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Machine safety and reduced-energy operating mode: Determining safe values

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MACHINE SAFETY AND REDUCED-ENERGY OPERATING MODE

Determining Safe Values

A decision assistance tool for people who use, design, modify, inspect and integrate reduced-energy operating modes on industrial machinery.

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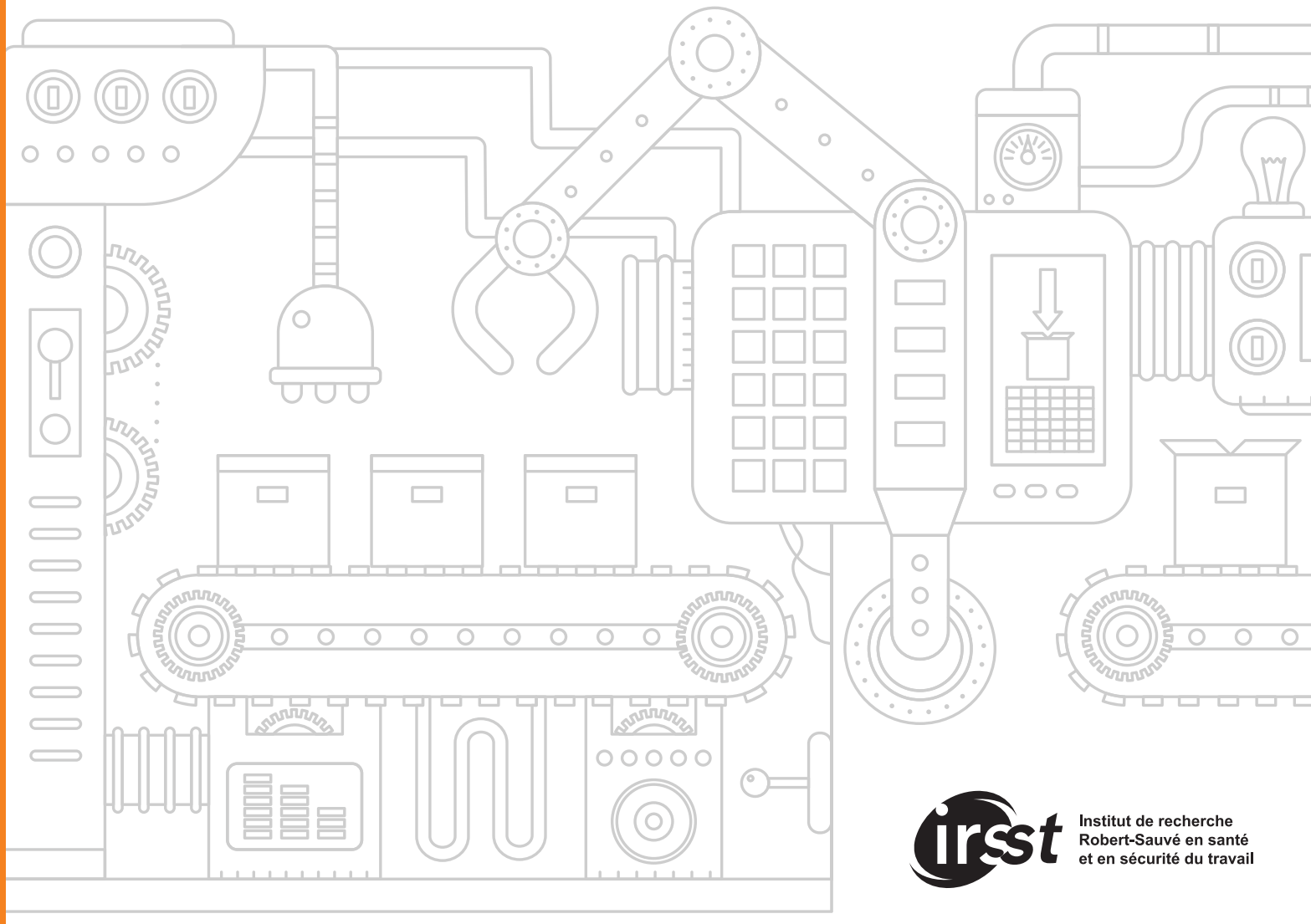

Institut de recherche Robert-Sauvé en santé et en sécurité du travail

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COMMENTS
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CONTENTS

NOTE

This guide is not a substitute for the need to conduct a risk assessment (e.g., process described in standard ISO 12100 [REF. 1]), but is intended as a decision assistance tool. If machinery needs to be modified, an engineer must supervise.

The content of this guide is taken from the *Study of Machine Safety for Reduced-Speed or Reduced-Force Work*, published as Report R-956 and downloadable free of charge from the IRSST website, www.irsst.qc.ca [REF. 2].

BACKGROUND

SECTION 1

The moving parts and tools of industrial machinery are hazards that expose workers to risks of crushing, being caught and drawn in, cutting, impact, pinching/entrapment, etc. That is why section 188.2 of the Regulation respecting occupational health and safety (ROHS) states that before beginning any maintenance on a machine, it must be shut down and lockout must be applied. Section 189.1 of the ROHS more specifically concerns setup, teaching, adjustment, troubleshooting and cleaning—all work which frequently entails close proximity to or being in contact with such hazards. This work often requires that a guard be moved or removed or that a protective device be neutralized in the danger zone of a machine that must remain, in whole or in part, in operation. In such a situation, an analysis, done with the help of the guide *Sécurité des machines: Phénomènes dangereux, situations dangereuses, événements dangereux, dommages*, based on standard ISO 12100-2010, for instance, will help assess the risks associated with the machinery in question [REF. 1, REF. 3].

The risk reduction methods given in Directive 2006/42/EC (Machinery), standard ISO 12100 and standard CSA Z432 for these special cases define standard industry practices in this area and are based on the use of a reduced-energy control mode [REF. 1, REF. 4, REF. 5]. This operating mode allows moving parts to move under certain conditions:

> Where, for setting, teaching, process changeover, fault-finding, cleaning or maintenance of machinery, a guard has to be displaced or removed and/or a protective device has to be disabled, and where it is necessary for the purpose of these operations for the machinery or part of the machinery to be put into operation, the safety of the operator shall be achieved using a specific control mode which simultaneously,
>
> a > disables all other control modes,
>
> b > permits operation of the hazardous elements only by continuous actuation of an enabling device, a two-hand control device or a hold-to-run control device,
>
> c > permits operation of the hazardous elements only in reduced risk conditions (for example, reduced speed, reduced power/force, step-by-step, for example, with a limited movement control device), and
>
> d > prevents any operation of hazardous functions by voluntary or involuntary action on the machine's sensors.
>
> [REF. 1]

Several types of equipment are subject to specific standards that precisely define this operating mode, both in terms of reduced-energy values and additional conditions to meet. That is the case, for instance, of standard ANSI B65.3-2011 with regard to straight guillotine cutters [REF. 6]. It recommends a maximum pressure of 300 N for the paper press on machines with a working width of less than 1.6 m and 500 N when it is over 1.6 m. The control must also be protected against any inadvertent operation. Yet many other machines are not covered by a specific standard in this regard. Manufacturers and users of such equipment must therefore choose from a wide range of values and other operating conditions.

This guide is based on state-of-the-art standards and practices, not solely the ROHS. It indicates a number of values for reduced speed, reduced force, reduced energy and reduced pressure taken from the literature. It also provides guidelines and specifies the aspects to consider in designing, using and modifying machines with a reduced-energy operating mode.

WHAT THE QUEBEC REGULATIONS SAY

Regulation respecting occupational health and safety, section 189.1 [REF. 7] **:**

Where a person does setup work, apprenticeship work, a search for defects or cleaning work requiring that a protector be moved or removed or that a protection device be neutralized in the danger zone of a machine that must remain, in whole or in part, in operation, the machine must be equipped with a specific control mode whose engagement must cause all other control modes of the machine to become inoperative and allow

1 > the dangerous parts of the machine to be operated only by using a control device requiring continuous action or a two-hand control device, or by continuous action of a validation device; or

2 > the machine to be operated only in conditions where the moving parts do not involve any danger for the health, safety and physical well-being of persons having access to the danger zone, for instance, at reduced speed, under reduced tension, step-by-step or by means of a separate step control device.

For greater safety, on the basis of their findings, the authors of the report recommend complying with both conditions set out in the ROHS at once.

HOW TO USE THIS GUIDE

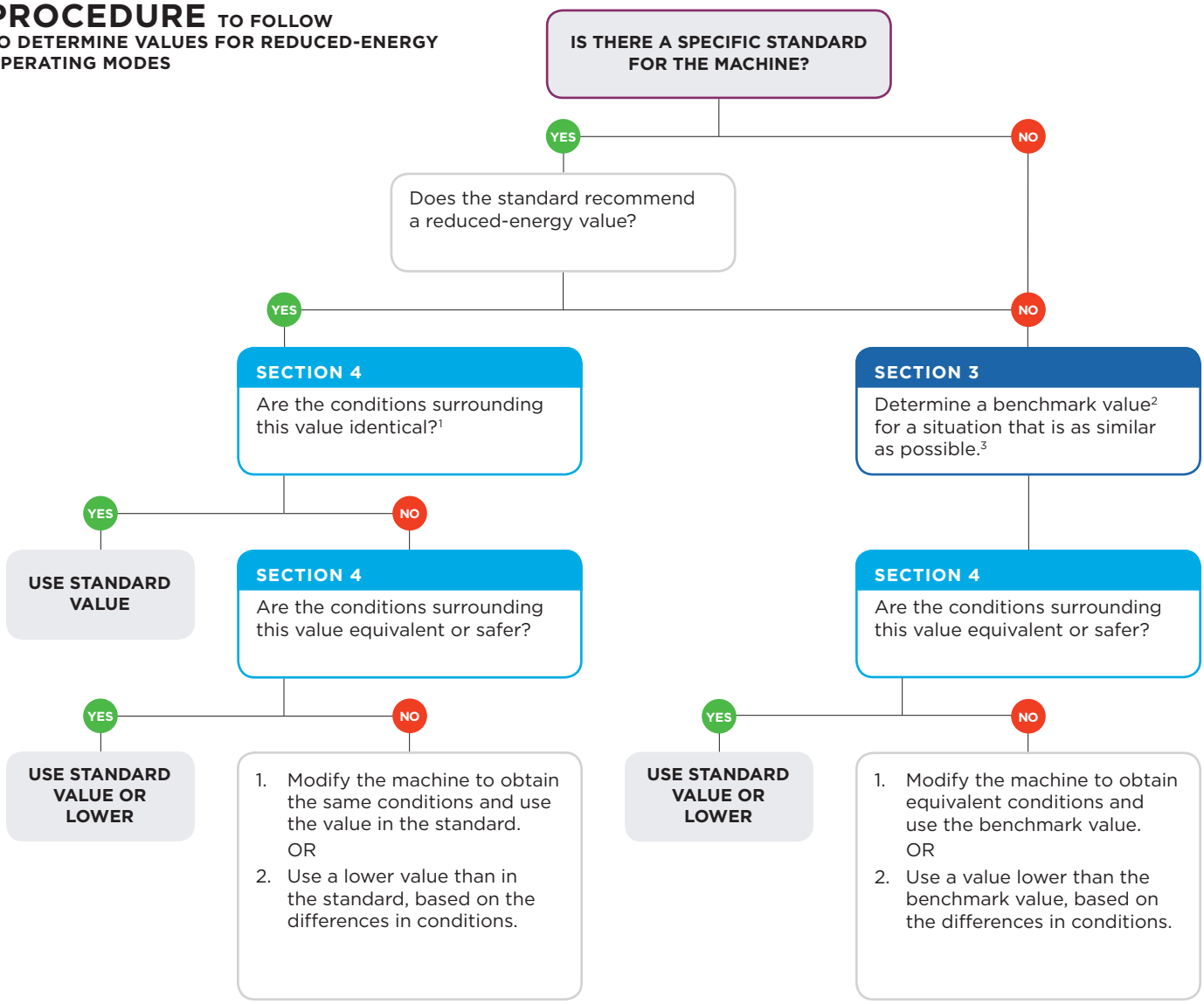
SECTION 2

Figure 2.1 is a flow chart of the procedure to be followed when a machine's designer or user wants to modify it or add a reduced-energy operating mode.

This procedure is based primarily on the comparison of *complementary conditions surrounding a value*. The conditions serve to better describe the situation and to take into account factors that can influence the choice of values. A prescribed value is only valid in a precise context and cannot be taken separately from it. The person or working group designing the reduced-energy operating mode must rely on their own judgment when determining the equivalency of conditions. Sections 3 and 4 of the guide will help them in their analysis.

FIGURE 2.1

PROCEDURE TO FOLLOW TO DETERMINE VALUES FOR REDUCED-ENERGY OPERATING MODES



1. An exhaustive, well-documented risk analysis makes it possible to closely compare the prescribed conditions around a value in relation to the conditions specific to the machine in question. Section 4 discusses most of the aspects to consider in making such a comparison.
2. The benchmark value may be taken from standards or other sources, such as technical guides.
3. Two situations are deemed similar when they involve the same hazard (type of danger) and when the other conditions are equivalent (see "Hazard" and "Other Conditions Required" columns in the tables in Section 3).

BENCHMARK VALUES

SECTION 3

The tables below present some maximum values (speed, force, kinetic energy, pressure) proposed in the literature, including standards. They are commonly used, state-of-the-art values. As the tables are not exhaustive, please refer to Report R-956, on which this guide is based, and which contains a more extensive list of benchmark values, or use other values taken from the literature as benchmark values. Furthermore, since the tables and the report they are taken from present simplified versions of the standards, please refer to the standards themselves to find out more about the additional conditions to consider and other information surrounding the benchmark values.

Note that it is of the utmost importance to pay attention to the other conditions associated with the values, because they determine whether lower values should be used.

TABLE 3.1

SPEED

BENCHMARK VALUES FOR REDUCED SPEED

INDUSTRY / MACHINE	HAZARD		MAX. SPEED	OTHER CONDITIONS REQUIRED	REF.
PRINTING GENERAL	General, if no specifications		17 mm/s	• Hold-to-run control • Control circuit reliability requirements	8 9 10
			83 mm/s* *If speed of 17 mm/s prevents machinery from doing its job	• Hold-to-run control • Control circuit reliability requirements	
MANUFACTURING MACHINING CENTRE	Impact, crushing, pinching/ entrapment		33 mm/s	• Manual control with enabling switch	11
MANUFACTURING PLASTIC INJECTION MOULDING MACHINE	Crushing, severing, amputation		10 mm/s	• Hold-to-run control • Training for operators and supervisors	12
ALL INDUSTRIES ROBOTS	Impact, crushing, pinching/ entrapment		250 mm/s	• Manual control with enabling switch	13

See Table 3 of Report R-956 for a more extensive list of low/reduced-speed values, in ascending order, with references **[REF. 2]**.

TABLE 3.2

FORCE

BENCHMARK VALUES FOR REDUCED FORCE

INDUSTRY / MACHINE	HAZARD		MAX. FORCE	OTHER CONDITIONS REQUIRED	REF.
GENERAL MOTORIZED MOVABLE GUARD	Pinching/ entrapment, crushing, severing (narrow surface or edge)		75 N	• None	14
	Pinching/ entrapment, crushing (flat surface)		150 N	• Automatic reversal of movement (e.g., pressure-sensitive edge or release of hold-to-run control)	
PRINTING STAPLING MACHINE RIVETING MACHINE	Crushing, shearing, cutting and severing		50 N	• Sensor to detect part of body (to apply force of work) • Control circuit reliability requirements	15
PRINTING STRAIGHT GUILLOTINE CUTTER SCREEN-PRINTING MACHINE	Pinching/ entrapment, crushing (flat surface)		300 N	Straight guillotine cutter: • Paper press, working width < 1.6 m Screen-printing machine: • Pressure-sensitive edge/bar OR • Limitation of closing force and no sharp edges	6 16
			500 N	Straight guillotine cutter: • Paper press, working width > 1.6 m	6
PRINTING FOLDER-GLUER	Drawing in, crushing (nip point)		500 N	Offset of at least 120 mm between return rollers (not shown)	17

See Table 4 of Report R-956 for a more extensive list of reduced-force values, in ascending order, with references **[REF. 2]**.

TABLE 3.3

KINETIC ENERGY

BENCHMARK VALUES FOR REDUCED KINETIC ENERGY

INDUSTRY / MACHINE	HAZARD	MAX. E_c*	OTHER CONDITIONS REQUIRED	REF.
BUILDING ELEVATOR	Pinching/entrapment, crushing	3.5 J	• Reopening device missing or not working	18
		4 J	• Horizontal elevator door • Automatic door • Reopening device missing or not working	19
		10 J	• Horizontal elevator door • Automatic door • Automatic reversal of movement in case of detection	18 19
		> 10 J	• Horizontal elevator door • Not automatic operation • Hold-to-run control • Max. speed limit of fastest panel: 300 mm/s	19
GENERAL	Pinching/entrapment, crushing	4 J	• None	20
		10 J	• Automatic reversal of movement device	

* Kinetic energy calculated or measured at average speed of movement.

See Table 5 of Report R-956 for a more extensive list of reduced-kinetic energy values, in ascending order, with references **[REF. 2]**.

TABLE 3.4

PRESSURE

BENCHMARK VALUES FOR REDUCED PRESSURE

INDUSTRY / MACHINE	HAZARD		MAX. PRESSURE	OTHER CONDITIONS REQUIRED	REF.
GENERAL GENERAL PACKAGING MACHINE	Pinching/ entrapment, crushing		25 N/cm²	• None	14 21 22
	Pinching/ entrapment, crushing		50 N/cm²	• Automatic reversal of movement	

See Table 6 of Report R-956 for a more extensive list of reduced-pressure values, in ascending order, with references **[REF. 2]**.

GUIDELINES FOR COMPARING CONDITIONS SURROUNDING REDUCED-ENERGY VALUES

SECTION 4

This section provides guidelines for comparing conditions surrounding reduced-energy values. When a standard that applies to a given machine indicates reduced-energy values or a benchmark value has been identified, this comparison should be done. If the conditions surrounding the recommended values are identical or equivalent, the reduced-energy value may be used as recommended. Otherwise, adjustments must be made until an equivalent level of safety has been reached, either by adapting the other conditions or by using a lower reduced-energy value.

RISK REDUCTION METHODS

The additional conditions to consider include risk reduction methods of various types and variable effectiveness. Table 4.1 lists the safeguards most frequently mentioned in the literature in conjunction with a reduced-energy operating mode.

TABLE 4.1
NATURE AND RELATIVE EFFECTIVENESS OF RISK REDUCTION METHODS

EFFECTIVENESS	TYPE	ADDITIONAL RISK REDUCTION METHODS
+	Risk reduction by design	• Limitation of energy by dimensioning • Safe clearance • Minimum gap between fixed and moving parts
	Protective devices	• Automatic reversal of movement device
	Control*	• Hold-to-run control • Enabling device • Nearby emergency stop • Mode selector switch
−	User	• Sound signal • Training • Visibility of danger zone from control

* Regardless of the type of control, make sure that the reliability level of the control system is tailored to the situation (see standard ISO 13849) **[REF. 23]**.

DETERMINING FACTORS TO CONSIDER

Several factors have to be taken into account in designing a reduced-energy operating mode (Table 4.2). These are guidelines that help compare two situations to determine whether the energy levels valid for one also apply to the other.

TABLE 4.2
FACTORS TO TAKE INTO ACCOUNT WHEN SAFEGUARDING THROUGH ENERGY LIMITATION

FACTOR	ENERGY	EXAMPLES OF PARAMETERS TO CONSIDER	CONSIDERATIONS
ACCESSIBILITY OF HAZARDOUS ZONE ANTHROPOMETRIC DIMENSIONS	Speed Force Pressure Kinetic energy	Height of hazardous zone Clearance Uneven, slippery floor	• A confined or cluttered space reduces the chance of avoiding harm. • An out-of-reach danger zone may maintain a higher energy level than one within a worker's reach (e.g., conveyor speed depending on its height).
PRESSURE ON PARTS OF BODY	Force Pressure	Resistance to pressure depends on part of body Severity of harm depends on part of body	• Parameters to use to reduce harm. • To be considered especially for nipping, pinching/entrapment or crushing areas, as well as shearing areas and nip points. • For a given force, the smaller the contact surface, the greater the resulting pressure will be. • See Table 4.4.
SHAPE AND SIZE OF CONTACT SURFACES	Speed Force Pressure Kinetic energy	Sharp, flat, rough, etc. surface Nip point, entrapment area, shearing area, etc.	
KINETIC ENERGY	Speed Kinetic energy	Speed, parameter to use to reduce risk Stopping time of machine Force of impact	• "The slow speed chosen must allow the moving parts to come to a stop, after the control is released, in a short enough time to ensure that the operator's safety is not put at risk." [REF. 20] • Parameter to use to prevent harm. • Parameter to use to reduce harm.
MECHANISM RESPONSE TIME	Speed Kinetic energy	Stopping time and distance of machine	

The literature sometimes accepts higher energy levels when certain other factors are involved. For instance, Table 4.3 lists two series of values to use, depending on the state of a determining factor.

TABLE 4.3
SERIES OF VALUES BASED ON STATE OF DETERMINING FACTOR

DETERMINING FACTOR	SERIES OF VALUES 1	SERIES OF VALUES 2	REF.
CONTACT SURFACE	Flat surface (plane) – 150 N	Edge – 50 N	8 16
AUTOMATIC REVERSAL OF MOVEMENT	With mechanism – 150 N	Without mechanism – 75 N	20 21
TYPE OF CONTROL	Hold-to-run – 83 mm/s	Automatic movement – 8.3 mm/s	17

Again, for reference purposes, Table 4.4 lists allowable reduced-energy values for contact by the part of the body exposed.

TABLE 4.4
TABLE TAKEN FROM STANDARD NF EN 415-10 ON CRUSHING FORCE, IMPACT FORCE AND STATIC SURFACE PRESSURE LIMITS ACCEPTABLE TO THE HUMAN BODY [REF. 22]

PARTS OF THE BODY	DETAILS OF PARTS OF THE BODY	CRUSHING FORCE [N]	IMPACT FORCE [N]	STATIC PRESSURE AT SURFACE OF BODY [N/cm²]
1 Head and neck	1.1 Skull/forehead	130	175	30
	1.2 Face	65	90	20
	1.3 Neck (sides/back)	145	190	50
	1.4 Neck (front/larynx)	35	35	10
2 Trunk	2.1 Back/shoulders	210	250	70
	2.2 Ribcage	140	210	45
	2.3 Stomach	110	160	35
	2.4 Pelvis	180	250	75
	2.5 Buttocks	210	250	80
3 Arms	3.1 Arm/elbow joint	150	190	50
	3.2 Forearm/wrist joint	160	220	50
	3.3 Hand/finger	135	180	60
4 Legs	4.1 Thigh/knee	220	250	80
	4.2 Lower leg	140	170	45
	4.3 Feet/toes/joints	125	160	45

* Excerpts from standard NF EN 415-10: 2014, *Safety of Packaging Machines. Part 10. General Requirements*, are reproduced here with the permission of AFNOR. Only the full original text of the standard, as distributed by AFNOR Publications—available online from www.boutique.afnor.org — has the authority of a standard.

To recap, here is a list of several common determining factors to consider:

- Contact surface, geometry of moving part (e.g., flat surface, edge)
- Type of control (e.g., hold-to-run control, two-hand control, pulse control [automatic movement])
- Guards within hazardous zone (e.g., nip point guards) or not
- Sound/light signal at start-up or not
- Accessibility of hazardous zone (e.g., impossible to reach or easy to get to)
- Safe clearance or not
- Relative position of movable/fixed parts (e.g., shearing areas)
- Automatic reversal of movement in case of detection of part of worker's body
- Emergency stop device nearby or not
- Parts of body exposed

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SECTION 5

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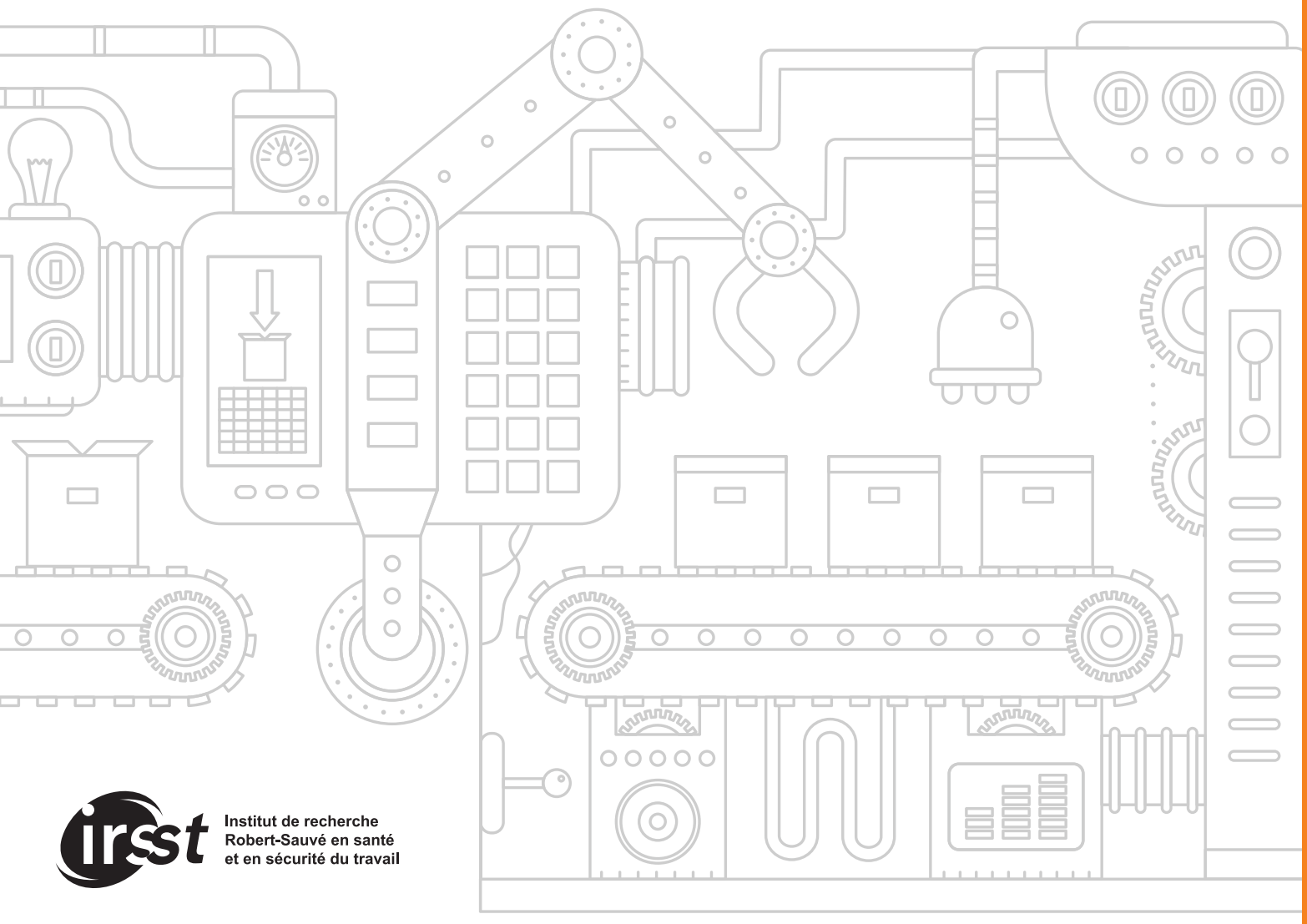

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