manufacturing Safety Alliance of BC

Machine Safeguarding 2

PROGRAM MODEL

manufacturing
Safety Alliance of BC

Prepared for
The Manufacturing Safety Alliance of BC

Prepared by
UBSafe

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This publication is intended solely for internal use as an awareness and information guide. It is not intended as a statement of the standards required in any particular situation, nor is it intended that this publication should in any way advise anyone regarding legal authority to perform any activities or procedures.

Every effort was made to ensure the accuracy and relevance of this information; however, this material may be subject to change due to various factors. These factors may include regulatory or interpretive changes, and a need to adapt the material to unique situations or procedures.

Nothing in this package and the course program absolve participants from using their sound judgment in the appropriate application of the material learned.

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Contents

Introduction

This model is the second model of a two-model set. We have not repeated the information from the first model; please ensure that the first model has been reviewed for basic safeguarding information.

1.1 Definition

Safeguarding refers to a variety of controls that are applied (generally) to machinery and equipment in an industrial manufacturing environment.

The OHS regulation in British Columbia defines a safeguard as follows:

"Safeguard" means the use of a guard, a safety device, a shield, an awareness barrier, warning signs, or other appropriate means, either singly or in combination, to provide effective protection to workers from hazards [OHS Regulation 12.1 Definitions].

The purpose of a safeguard is to reliably protect a worker from danger. Where safeguarding is applied, risk reduction is achieved in part by the reliability of the devices used in conjunction with the performance level of the circuit they are integrated to.

1.2 Objectives of this model

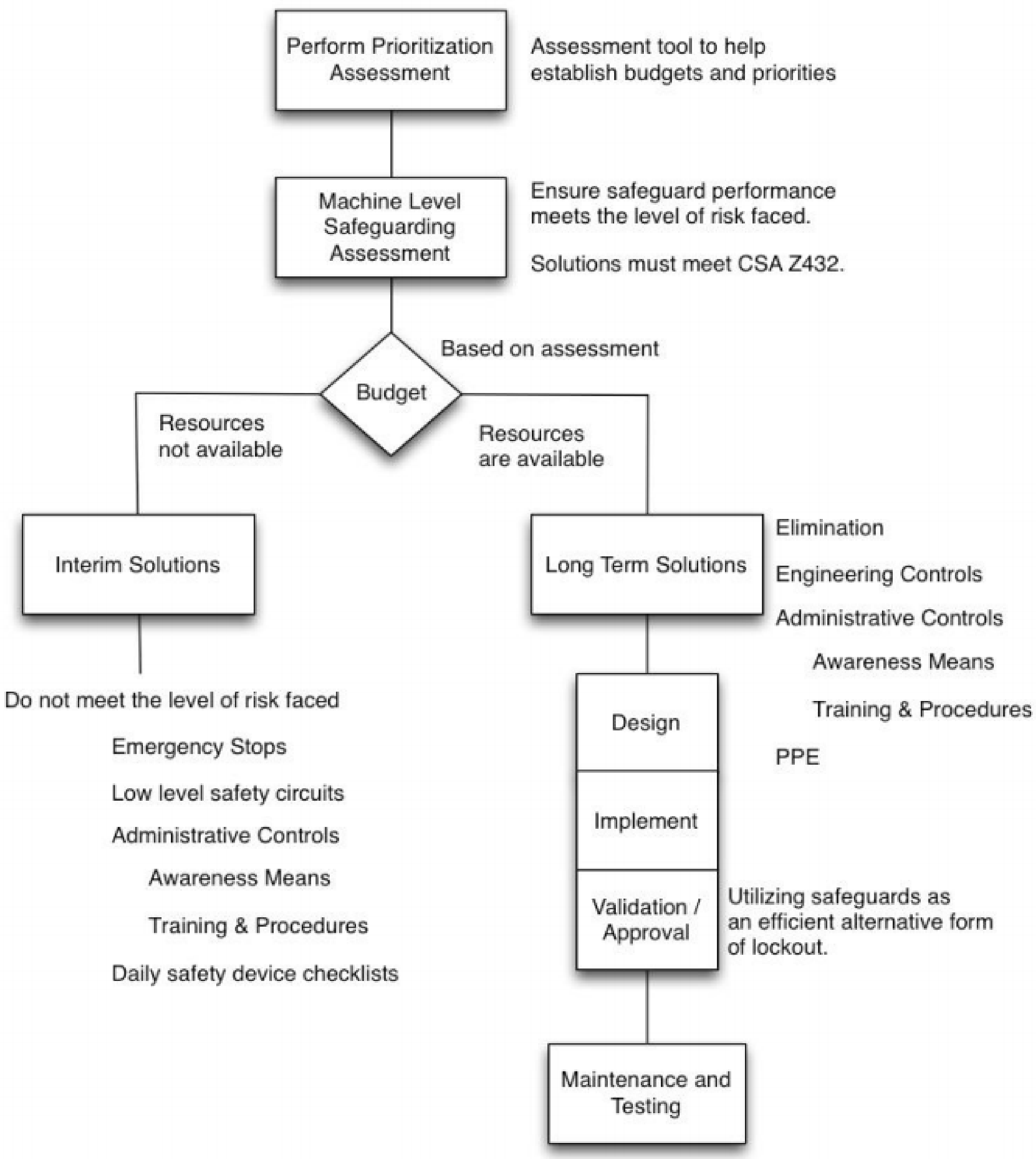
This program model is intended to aid the employer in applying safeguarding techniques and ensuring that reliable design is inherent in the safeguarding applied. The tools discussed as follows;

- Assessment
- Prioritization
- Resources
- Interim Solutions
- Long Term Solutions
- Safeguarding System Design Basics
- Validation and Approval
- Monitoring and Maintenance

Only qualified people should be using this assessment model. If you are unsure of the types of qualifications that you should have, contact Manufacturing Safety Alliance of BC. Model one plus the technical training paired with the first model should be taken prior to attempting to use this model. Refer to model one for basic information.

2.1 Safeguarding Project

There are basic steps to any engineering project, safeguarding is no different. Below is a flow chart of the essential components.



2.2 Complete Safeguarding Assessment

This model is taken from CSA Z434-03 (robotic safeguarding standard). It expands upon the CSA Z432-04 method by adding a validation step to ensure that the safeguarding plan will reduce the risk index to a tolerable level. Other models exist such as the model presented in ISO-13849. While this is current and an excellent model, there are too many steps from our legislated minimum to cover in these models. If you follow this model as presented, you are close to the current international standards model and beyond the minimum requirements of WorkSafeBC.

2.2.1 Assessment

Prioritization and machine level assessment should be performed in the reverse order to what is shown in the flow chart. Ideally, perform detailed machine guarding assessments on all of your equipment and gather budget information while applying interim measures. If your organization has a small number of machines, this will be your best approach.

An assessment is at least a three-day process that involves a team. If you are a medium to large size manufacturer the assessment process may require budgeting, planning and scheduling. There are two prioritization models shown in the 1st model that may be appropriate to help you start down the path. Your highest ranked items in the matrix should be the areas where detailed assessment is prioritized. This is not a complete safeguarding assessment and will leave you with residual liabilities. You must understand that the correct way to assess you equipment is the complete assessment method.

2.2.2 Dimension Model

The first step is to review every task performed on the machine one task at a time. For that task, multiple hazards could be noted. Each task/hazard combination will then be assigned one of the three dimensions being severity, frequency of exposure, and likelihood of avoidance levels as detailed in Table 1 from CSA Z434-03.

It is important to note that the initial risk level estimation is performed with no safeguards being considered, even if they exist. This will give us a 'raw' risk level of the task/hazard combination.

Table 1: Hazard Severity / Exposure / Avoidance Categories
(See clauses 9.4, 9.5, 9.7, and C.3.)

Table 1
Hazard Severity/Exposure/Avoidance Categories
(See Clauses 9.4, 9.5, 9.7, and C.3.)

Factor	Category		Criteria
Severity	S2	Serious injury	Normally irreversible, or fatality, or requires more than first aid
	S1	Slight injury	Normally reversible or requires only first aid
Exposure	E2	Frequent exposure	Typically exposure to the hazard more than once per hour (see notes below)
	E1	Infrequent exposure	Typically exposure to the hazard less than once per day or shift (see notes below)
Avoidance	A2	Not likely	Cannot move out of way, or inadequate reaction time, or robot speed greater than 250 mm/s
	A1	Likely	Can move out of way, or sufficient warning/reaction time, or robot speed less than 250 mm/s

Notes:

1) *Exposure can be affected by either a change in the frequency with which the task is performed or by the application of an index R2 risk reduction safeguard or application of lockout to control the hazard by removal of the energy source that reduces exposure to the hazard.*

2) *Determining frequency of access can require judgment decisions by the person(s) performing the risk assessment.*

3) *Access can range from cyclical production to maintenance tasks associated with periodic maintenance.*

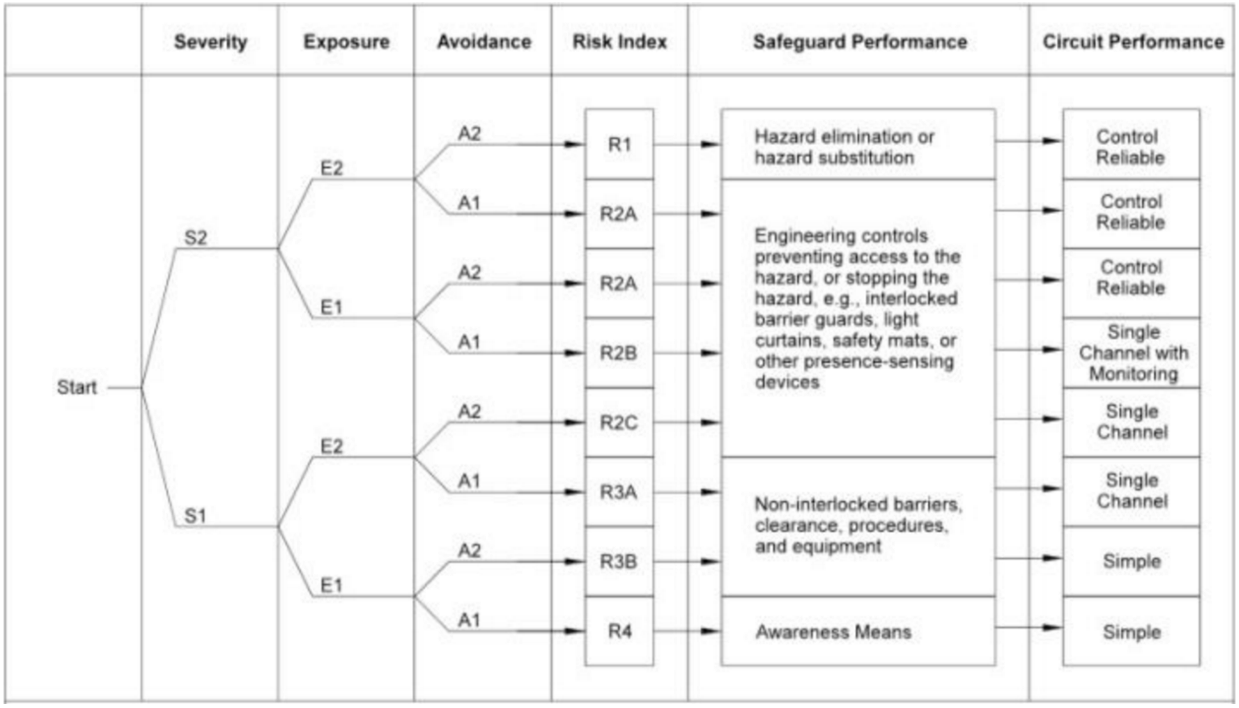
4) *When determining proper safeguards, it should be noted that serious injuries have resulted from infrequent tasks.*

5) *A hazard may be considered as avoidable if the following conditions are met simultaneously:*
- *a) the nature of the hazard and its propagation speed are such that the hazard can be detected and avoided in time by a person, based on ergonomic characteristics (for instance, speed of less than 250 mm/s (10 in/s) for a moving part toward the exposed person);*
- *b) clearance distance is large enough, e.g., 0.5 m (20 in) or more; and*
- *c) the exposed person has been trained to identify the hazard.*

6) *Avoidance can be affected by*
- *a) reducing the speed of the hazard to give sufficient warning/reaction time;*
- *b) the application of an index R2 risk reduction safeguard; or*
- *c) installation of awareness devices.*

2.2.3 Risk Level

The risk level of each task hazard combination is initially computed from the following matrix with no safeguards being considered.



Taken from CSA Z434-2003 Revised by MSABC

Factor	Category	Criteria	
Severity	S2 - Serious Injury	Normally irreversible, or fatality, or requires more than first aid	
	S1 - Slight Injury	Normally reversible or requires only first aid	
Exposure	E2 - Frequent Exposure	Typically exposure to the hazard more than once per hour	
	E1 - Infrequent Exposure	Typically exposure to the hazard less than once per day or shift	
Avoidance	A2 - Not Likely Avoidance	Cannot move out of way, or inadequate reaction time, or machine speed greater than 250 mm/s	
	A1 - Likely Avoidance	Can move out of way, or sufficient warning / reaction time, or machine speed less than 250 mm/s	Taken From: CSA Z432-04 CSA Z434-03 Revised By: UBSafe Inc

Index	Safeguard Performance	Safety Control Performance
R1	Hazard Elimination or Hazard Substitution	Control Reliable
R2A	Engineering controls preventing access to the hazard, or stopping the hazard, e.g. interlocked barrier guards, light curtains, safety mats or other presence-sensing devices	Control Reliable
R2B		Single Channel with monitoring
R2C		Single Channel
R3A	Non-interlocked barriers, clearance, procedures and equipment	Single Channel
R3B	Administration Controls (Awareness Means, Training & Procedures)	Simple
R4		Simple

Taken from Z434-2003 Revised by MSABC

The safeguard selection matrix, applied horizontally, will show you the type of control that must be used and the level of circuit performance to be applied. The circuit performance level is the structure of the safeguarding circuit applied to all energy types.

The integrity of the devices used, generally speaking, must be rated to meet the EU Category shown. In the last two years the EU categories are less prevalent with most manufacturers switching to the ISO 13849-1 classification system of Performance Level. Converting from EN Category system to ISO PL system is a bit complicated. The way the circuit is structured in combination with the reliability of the devices used can affect the final PL level rating of the circuit. Roughly speaking, the following conversion applies:

PLa/b = Cat B
PLc = Cat 1 / 2
PLd = Cat 2 / 3
PLe = Cat 3 / 4

Knowledgeable individuals in applying the safeguarding techniques must perform design of the circuits. When you purchase safeguarding devices, the manufacturers will provide you with example circuits and their ratings. These are simplified circuits and a great place to start with respect to basic safeguarding circuit design.

2.2.4 Safeguard Selection Matrix

When selecting safeguards, you must consider elimination first from the hierarchy of safeguarding controls. The risk index level established in the second step will point you to the minimum effective control to meet the level of risk faced (thereby meeting the requirements of the standard).(See Clause 5.2.3.)

Most effective	1. Elimination or substitution	• eliminate human interaction in the process • eliminate pinch points (increase clearance) • automated material handling
↓	2. Engineering controls (safeguarding technology)	• mechanical hard stops • barriers • interlocks • presence-sensing devices • two-hand controls
↓	3. Administration controls (Training, safe operating procedures Visual warnings, and audio warnings)	• lights, beacons, and strobes • computer warnings • horns • signs • restricted space painted on floor • beepers • labels • safe job procedures • safety equipment inspections • training • lockout
Least effective	4. Personal protective equipment	• safety glasses • ear plugs • face shields • gloves

2.2.5 Validated Solution

Once the safeguarding solution has been considered through discussion with the assessment team, the solution needs to be considered in a validation matrix to ensure that the residual risk level is tolerable once the solution has been installed.

In the chart on the next page, emphasis is placed upon Frequency of Exposure to the hazard and Likelihood of Avoidance of the hazard. These are the dimensions that safeguarding solutions can affect. Severity of the hazard never changes unless the hazard is completely eliminated (change in process).

Table 2
Safeguarding selection matrix
(See Clause 5.6.1.)

Severity of Injury	Exposure	Avoidance	Safeguard Performance.*	Circuit Performance	European Category
Serious	Frequent	Not Likely	Hazard elimination or hazard substitution.	Control Reliable	Category 3 and 4
		Likely		Control Reliable	Category 3 and 4
	Infrequent	Not likely	Engineering controls preventing access to the hazard, or stopping the hazard, e.g., fixed guards, interlocked barrier guards, light curtains, safety mats, or other presence sensing devices.	Control Reliable	Category 3 and 4
		Likely		Single channel with monitoring	Category 2
Slight	Frequent	Not likely		Single channel	Category 1
		Likely	Non-interlocked barriers, clearance, procedures, and equipment.	Single channel	Category 1
	Infrequent	Not likely		Simple	Category B
		Likely	Administrative controls.	Simple	Category B

** All safeguarding methods should be considered at all risk levels, starting with "hazard elimination or hazard substitution".*

***Note:** There is no intent to imply that circuit performance classifications are equivalent to ISO 13849-1 machinery categories. See Table A.2 for example descriptions of risk factor categories.*

Rules must be followed in applying reductions to Exposure and Avoidance based on the safeguarding solution as follows:

Reducing frequency of Exposure:

1. Application of Lockout
   (used singularly this is only applicable to R3A/B or R4 hazards)
2. Reduce the frequency of performing the task to meet the definition of E1.
3. Application of an R2 risk reduction safeguard
   (at the level of risk faced - i.e. R2A safeguard for an R2A risk).

Reducing likelihood of Avoidance:

1. Reduce the speed (<250mm/sec) and increase the distance (>20 inches) and ensure employees are trained to recognize the hazard.
2. Application of an R2 risk reduction safeguard
   (at the level of risk faced-i.e. R2A safeguard for an R2A risk).
3. Installation of awareness devices (used singularly this is only applicable to R4 hazards).

2.2.6 Validation Method (After Safeguards / Modifications)

Exposure	Avoidance	Severity of injury	Risk Index
E2 Frequent exposure	**A2** Not likely	**S2** Serious injury	**R1**
		S1 Slight injury	**R2C**
	A1 Likely	**S2** Serious injury	**R2A**
		S1 Slight injury	**R3A**
E1 Infrequent exposure	**A2** Not likely	**S2** Serious injury	**R2A**
		S1 Slight injury	**R3B**
	A1 Likely	**S2** Serious injury	**R3A**
		S1 Slight injury	**R4**

* Target Risk index after modifications / installation of safeguards is R3 or R4

Taken From CSA Z434-2003

Continue to apply safeguarding solutions until the residual risk index is at an R3 or R4 level.

Once a safeguarding solution is selected, be sure to include what is applicable below it in the hierarchy of safeguarding controls as well. For example, though a control reliable engineered solution is planned for an R2A risk level task/hazard combination, one must also update procedures, install awareness means and train employees in the use of the new safeguard.

2.2.7 Risk Assessment Process Flowchart

The process just described follows this flowchart;

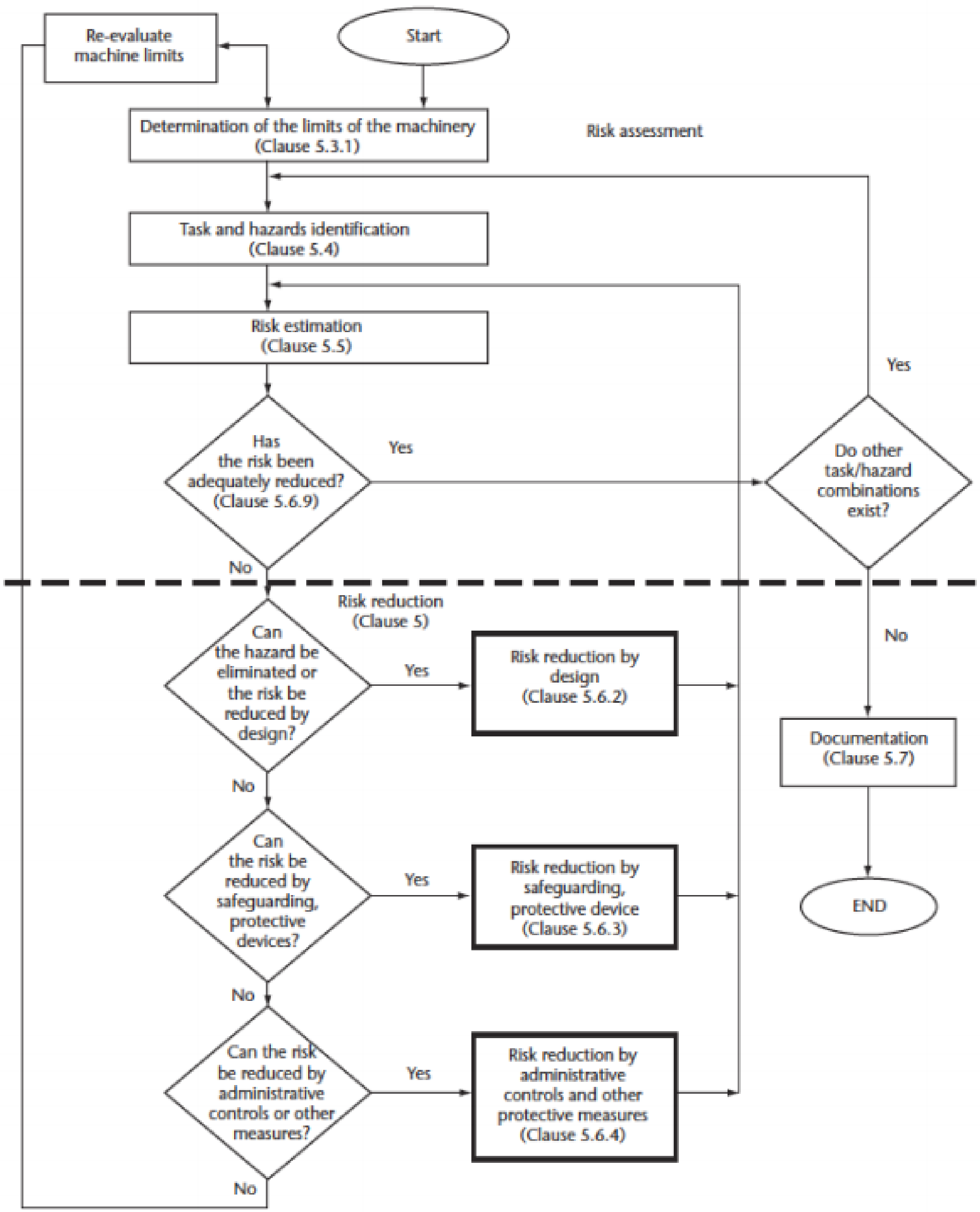


Figure 2: Schematic Representation of the risk Assessment / reduction Process Model (See Clause 5.6.1.)

2.2.8 Interim Controls and Understanding Safeguarding and Lockout

In many situations you will need to budget, plan and engineer your safeguarding solutions, which takes time. In the meantime, now that you recognize the hazards faced, apply interim controls and list them in your safeguarding report.

Examples of interim controls are:

- Use of lockout
- Updated procedures
- Daily safety device test check sheets
- Additional emergency stop devices
- Signage and awareness devices

Recognize that it is likely that none of these interim controls meet the level of risk faced and therefore the risk index level remains the same (assuming the risk index is higher than R3 or R4). You have not met the standard or regulatory requirements. The sole purpose of interim solutions is to try to avoid injuries or accidents while the long term safeguarding solution is being designed and implemented.

You must be very careful in how safeguards are being utilized and for what tasks. To use your safeguards as an alternate form of lockout for maintenance activities (such as setup and clearing jams) you must obtain an approval from WorkSafeBC.

The specifics of this approval are contained in guideline 10.10. It is recommended to obtain a third party validation report for the approval process. In guideline 10.10 you'll find that the performance level of the safeguarding system is measured against CSA Z432-2004 or ISO 13849. These are current safeguarding standards – so while CSA Z432-94 is the legislated minimum, any interlocking circuits will be measured against the current standard revision.

Maintenance activities still require lockout, as do production activities where effective safeguarding is not in place. Be sure that you understand the difference.

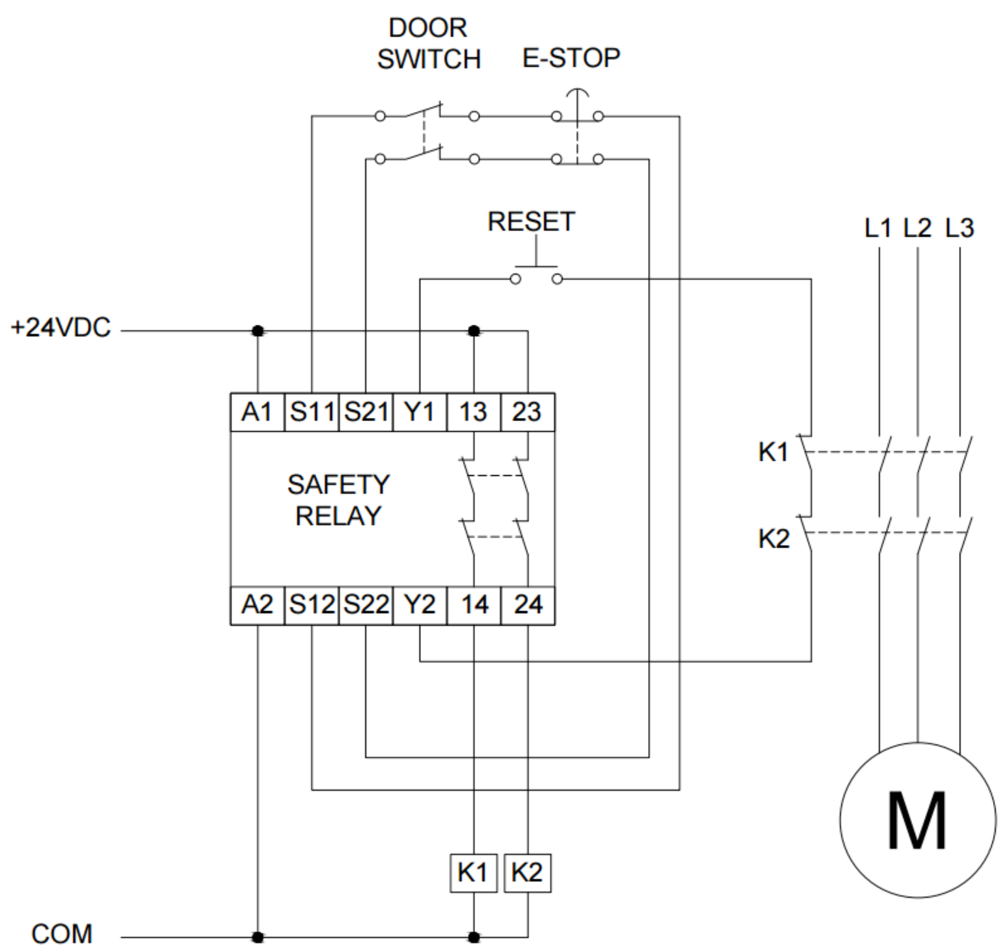
2.3 Safeguarding System Design Basic

Most of the risk levels that you will have assessed will be at the R1 or R2 level. Elimination must always be considered, particularly with an R1 level risk index. If you cannot eliminate an R1 level risk, document why you cannot and then apply an R2A solution.

All energy sources must be considered in your safeguarding solutions. This encompasses a wide variety of situations and technical systems. Some of the more frequently encountered scenarios are as follows;

2.3.1 Electrical control reliable circuit

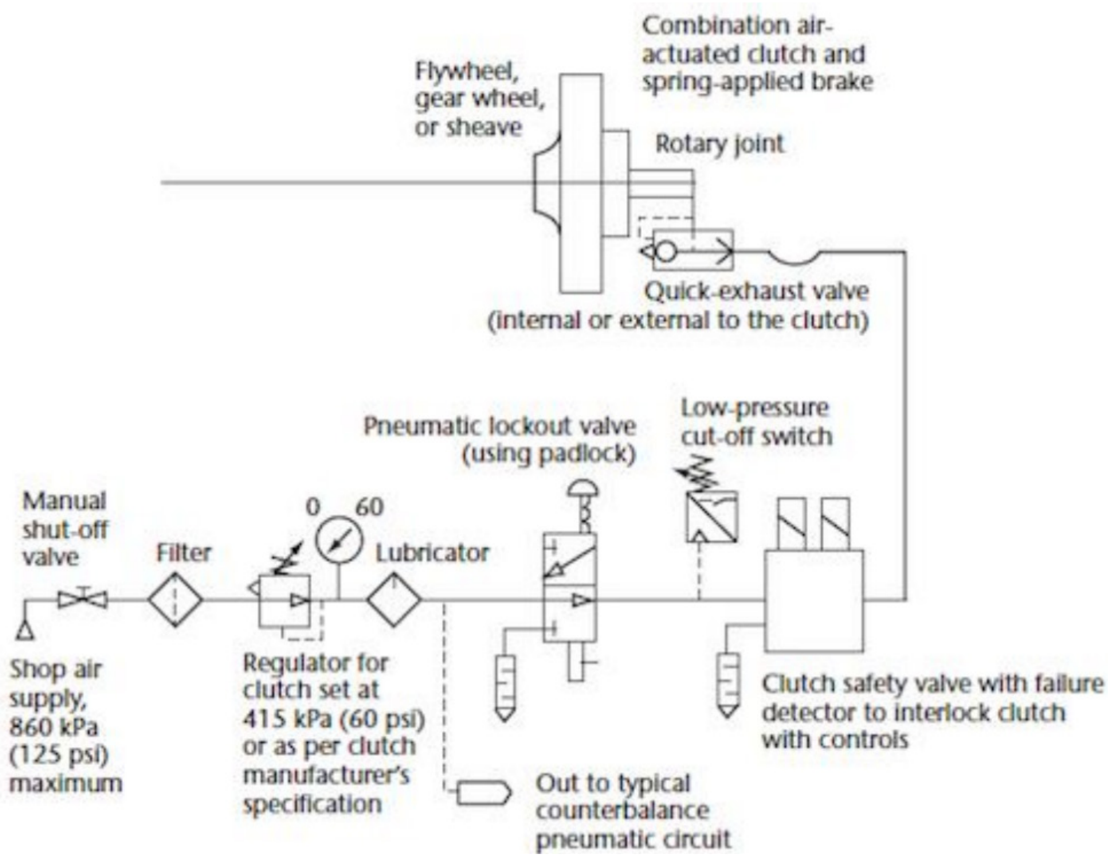
Control reliable Circuit Example



The above schematic is for demonstrative purposes only and may not be complete or accurate in details. Always refer to manufacture's literature before wiring devices.

2.3.2 Example of a pneumatic clutch / break unit

Figure 2 Pneumatic System: Combination Clutch / Break Unit



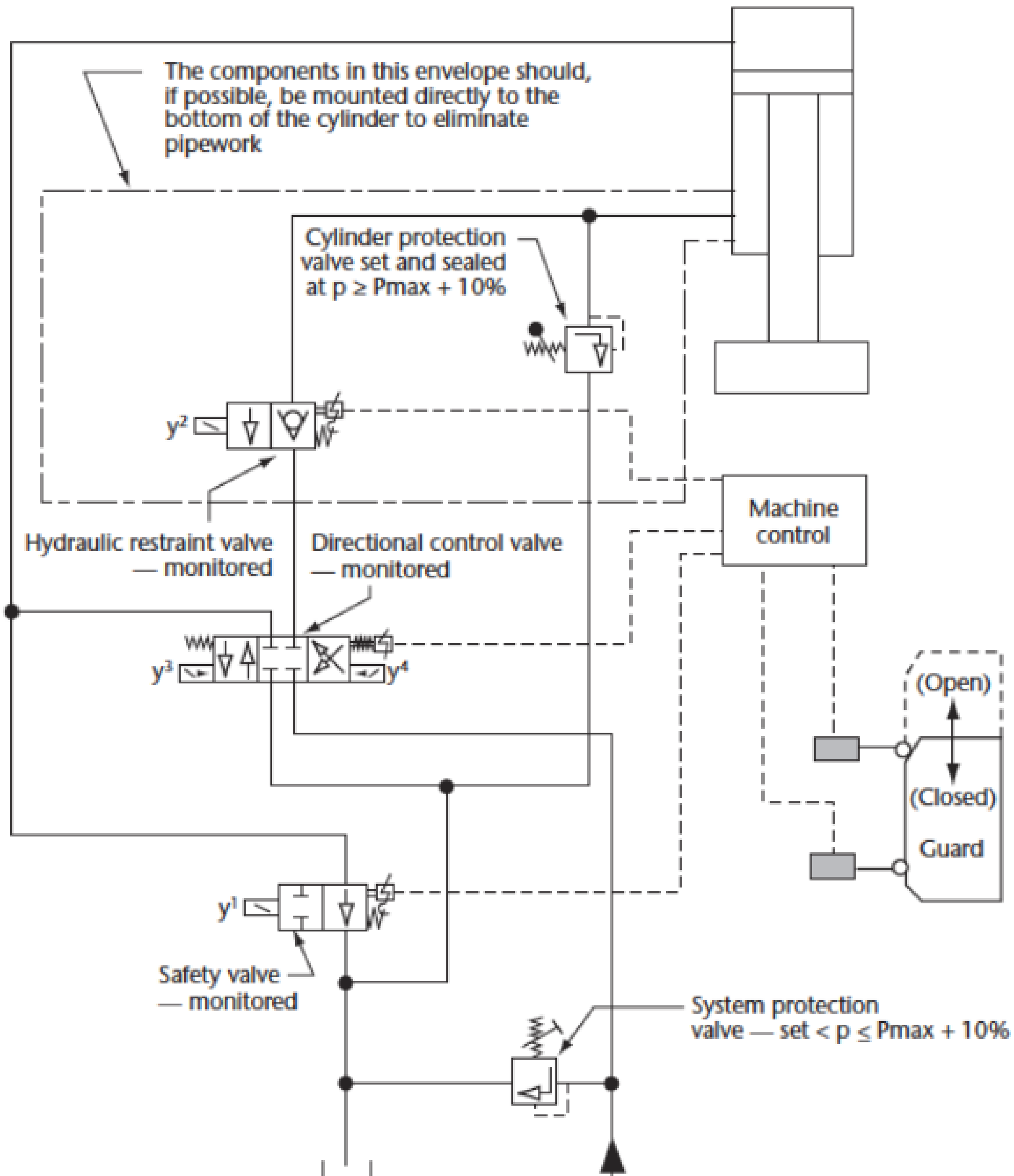
Taken from CSA Z142-10

Notes:

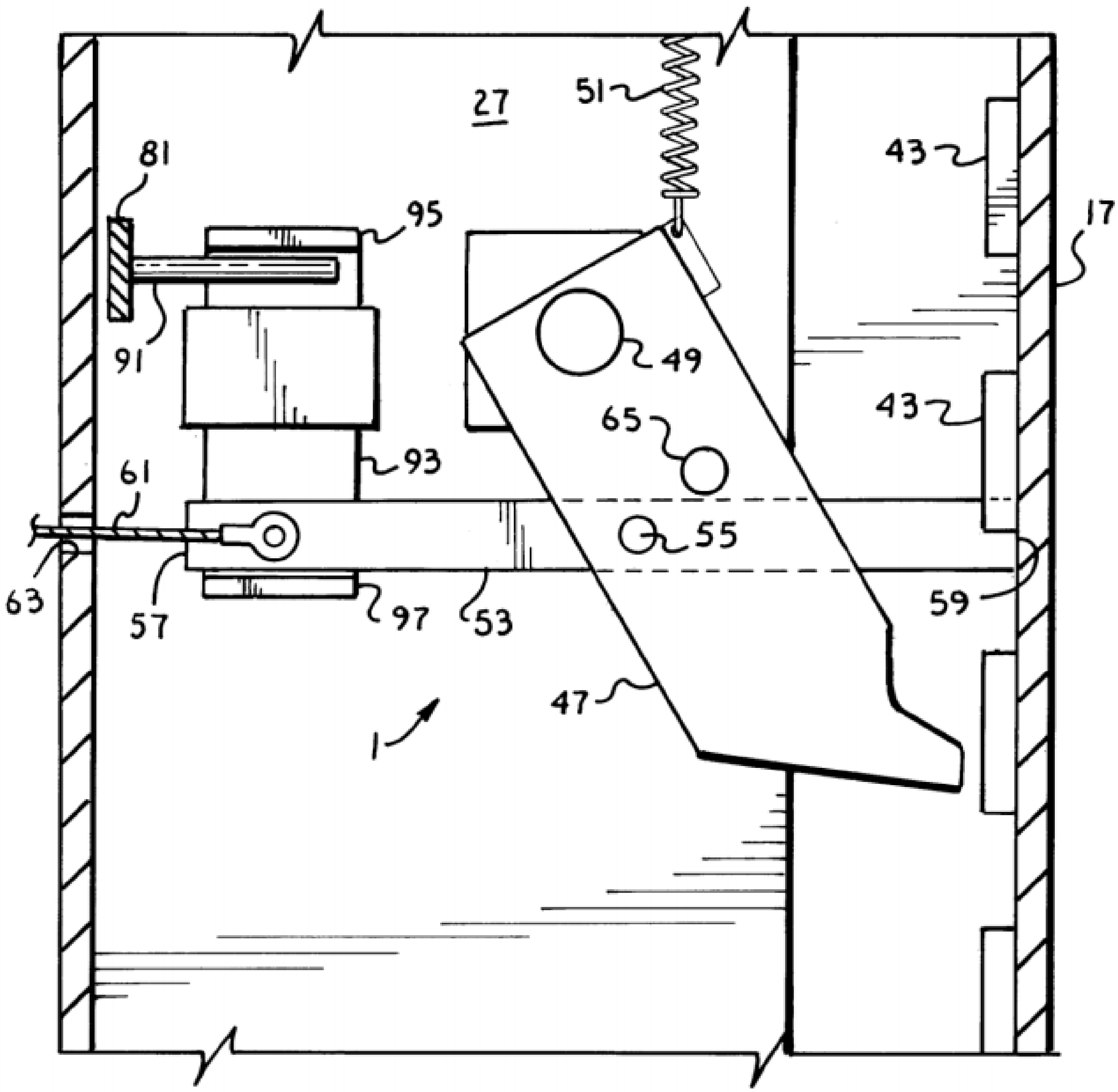
(1) *The lines shall not be over-lubricated.*
(2) *Pipes and hoses shall be sized to not restrict flow.*
(3) *Press safety valves shall be installed on the combination clutch/brake.*
(4) *Regulators should be protected but accessible to the operator, and need not be side by side.*
(5) *The low-pressure cut-off switch may be remote from the operator.*
(6) *The pneumatic lockout valve shall be accessible to the operator.*
(7) *Press safety valves shall be mounted and installed in accordance with the manufacturer's instructions.*
(8) *Flexible hoses shall be the only link after the solenoid valves and should not be flexed acutely.*
(9) *Regulators shall be adjusted for smooth operation, with minimum slippage.*
(10) *The layout of the flywheel brake circuit is intended only as a guideline. The installation methods and designs of flywheel brake devices can vary.*
(11) *Pneumatic lines from valves to brakes shall be as short as possible and minimize the use of elbows.*
(12) *Quick-exhaust valving may be used to increase brake performance and where the press safety valve cannot be installed nearby.*

2.3.3 Example of a Control Reliable Circuit for a Downstroking Hydraulic Press

Figure 6 Example of a Redundant and Monitored Control Circuit for a Downstroking Hydraulic Press (see clause 7.3.1.and 7.3.2.12)



2.3.4 Gravity Hazards



Solutions when facing gravity hazards should be considered in the following order:

1. Ratchet and catch system as used in an automotive lift. There are two catch systems employed in the auto lift for redundancy.

2. Assuming the automotive lift example above is hydraulic, a monitored check valve could be incorporated into the lift's lower cylinder. The check valve blocks the flow out of the cylinder arresting any motion. The pilot circuit of the check valve is either tied to the pressure line (top port) or controlled electrically from the safety controller (preferred). Used singularly this option leaves residual hazards from mechanical failure of the rod coupling, the packing of the cylinder, etc.

3. Rod locks can also be incorporated into hydraulic and pneumatic cylinders in much the same method as described above.

4. The final option is to only control the pilot signal of the actuator by the control reliable circuit. Sometimes this must be done (particularly in pneumatics) to avoid synchronizing issues from drifting of machine actuators. This results in residual energy that must be identified and the operator trained to recognize this. This is not effective or acceptable if the persons entering the area will be directly exposed to a gravity hazard under the machine part. Residual hazards exist in this scenario so you must be cautious where and how this solution is applied. You must provide a blocking device (preferably monitored by the safety circuit) for employees to mechanically restrain the gravity hazard if they require access to the hazard area.

2.4 Barrier Guards

Ensure that your guards meet the A.U.T.O. concept, meaning that one cannot reach around, under, through, or over a guard to a hazardous point of operation.

There are two types of effective barrier guards:

1. Fixed guards
2. Interlocked guards

If you do not require normal operational access to the area, apply fixed guards that are securely fastened requiring tools to remove (this is a key point). Where routine access is required, apply interlocked movable guards connected to the correct performance level safeguarding circuit.

In either case, the mechanical characteristics must be in accordance with the following tables to meet the requirements of CSA Z432-94.

2.4.1 Minimum distance from hazard

Table 3 is applied in deciding upon mesh opening sizes of barrier guards or general openings around guarding.

Table 3 and Figure 5 show the distance that guards shall be positioned form the nearest point-of-operation hazard. The various opening are such that for average-sized hands, an operator's fingers will not reach the point of operation. After installation of point-of-operation guards, and before a job is released for operation, a check should be made to verify that the guard will prevent the operator's hands, or other body parts, from reaching the point of operation.

Figure 5: Graphic Illustration of Table 3 (See Clause 10.11.)

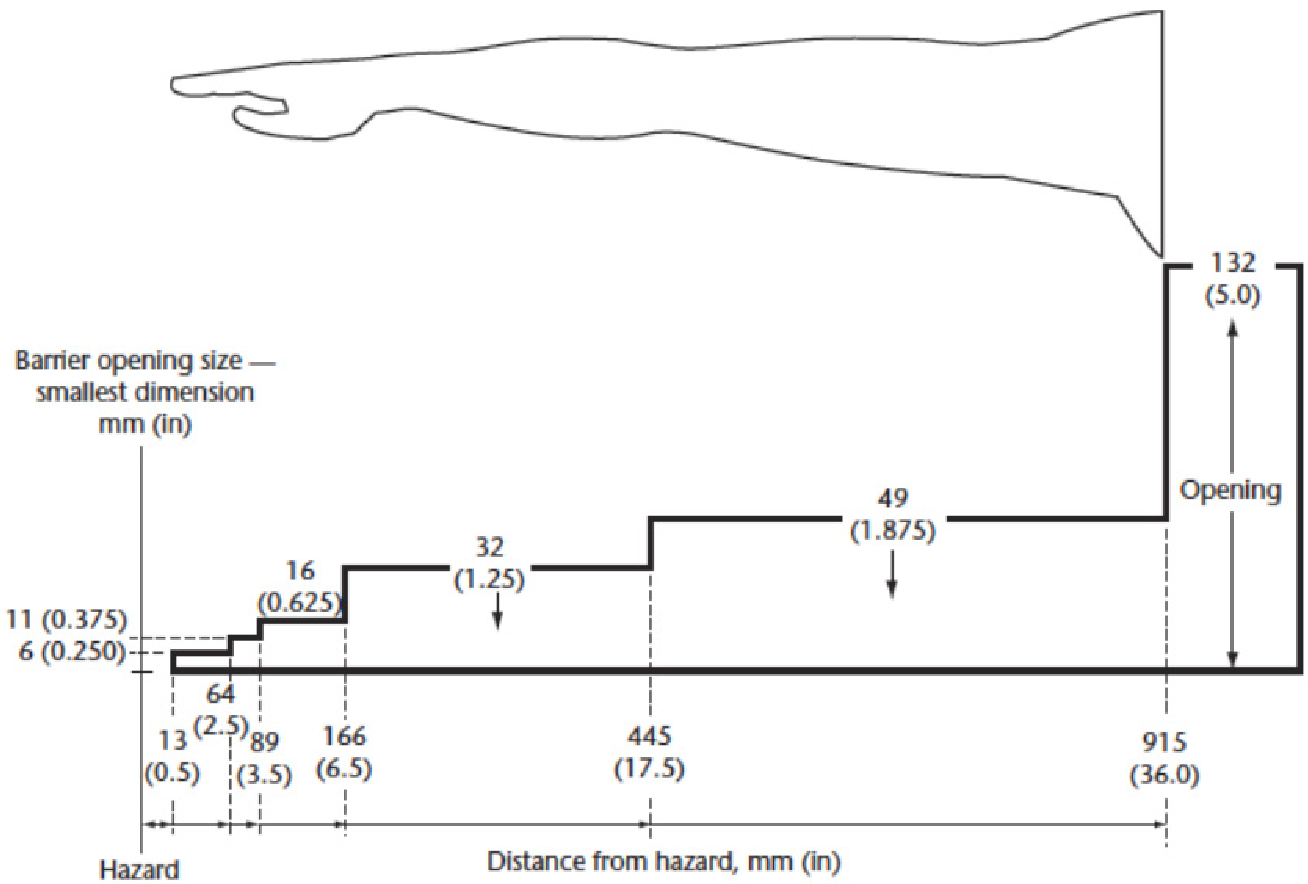
Table 3: Minimum Distance from Hazard as a Function of Barrier Opening Size
(See clauses 6.2.2.2, 6.2.3.1.2, 10.2.1, 10.2.3, 10.7, 10.9, 10.12, and 13.1.1 and Figure 5)

Barrier opening size (smallest dimension)		Minimum distance from hazard	
mm	**in**	**Slotted opening**	**Square opening**
0.0– 6.0	0.000–0.250	≥13.0 mm† 0.5 in	≥ 13.0 mm† 0.5 in
6.1– 11.0	0.251–0.375	≥64.0 mm 2.5 in	≥ 48 mm 1.9 in
11.1– 16.0	0.376–0.625	≥89.0 mm 3.5 in	≥ 66 mm 2.6 in
16.1– 32.0	0.626–1.250	≥166.0 mm 6.5 in	≥166.0 mm 6.5 in
32.1– 49.0	1.251–1.875	≥445.0 mm 17.5 in	≥ 445.0 mm 17.5 in
49.1–132.0‡	1.876–5.000‡	≥915.0 mm 36.0 in	≥ 915.0 mm 36.0 in

* *Based on data presented in Donald R. Vaillancourt and Stover H. Snook, "A Review of Machine-Guarding Recommendations,"* Applied Ergonomics, *Vol. 26, No. 22, pp. 141–145, The Liberty Mutual Research Center for Safety and Health; and Standard Drawing 2063-2, ©1998 Liberty Mutual Group. Used with permission.*
† *Barriers shall not be located less than* 13.0 mm *(0.5 in) from the hazard.*
‡ *Barrier openings shall not be greater than* 132.0 mm *(5.0 in) unless a risk assessment is performed.*
Note: *These criteria are for new installations only.*

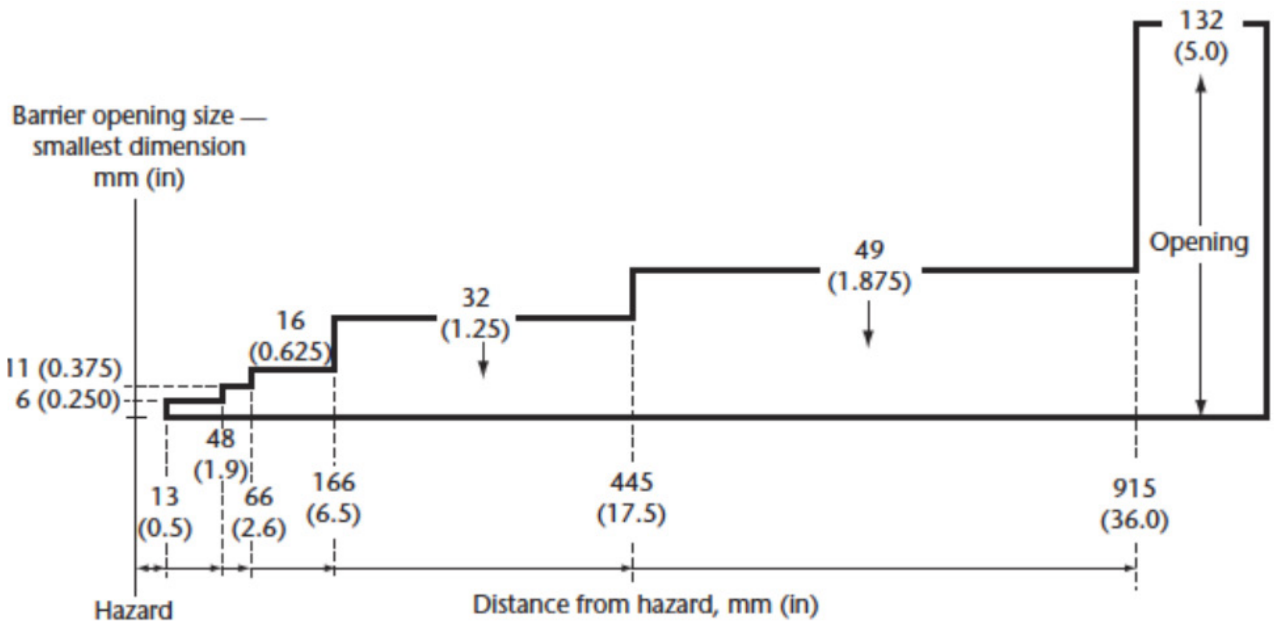
Taken from CSA Z432-04

Slotted Opening



Taken from CSA Z432-04

Square Opening



Taken from CSA Z432-04

2.4.2 Table C.1 (low risk values) and C.2 (high risk values)

Table C.1 of CSA Z432-04 is the same as table A1 presented in CSA Z432-94. There is also a table C.2 in Z432-04 that is used for high-risk hazards (i.e. R2 and R1 level hazards). We recommend that you follow table C.2, but the legislated minimum requirement is table C.1.

Table C.1: Low Risk values of a, b, and c, for Figure C.2
(See Clause C.2 and Figure C.2)

Height of danger zone*	Height of fixed barrier or protective structure†								
	1000	1120	1400	1600	1800	2000	2200	2400	2500
	Horizontal distance to danger zone								
2500	—	—	—	—	—	—	—	—	—
2400	100	100	100	100	100	100	100	100	—
2200	600	600	500	500	400	350	250	—	—
2000	1100	900	700	600	500	350	—	—	—
1800	1100	1000	900	900	600	—	—	—	—
1600	1300	1000	900	900	500	—	—	—	—
1400	1300	1000	900	800	100	—	—	—	—
1200	1400	1000	900	500	—	—	—	—	—
1000	1400	1000	900	300	—	—	—	—	—
800	1300	900	600	—	—	—	—	—	—
600	1200	500	—	—	—	—	—	—	—
400	1200	300	—	—	—	—	—	—	—
200	1100	200	—	—	—	—	—	—	—
0	1100	200	—	—	—	—	—	—	—

* *Protective structures less than* 1000 mm *in height are not included because they do not sufficiently restrict movement of the body.*
† *For danger zones above* 2500 mm, *see Clause C.1.*
Note: *Dimensions are in millimetres.*

Table C.2: High Risk values of a, b, and c for Figure C.2
(See clause C.2.2 and Figure C.2)

Height of danger zone*	Height of protective structure†									
	1000	1200	1400	1600	1800	2000	2200	2400	2500	2700
	Horizontal distance to danger zone‡									
2700	—	—	—	—	—	—	—	—	—	—
2600	900	800	700	600	600	500	400	300	100	—
2400	1100	1000	900	800	700	600	400	300	100	—
2200	1300	1200	1000	900	800	600	400	300	—	—
2000	1400	1300	1100	900	800	600	400	—	—	—
1800	1500	1400	1100	900	800	600	—	—	—	—
1600	1500	1400	1100	900	800	500	—	—	—	—
1400	1500	1400	1100	900	800	—	—	—	—	—
1200	1500	1400	1100	900	700	—	—	—	—	—
1000	1500	1400	1000	800	—	—	—	—	—	—
800	1500	1300	900	600	—	—	—	—	—	—
600	1400	1300	800	—	—	—	—	—	—	—
400	1400	1200	400	—	—	—	—	—	—	—
200	1200	900	—	—	—	—	—	—	—	—
0	1100	500	—	—	—	—	—	—	—	—

* *Protective structures less than* 1000 mm *in height are not included because they do not sufficiently restrict movement of the body.*
† *For danger zones above* 2500 mm, *see Clause C.1.*
‡ *Protective structures lower than* 1400 mm *should not be used without additional safety measures.*
Note: *Dimensions are in millimetres.*

Taken from CSA Z432-04

manufacturing
Safety Alliance of BC

About us

The Manufacturing Safety Alliance of BC, formerly known as FIOSA-MIOSA Safety Alliance of BC, was established in December 2007 to reduce the high injury rate in the food and manufacturing industries.

Our mission

We are catalysts for improving workplace health and safety within the BC Manufacturing Industry. Our leading edge health and safety programs, services and tools enable companies to make a difference in the lives of their employees – every day.

Our vision

Partnering with BC's industry leaders to achieve cultural change that ensures safe workplaces for all employees. The Manufacturing Safety Alliance of BC strives to accomplish our mission and vision through the delivery of a variety of core services including:

- Training in areas such as occupational health and safety (OHS) leadership, program building, and auditing.
- Consultation and advisory services.
- The certifying partner for the Occupational Safety Standard of Excellence (OSSE) in partnership with WorkSafeBC.

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