MINISTRY OF BUSINESS,
INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

ERGONOMICS OF MACHINE GUARDING GUIDE

DOL 12198 3 MAY 13

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Ministry of Business, Innovation and Employment (MBIE)

Hikina Whakatutuki Lifting to make successful

MBIE develops and delivers policy, services, advice and regulation to support economic growth and the prosperity and wellbeing of New Zealanders.

MBIE combines the former Ministries of Economic Development, Science + Innovation, and the Departments of Labour, and Building and Housing.

More information

www.mbie.govt.nz

0800 20 90 20

Information, examples and answers to your questions about the topics covered here can be found on our website www.mbie.govt.nz or by calling us free on 0800 20 90 20.

Disclaimer

This document is a guide only. It should not be used as a substitute for legislation or legal advice. The Ministry of Business, Innovation and Employment is not responsible for the results of any actions taken on the basis of information in this document, or for any errors or omissions.

ISBN 978-0-478-41349-6 (print)
ISBN 978-0-478-41348-9 (online)

June 2013

CONTENTS

→ INTRODUCTION

Machinery safety remains a critical issue with many serious harm injuries each year occurring due to inadequate guarding of machines.

All machinery needs to be adequately guarded at all times and machinery and guarding must be maintained in a safe working condition.

Duty holders must take all practicable steps to ensure the safety of workers when using machinery.

The Health and Safety in Employment Act 1992 (the HSE Act) sets out the performance required by duty holders such as employers, employees, designers, manufacturers, suppliers and hirers of machinery.

The Australian Standard AS4024 (2006) *Safety of Machinery* represents current state of knowledge in relation to the safeguarding of equipment and should be referred to by duty holders as the primary standard against which to benchmark. Employers, suppliers, manufacturers and designers remain free to work to other standards but will need to demonstrate that they are capable of achieving an equivalent level of safety in the circumstances in which they are used.

→ ERGONOMICS AND MACHINE GUARDING

A critical aspect of machine guarding is to ensure workers cannot reach past the guarding into the machine. The way a worker uses and interacts with a machine (ergonomic principles) needs to be considered when deciding how to best guard a machine.

Typical ergonomic principles include:

- the nature of postures and movements
- the ease of physical operation
- the effects of noise or temperature

- the lighting environment
- the clarity and location of manual controls
- the design of dials, markings and displays.

All these aspects need to be considered along with the tasks being performed and the capacity of the people performing this work.

An important application of ergonomics is the use of data from studying human body measurements (anthropometric studies) in machinery design. This type of information helps when making decisions about the dimensions of access openings for:

- maintenance and repairs
- the space requirements for operators
- the safety distances and gaps to prevent contact of parts of the body with danger zones
- out of the ordinary events, such as a breakdown or product blockage.

→ CHOOSING GUARDING

The distance an operator can reach decides the minimum height of certain kinds of guards, or the minimum distance of barriers from the machines they are intended to guard. These minimum distances were developed based on data about the average human measurements.

It is important to make sure the guard can actually prevent an operator from reaching into the dangerous parts of machinery. To make sure the operators are protected from the dangerous parts, the safest guarding for a machine must take into account an operator's ability to in any way reach into the dangerous area.

A person's reach is limited by the length of their arms and, in the case of openings, by the length of their fingers and hands. Less often, dangerous parts may be reached by an operator's lower limbs.

Machine guarding can become useless if an operator can reach past it. The general way this occurs is when an operator can reach:

- upwards
- over a guard
- into the machine
- around or along a guard.

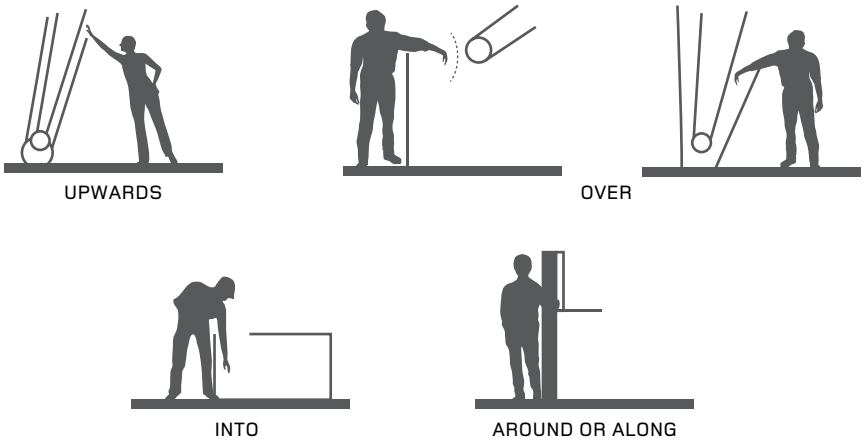


Figure 1: Various types of reach in relation to the guarding of machinery.

→ REACHING UPWARDS

Any hazard assessment for machine guarding should take into account how workers could access the machinery. The operator may be able to raise themselves above floor level and access machinery that is normally out of reach. Workers could access the machine by standing on ladders, furniture or parts of machines. By doing this they may be able to reach into the dangerous areas.

→ REACHING OVER BARRIERS

The height of a barrier or guard needs to limit an operator being able to reach over into the danger zone. Where the barrier is low, the worker can bend over and increase their reach longer than their arm.

Where the barrier is at armpit height, reach is equal to the length of the arm. If the barrier is above shoulder height, interruption is at the elbow, or when higher still, at the wrist or fingers.

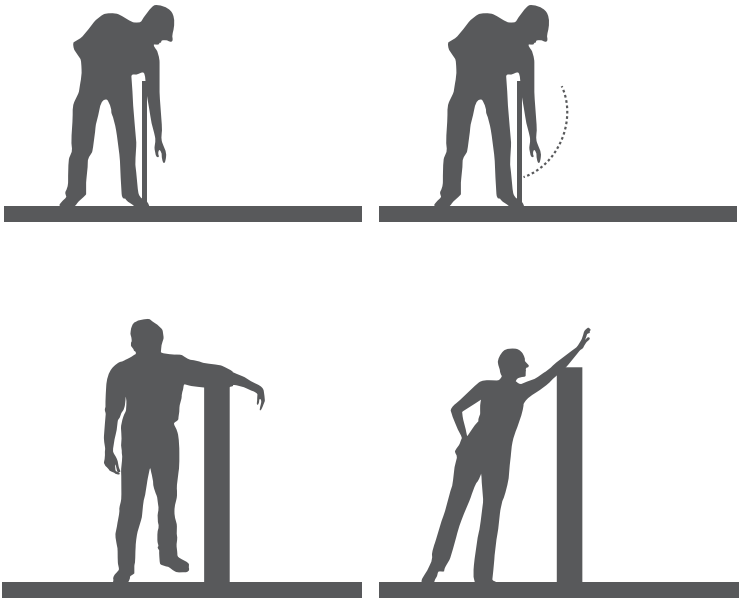


Figure 2: The height of guarding can change reach lengths.

→ REASONABLE REACH VALUES – MINIMUM RECOMMENDED HEIGHTS AND DISTANCES FOR GUARDING

Table 1 shows the reasonable reach values (RRVs) that are the minimum recommended heights and distances for guarding. RRV calculate the minimum distance (C) for guarding in relation to the distance the dangerous part of the machine is from the floor level (A), and the height of the guard (B).

This is the minimum distance that guards of various heights should be from dangerous parts and is calculated to conform to the principles of average human reach.

When the guard is positioned close to the dangerous part, consideration must be given to the size of any opening in the guard.

When a dangerous part is between two heights in the left column of Table 1 (A), the height that provides the longer distance should be used when calculating distance from the guard. When a dangerous part is between two distances from the guard (C), the shorter distance should be used when calculating height of the guard (B).

The Australian Standard AS 4024 *Safety of Machinery* recommends longer distances in most circumstances and it is advisable to also refer to the relevant tables in this standard and apply the longer distances where practicable.

→ REASONABLE REACH VALUES

HEIGHT OF GUARDS IN MM (B)

HEIGHT OF DANGEROUS PARTS FROM FLOOR LEVEL IN MM (A)	1220	1370	1520	1680	1830	1980	2130	2280	2440
2440	0	0	0	0	0	0	0	0	0
2360	230	230	230	230	230	150	130	100	
2280	380	380	380	380	300	230	180	100	
2210	530	530	530	460	380	300	200	0	
2130	610	610	610	530	460	300	200		
2060	680	610	610	610	460	300	80		
1980	760	680	680	610	460	300	0		
1900	840	680	680	610	460	230			
1830	840	760	680	610	460	0			
1750	910	760	680	610	460				
1680	910	760	680	610	380		Horizontal distance from the guard to danger zone in mm (C)		
1600	910	760	680	610	380				
1520	910	760	680	610	230				
1450	910	760	680	530	0				
1370	910	760	680	460					
1300	910	760	680	380					
1220	910	760	610	0					
1140	910	760	610						
1070	910	680	530						
990	910	680	460						
910	840	610	300						
840	840	530	0						
760	760	380							
680	610	150							
610	530	0							
530	380								
460	0								
380									
300									

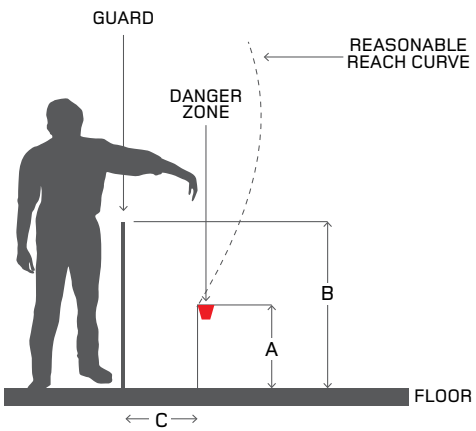


Table 1: This table calculates the reasonable reach values and the minimum distance (C) for guarding in relation to the distance the dangerous part of the machine is from the floor level (A) and the height of the guard (B).

REASONABLE REACH–OVER EXAMPLE

a. The height of the dangerous part from the floor is 610 mm.

b. A guard is 1220 mm high.

c. The distance the guard must be from the dangerous part is 530 mm.

Figure 3: The height of guarding and the dangerous part determines the distance of the guard from the dangerous part.

→ REACH AROUND BARRIERS

When an operator's arm reaches over or around a barrier, the action is described as a 'reasonable reach curve'.

The ability to reach around barriers is determined by the distance of the elbow joint and wrist joint from the reach curve (e.g. from the finger tip). The average elbow joint is 460 mm from the finger tip. Therefore, if an additional barrier is placed with its edge only 430 mm (or less) from the curve, the forearm cannot be fully bent around it. This is illustrated in Figure 4.

When the edge of the barrier is 430 mm or less from the reach curve, the shaded area is "safe by position" since no part of the arm or hand can reach into it.

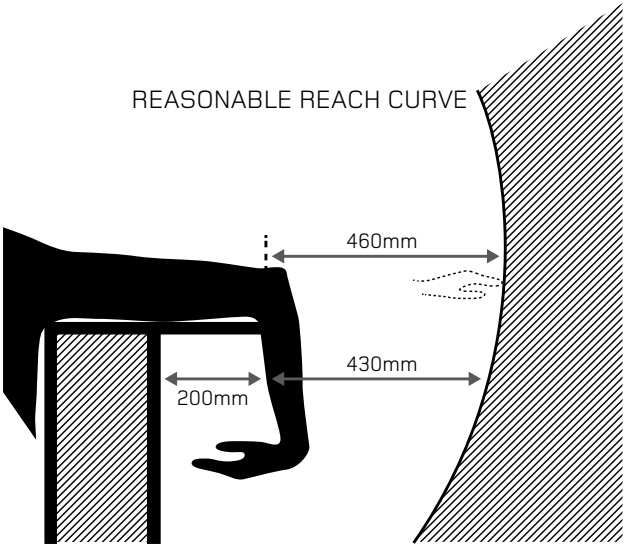


Figure 4: An example of the reasonable reach curve.

If the arm is pulled back until the wrist is near the edge of the additional barrier, the hand can be bent around the barrier and may reach the dangerous part if it is too close. Generally the hand will not reach as far as 200 mm around that point. The reach of a hand bent around the end of a barrier will therefore be a curve of radius 200 mm with a centre point at the end of the barrier.

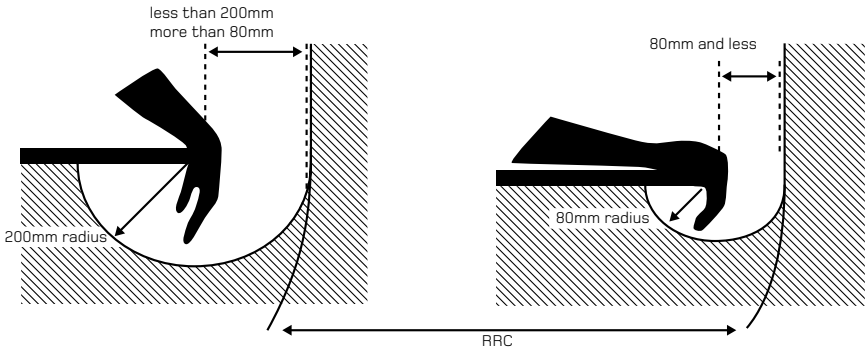


Figure 5: Examples of reasonable reach distances

When the whole hand cannot be bent around a barrier or guard, it may be possible to bend the fingers around it. The reach of the fingers alone does not generally exceed an 80 mm radius.

If the edge of the additional (horizontal) barrier is 460 mm or more from the reach curve, the whole forearm and hand can be bent around it, and therefore the additional barrier is ineffective in providing a safe area below it.

If the edge of the additional barrier is 430 mm from the reach curve, the forearm and hand can be partly bent around it as shown in Figure 4, but the barrier has increased the safe-by-position area to the whole of the space shaded in the drawing. The arm can still reach out and down but not back under the barrier. However, the hand can reach underneath the barrier to a distance of almost 200 mm from the edge.

If the edge of the additional barrier is less than 430 mm from the reach curve, the arm can still be partly bent around it, though not so far as in Figure 4. The closer the edge of the additional barrier is to the reach curve, the less ability

the arm has to be bent round it. At 200 mm from the reach curve it is no longer possible to reach around the additional barrier because the arm is fully extended, stopping the wrist from reaching the edge of the barrier.

With the barrier in each of these positions it is still possible for the hand to reach back underneath the barrier to a maximum of nearly 200 mm from the edge. The space below the barrier is unsafe, as well as any space in front of the barrier, which can be reached by the bent arm and hand.

When the edge of the additional barrier is only 200 mm from the reach curve, only the hand can be bent round it. Any dangerous part should be beyond a 200 mm radius from the edge of the barrier. If the barrier *is less* than 200 mm from the reach curve, the bending of the hand becomes more restricted, until at 80 mm only the fingers can be curled under the barrier.

If the fingers alone can be bent around the edge of the barrier, any dangerous part should be beyond an 80 mm radius from the edge of the barrier.

→ OPENINGS, ADMITTING THE FINGERS OR HAND

If the opening will admit one, two or three fingers, the reach is restricted by the roots of the fingers (Figure 6). The distance between the guard and the dangerous part must be longer than the reasonable maximum length of the longest finger plus a clearance allowance.

Figure 6: The reach is restricted by the roots of the fingers.

If all four fingers can be admitted through the one opening, the size and shape of the opening will be an important factor in determining the extent of the reach. In some cases, reach will be limited by the root of the thumb, and in others by the thickness of the hand, the wrist or the arm. In a case where reach is restricted by the root of the thumb, the distance from dangerous parts necessary is the reasonable maximum length of a hand from fingertip to root of thumb, plus clearance.

The thumb can be folded within the palm of the hand, and the width of the hand in this case, is the width of the palm. The depth of the hand is increased by the thickness of the palm and thumb folded in. This limits the reach through potential depending on the width and depth of the opening.

The distance of the guard from the dangerous parts is determined by the maximum reasonable length of fingers and hand, or of fingers, hand and arm at different points.

If the opening can admit the whole arm and a portion of the shoulder (but excludes the head and trunk) the reasonable reach is assessed as the distance from fingertips to armpit and the minimum guarding distance should be not less than 840 mm.

Figure 7: The distance of the guard from the dangerous part is worked out by how far someone can reach.

→ REACHING SAFELY THROUGH OPENINGS

There are many reasons to put an opening in a machine guard. The operator may need to insert or retrieve material, watch the work in progress, adjust the equipment or clean machinery.

Openings should meet the needs of production, but ensure that entry through the guard prevents reaching into danger. Hazards of the machine are isolated by restricting the distance a person can reach through the opening.

Safe separation distances for smaller openings are subject to rules depending on whether they are slots, squares, or circles.

Opening Shape	Reach Rule	Rule applies for opening sizes
	Operators can reach furthest through slots	Provided slots, squares, and circles measure more than 16 mm but no more than 38 mm.
	Operators cannot reach as far through square openings as through slots	When slots and squares measure more than 16 mm but no more than 38 mm. Above 38 mm reach through squares and circles is the same.
	Operators have more limited reach when reaching into round openings	When slots, squares, and circles measure more than 16 mm, reach through circles is more limited, up to 50 mm. Above 50 mm reach through slots squares and circles is the same.

Table 2: Reach rules for openings of various shapes.

→ SLOTS – ELONGATED OR PARALLEL OPENINGS

There are five rules to determine the distance of the opening from the hazard, and the maximum permissible opening in the guard.

1. Openings with a gap up to 6 mm can be treated as so small as to be insignificant. The guard is virtually the same as solid material and a working clearance of 25 mm is all that is required for safe separation.

2. Openings with a gap above 6 mm but no greater than 13 mm will admit part of a finger. The distance required is 50 mm which is part of a finger length plus a working clearance.

3. Openings with a gap above 13 mm but no greater than 16 mm will admit a finger. The distance required is 100 mm which is a finger length plus a working clearance.

4. Openings with a gap in between 16 mm and 82 mm are calculated from the formula:

$$\text{“y”} = x/10 + 6$$

Where:

- y is the distance between sides of the slot, or opening size
- x is the safe distance from the outside of the guard to the hazard.

To find the safe distance x the formula can be written:

$$x = 10(y - 6)$$

---

5. The distance between the guard and the dangerous part in the case of an opening between 82mm and 152mm should be at least 840mm, or arm's length from armpit to fingertip plus a clearance.

Openings more than 152 mm are subject to the RRV over guards set out in Table 1.

EXAMPLE OF SLOT SIZE AND DISTANCE FROM DANGEROUS PART

If the distance of a guard from a dangerous part is 300 mm, find the maximum opening size of a slot.

x = 300 mm

y = X/10 + 6

y = 300/10 + 6

y = 36 mm

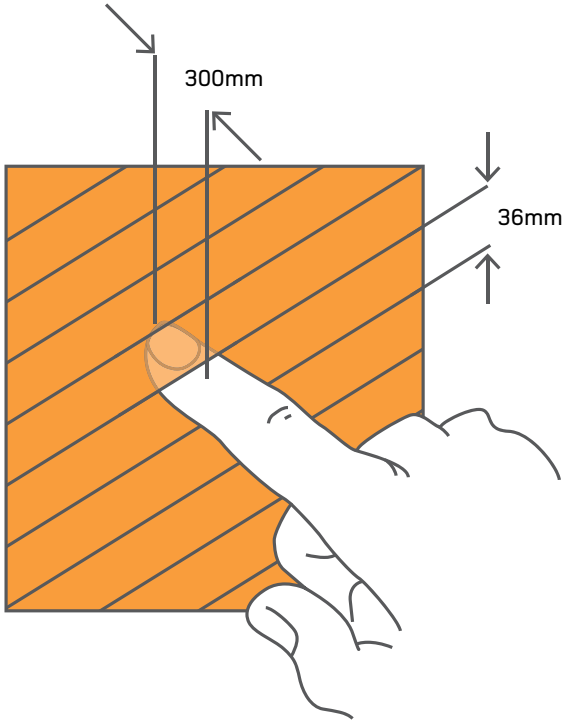


Figure 8: An example of how the guarding equation works to calculate the size of the slot depending on the distance of the guarding.

→ SQUARE AND ROUND OPENINGS

Reach through square and round openings is restricted by the thumb. Restrictions on reach though square and round openings are explained in Table 3 below.

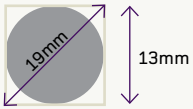
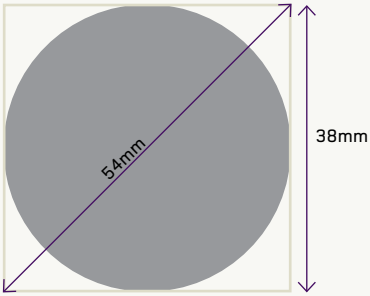
Openings in guard (up to and including dimensions shown)	Distance required between guard and dangerous part	How distance is derived
	25 mm	Virtually same as solid sheet, working clearance only
	50 mm	Part of finger length plus clearance
	100 mm	Finger length plus clearance

Table 3: Restrictions on reach though square and round openings and distances required between guarding and the dangerous part.

→ SQUARE OPENINGS

1. For square openings up to 38 mm, apply distances as given in Table 3. (These distances may also be applied to round openings of diameters equivalent to the squares indicated and to other shapes such as rectangles and diamonds with a diagonal measurement of up to 54 mm).

2. Gaps in square openings from 38 mm up to 82 mm are subject to the formula:

"y"=x/10+6

Where:

- y is the distance between sides of the square, or opening size;
- x is the safe distance from the outside of the guard to the hazard.

To find the safe distance x the formula can be written:

x=10(y–6)

---

3. The distance between the guard and the dangerous part in the case of an opening between 82 mm and 152 mm square must not be less than 840mm.

4. Openings in excess of 152 mm square are subject to the RRV over guards set out in Table 1.

NOTE: An opening 38 mm square is the maximum safe opening permissible at a distance of 100 mm from a dangerous part.

EXAMPLE OF DISTANCE FROM DANGEROUS PART FOR SQUARE OPENING

If the square opening is 80 mm find the required safe distance from the guarding to the dangerous part.

y = 80mm

x = 10(y - 6)

x = 10(80-6)

x = 10x74

x = 740mm

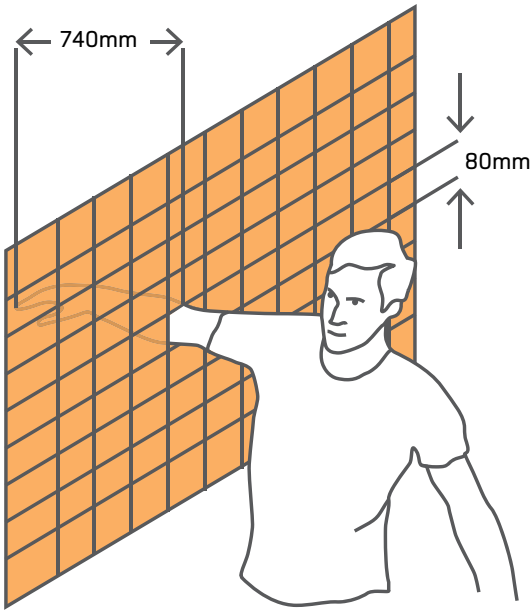


Figure 9: An example of how the guarding equation works to calculate the distance of the guarding depending on the size of a square opening.

→ ROUND OPENINGS

1. Openings up to 38 mm in diameter should use the table values in Table 3.
2. For openings between 38 mm and 50 mm in diameter, the minimum acceptable distance between the opening and the dangerous part is 152 mm
3. Openings from 50 mm up to 82 mm in diameter are subject to the formula:

"y"=x/10+6

Where:

- y is the diameter of the opening;
- x is the safe distance from the outside of the guard to the hazard.

To find the safe distance x the formula can be written:

x=10(y–6)

---

4. For openings more than 82 mm in diameter, apply RRV over guards as set out in Table 1.

Where the opening is 50 mm square, a small hand can be inserted and the reach through values in Table 4 needs to be applied. The safe distance from a 50 mm square opening is 440 mm. In the case of an opening 45 mm square, a small hand can almost be squeezed through, but in any case the reach through this opening is at least 390 mm.

A small hand can be inserted through a 50 mm square opening. It is not possible to do this with a round opening of 50 mm in diameter where reach is restricted to 152 mm. The whole forearm can reach through if the diameter is increased to 55 mm.

→ REACH THROUGH OPENINGS

As an alternative to working through the rules of calculation above, you may prefer to simply use the lookup table below in Table 4. The table is a summary and a more precise measurement will require calculation.

Opening in guard mm	Safe distances from openings in guards – mm		
	Parallel	Squares	Circles
6	25	25	25
13	50	50	50
15	100	100	100
20	140	100	100
25	190	100	100
30	240	100	100
38	320	100	100
39	330	330	152
40	340	340	152
45	390	390	152
50	440	440	152
55	490	490	490
60	540	540	540
75	690	690	690
81	750	750	750
82	840	840	840
100	840	840	840
125	840	840	840
150	840	840	840
152	840	840	840
155	Reasonable reach over barriers		

Table 4: Safe distances from openings in guards to dangerous parts.

→ REFERENCES

Ministry of Business, Innovation and Employment (MBIE) Guidance

- *Safe use of machinery – An introduction*
- *Safe use of machinery factsheets –Information, Installation, Operation and Maintenance*
- *Safe use of machinery factsheets –General principles of machine guarding*

Australian Standard (available from www.saiglobal.com)

- AS 4024: *Safety of machinery* (series)

New Zealand Government