Hazardous Motion	enabling devices, jog controls				•	•	•	•
Control	Restricting Operation	controlled selection of operating modes					•		•
Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting		•		•	•	•	
Emergency Action		emergency stop devices		•		•	•	•	

Alternative Methods/Measures routine, repetitive and integral to the operation of the machine



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			Ris	k Reduction Measures	Possible Effect on Risk Factors Probability			Risk	Possibly susceptible to:		
			Hierarchy	Examples	everity	xpo-	void-)ccur-	Failure	Error / Misuse	
		Classification	Туре		S	ω	A a	0 2			
			Limiting Interaction	modify the process to eliminate/reduce human interaction		•		•		•	
	Most	1	Flimination	replace task, increase clearance	•	•					
	Preferreu	Inherently Safe		energy magnitude reduction	•			•	•		
		(Redesign)		automated material handling	•	•	•	•	•	•	
			Substitution	use less hazardous chemicals	•			•		•	
		l'		reduce force, speed, etc. through selection of inherently safe components	٠		•				
			Separation	fixed guards, shields		•		•	•	•	
		Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•	
	Controls	Controls		two-hand / single actuating controls		•	•	•	•	•	
		(Guards,	Guards, Control Hazardous Motion enabling devices, jog controls	enabling devices, jog controls			•	•	•	•	
		Control	Restricting Operation	controlled selection of operating modes				•		•	
		Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•		
		1	Emergency Action	emergency stop devices	•		•	•	•		
						•	٠	•		•	
		1	Awareness Means (Warnings &	N I a service I set also			•	•	•	•	
			mardonoria	NO ACTUAL LISK			•	•		•	
Administrative		Administrative	Information for Use (Training & Procedures)				•	•		•	
Controls	7 7	Controls	Administrative Methods	reduction in the			•	•		•	
CUITIOIS	$ \rangle /$		Supervision				•	•		•	
	$ \rangle /$		Control of hazardous energy	DIA standard	•	•		•		•	
	V		Tools	RIA Stanuaru	•		•	•	•	•	
	Preferred	Ν '	PPE		•		•	•	•	•	

Table 6 — Potential Effects/Additional Characteristics of Risk Reduction Measures



Redesign the machine or change the process Machine Guard

Minor Servicing Exception

E-stop Signs, lights, horns, training Training/Awareness Boss, keys, camera Lockout/Tagout

Safety glasses, hardhat, tools

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			Ris	k Reduction Measures	Pos	sible Eff Fac	fect on tors	Risk	Pos suscep	sibly tible to:	
			Hierarchy	Examples	everity	xpo-	void- nce	ccur-	Failure	Error / Misuse	
		Classification	Туре		S	шŏ	a A	0 2			
			Limiting Interaction	modify the process to eliminate/reduce human interaction		•		•		•	
	Most		Elimination	replace task, increase clearance	•	•					
	Preferred	Inherently Safe		energy magnitude reduction	• •	•					
		(Redesign)		automated material handling	•	•	•	٠	•	•	
				Substitution	use less hazardous chemicals	•			•		•
				reduce force, speed, etc. through selection of inherently safe components	•		•				
rding			Separation	fixed guards, shields	1	•		٠	٠	•	
		Engineering	Detect / Control Access	Interlock devices, presence sensing devices		•		•	•	•	
cing		Controls	ols	two-hand / single actuating controls		•	•	•	•	•	
Cing		(Guards,	Control Hazardous Motion	enabling devices, jog controls			•	•	•	•	
n		Control	Restricting Operation	controlled selection of operating modes				•		•	
		Functions)	Monitor / Limit Hazards	speed / force monitoring and limiting	•		•	•	•		
			Emergency Action	emergency stop devices	•		•	•	•		
S				awareness barriers		•	٠	٠		•	
			Awareness Means (Warnings &	awareness signals (audible and/or visible)			•	•	•	•	
ing				awareness signs / markings			•	•		•	
eness	5	Administrative	Information for Use (Training & Procedures)	safe work procedures, training			•	•		•	
neras	7 7	Controls	Administrative Methods	safe-holding safeguarding method			•	•		•	
	$ \rangle /$		Supervision	supervisory control of configurable elements			•	•		•	
out			Control of hazardous energy	isolation of hazardous energy	•	•		•		•	
es,			Tools	hand tools	•		•	•	•	•	
ols	Preferred		PPE	safety glasses, hearing protection, gloves	•		•	•	•	•	

Table 6 — Potential Effects/Additional Characteristics of Risk Reduction Measures

ISO, IEC, ANSI, RIA, etc. Functional Safety Life Cycle





Risk Reduction Measures/Methods In Manufacturing

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3. Design & Verification