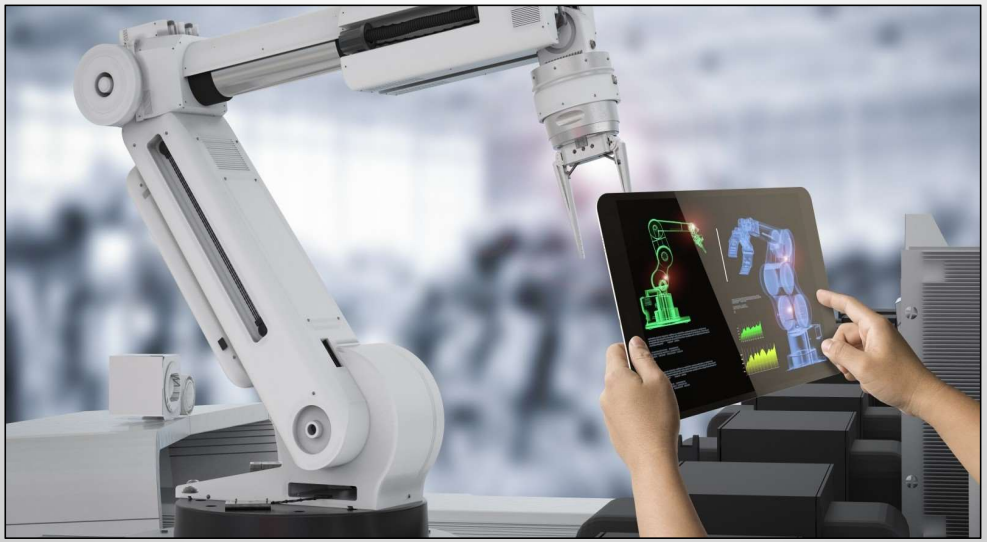
INDUSTRIAL ROBOT SAFETY

COLLABORATIVE APPLICATIONS



Presented by Cobot Safety

TODAY'S AGENDA

- Review of agenda and brief speaker introduction
- Brief history of industrial robot safety standards (CSA vs ISO)
- Debunking the myth – what is a "Cobot"
- Collaborative operations - 4 Types
- Introduction to Risk Assessment – requirements and mock exercises
- Question & answer period

DISCLAIMER

- presentation material is intended to be illustrative only
- each collaborative robot application is unique
  - a task based risk assessment must be completed for 100% of collaborative applications
- material developed by utilizing and interpreting excerpts from industry safety standards
  - purchasing industry safety standards relevant to your application, and reading them in their entirety, is highly recommended
- check all relevant standards /regulations applicable to your robot / application (i.e., Pre-Start Health & Safety Reviews in Ontario*)

  * Note : in the opinion of Cobot Safety , a Pre-Start Health & Safety Review is applicable to collaborative applications implemented in Ontario.

Dave Smith – Cobot Safety

Work History

Period	Company	Department	Role
1988 - 1991	Honda of Canada Mfg. (HCM)	Weld : Plant 1	Production
1992-2001		Weld : Plant 1	Dept. Safety Specialist
2002-2003		Assembly : Plant 2	Dept. Safety Specialist
2004-2020		Safety / Medical	Corporate Equipment & Construction Safety Specialist
2020 - Present	Cobot Safety	N/A	Owner, Lead Auditor & Technical Trainer

Professional Development

Item	Description	Since
CRSP	Canadian Registered Safety Professional	1999
TUV FS Tech	Registered Functional Safety Technician	2017
CSA Z434	Industrial Robot Safety	2000
CSA Z432	Safeguarding of Machinery	2002
CSA Z460	Lockout & Other Methods	2003
ISO / TC299	Robotics & Robotic Devices	2001
ISO / TC199	Machinery Safety	2005

PRE-TRAINING BASE LINE KNOWLEDGE ASSESSMENT

PRE-TRAINING BASE LINE KNOWLEDGE ASSESSMENT

Which CSA Standard applies to Industrial Robot Safety ?

- Z432
- Z460
- Z434
- Z142

Which ISO Standard applies to Industrial Robot Safety ?

- 13855
- 10218
- 13857
- Z142

Which Industrial Robot Safety Standard should I follow in Canada ?

- ISO 10218
- RIA R15.06
- CSA Z434
- The most current industry standard

There is no such thing as a Collaborative Robot or “Cobot” ?

T or F

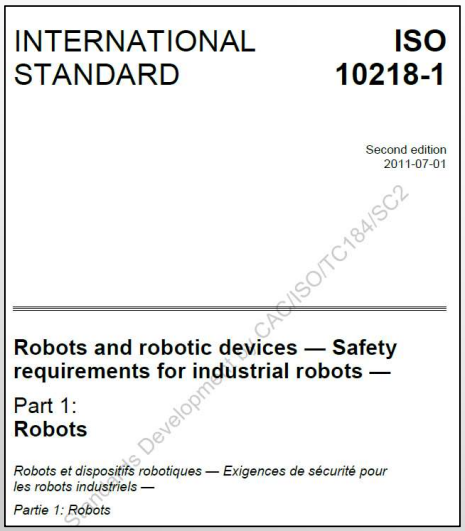
INDUSTRIAL ROBOT STANDARDS

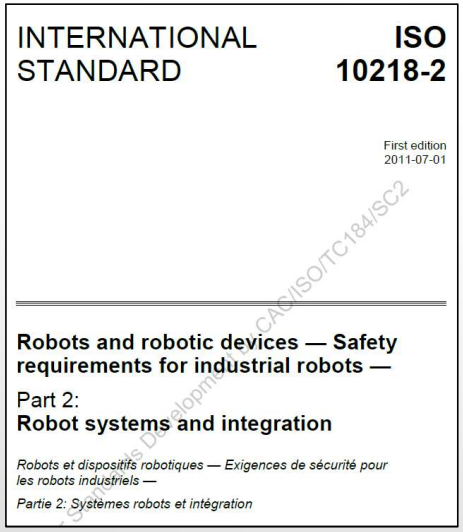
A BRIEF HISTORY

INDUSTRIAL ROBOT STANDARDS

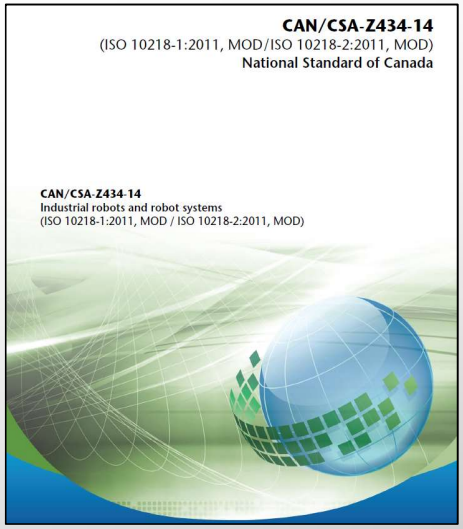
(CURRENT SITUATION)

International
(2011)





National
(2014)



ISO Standards

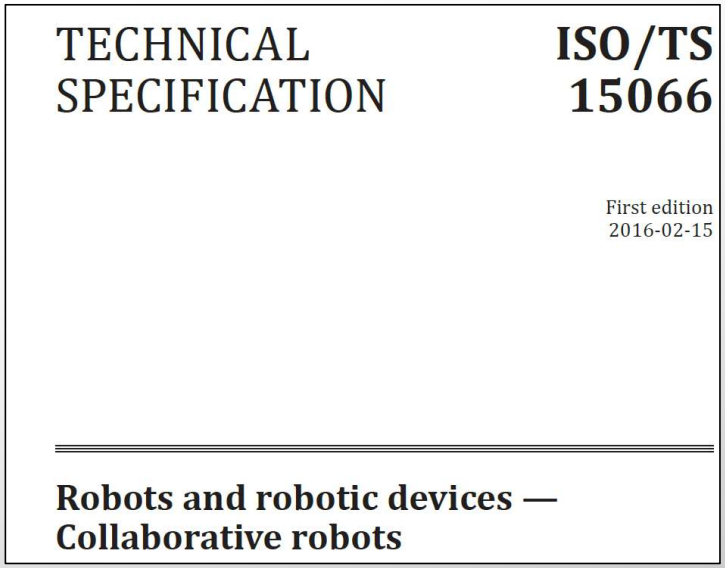
- never speak to the manufacturer and integrator in the same document
- do not include user requirements

CSA Standards

- can speak to all stakeholders in one document
- Z434 combines ISO 10218 Parts ½ and adds user requirements

INDUSTRIAL ROBOT TECHNICAL SPECIFICATION (ISO/TS 15066)

- development began immediately after ISO 10218 Parts 1 & 2 were published in 2011
- goal was to provide more guidance on collaborative applications
- ISO / TS 15066 published in 2015
- the requirements are being incorporated into the next version of ISO 10218 (2022 – target date)



INDUSTRIAL ROBOT STANDARDS

(PATH FORWARD)

ISO 10218-1
Manufacturer
2011

ISO 10218-2
Integrator
2011

ISO / TS 15066
Collaborative Robots
2016

ISO / TR 20218-1
End Effectors
2018

ISO / TR 20218-2
Manual Load Stations
2017

ISO 10218-1
Manufacturer
202x

ISO 10218-2
Integrator
202x

ANSI / RIA R15.06-202x
Robotics Industries Association

CSA Z434-202x
Canadian Standards Association

DEBUNKING THE MYTH

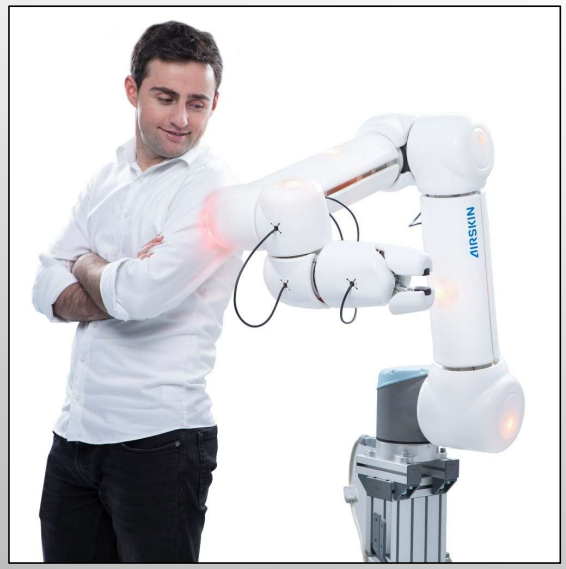
Is there any such thing as a Collaborative Robot or “Cobot”?

HISTORY OF THE TERM COBOT IN ISO 10218

Introduced in ISO 10218 Part 2 2011 (integrator's requirements)

collaborative robot

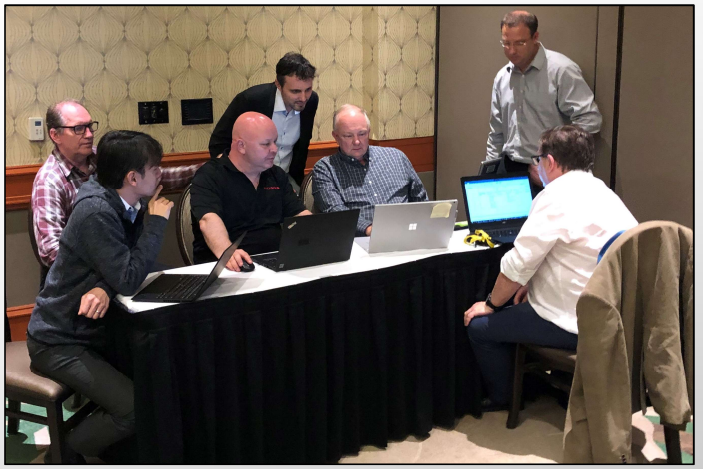
robot designed for direct interaction with a human within a defined collaborative workspace



HISTORY OF THE TERM COBOT IN ISO 10218

Conclusion : after several spirited debates between working group experts, it was determined that there is **no such thing** as a collaborative robot or Cobot !

- it is simply a type of industrial robot
- the application is critical, not the robot
- the term collaborative robot has been deleted in the next edition (2022)



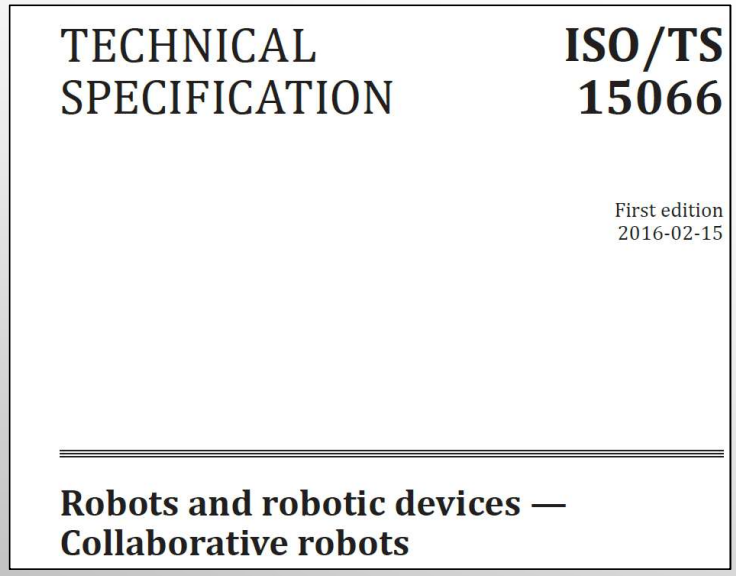
Cobot Safety Definition of Collaborative Robot * :

- an industrial robot with safety features that make it suitable for integration into a collaborative application.

* Note : this definition was not accepted by the committee

ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS


TECHNICAL SPECIFICATION

ISO/TS 15066

First edition
2016-02-15

Robots and robotic devices — Collaborative robots

Key Points :

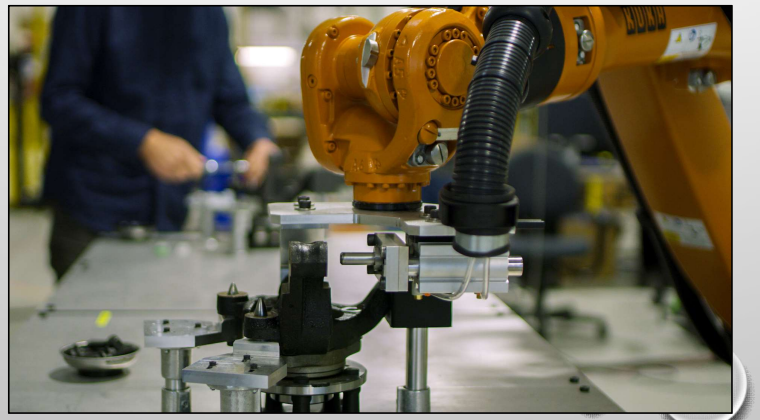
- robots utilized in a collaborative manner must comply with ISO 10218-11 part 1
- integration of collaborative applications must comply with ISO 10218 part 2
- this technical specification was developed to supplement and enhance these requirements
- it provides additional guidance with respect to collaborative operations
- introduces threshold values for power and force limiting applications

ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Collaborative industrial robot system design

- the operational characteristics for collaborative applications are much different than those of a traditional installation
- the operator works in close proximity to the robot in the same workspace.
- contact situations can be intended or unexpected
- risk reduction measures must be determined in the risk assessment



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ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Collaborative robot operations

There are 4 types of Collaborative Operation

- Power and force limiting
- Speed and separation monitoring
- Hand guiding
- Safety rated monitored stop

POWER AND FORCE LIMITING

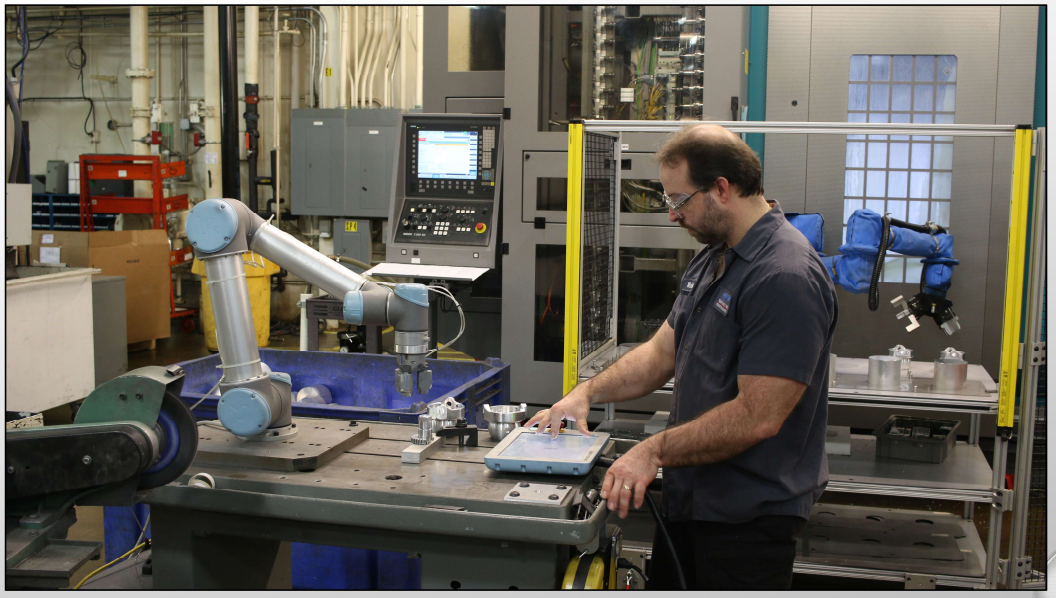
ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Power and force limiting

Description

- physical contact between the robot and operator can occur
- contact may be intended or unintended
- contact situations can be :
  - quasi-static (pinching or clamping)
  - transient (dynamic)
- Contact can occur due to :
  - intended contact situations
  - unintended contact caused by operator
  - unintended contact due to a technical failure



ISO / TS 15066 – 2016

Two main types of contact (further described)

Quasi-static contact characteristics :

- clamping or crushing of a body part
- pressure or force is exerted on the trapped body part for a longer period

Transient contact characteristics :

- also referred to as dynamic impact
- body can recoil or retract and avoid being pinched or crushed
- pressure or force is exerted on the trapped body part for a shorter period

Note: Clamping of a body part is also considered quasi-static contact

ISO / TS 15066 – 2016

Risk reduction measures to prevent contact between robot and operator

Contact between the robot and operator is expected in a power and force limited collaborative application :

The key is to ensure this contact does not result in harm ; this can be achieved by :

- identifying conditions that would result in contact situations (intended or reasonable foreseeable)
- evaluation of the risk of each contact situation identified
- design of the robot system and collaborative workspace to minimize contact situations
- applying risk reduction measures to ensure contact forces do not exceed the threshold limits

ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Speed and separation monitoring

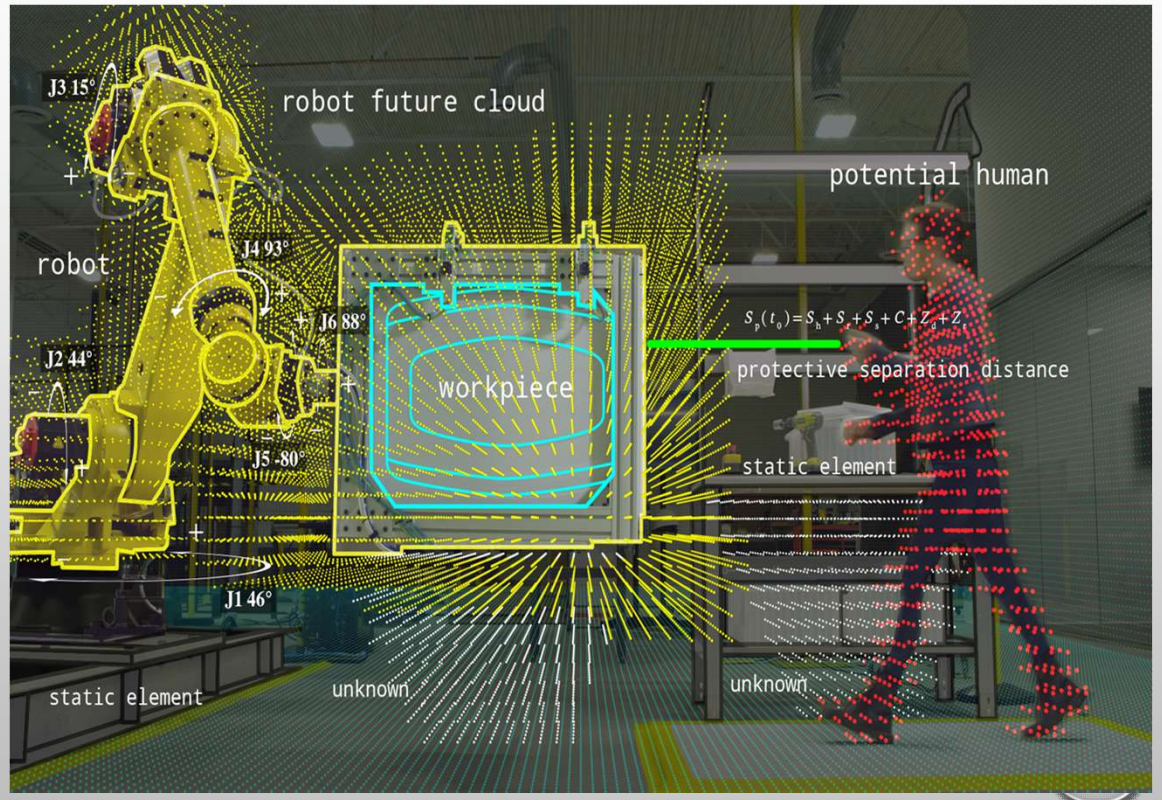
Description

- operator and robot system may move at the same time in the collaborative workspace
- risk reduction is achieved by maintaining the protective separation distance between the operator(s) and the robot at all times
- can be used with any robot (large or small payload)

ISO / TS 15066 – 2016

Speed and separation monitoring relies on knowing where people and robots are in the collaborative workspace

- therefore, continuous monitoring of the workspace is required



ISO / TS 15066 – 2016

Maintaining the protective separation distance (5.5.4.2.3)

$$S_p(t_0) = S_h + S_r + S_s + C + Z_d + Z_r$$

$S_p(t_0)$ - protective separation distance at time **t_0**

t_0 - current time

S_h - contribution to the protective separation distance attributable to the operator's change in location

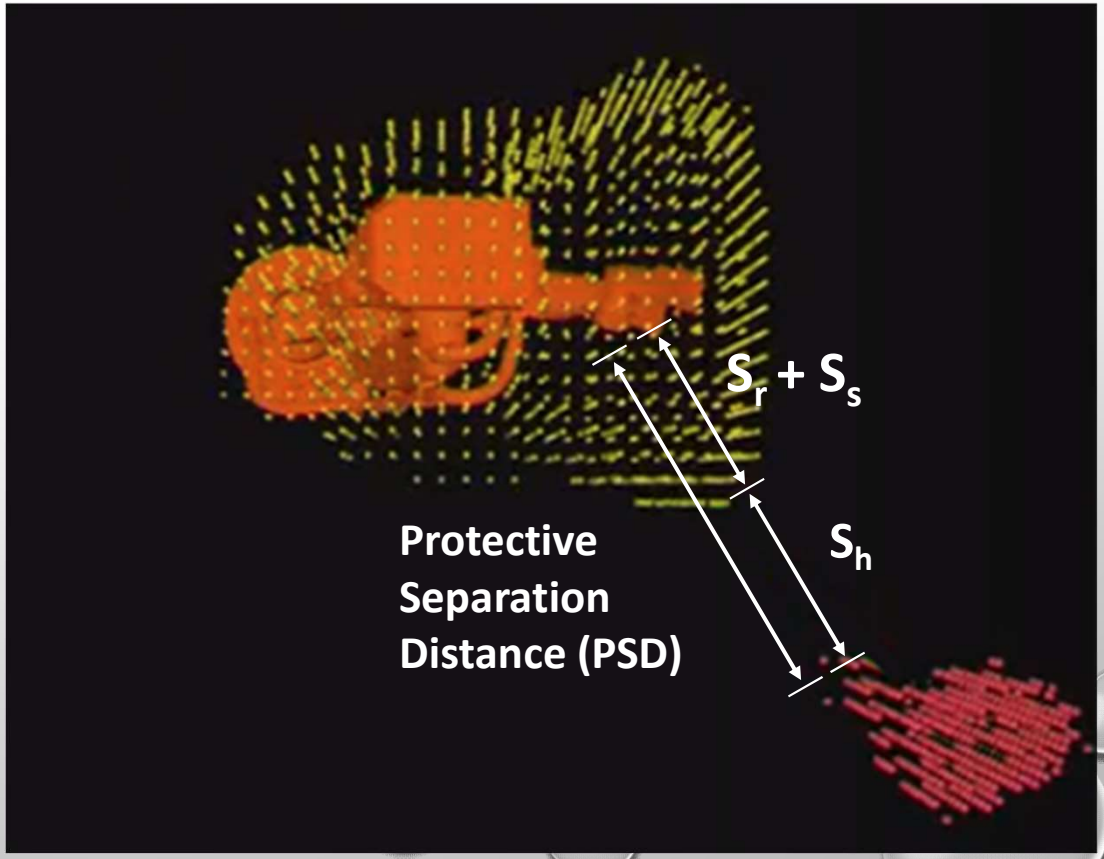
S_r - contribution to the protective separation distance attributable to the robot system's reaction time

S_s - contribution to the protective separation distance due to the robot system's stopping distance

C - intrusion distance, as defined in ISO 13855; this is the distance that a part of the body can intrude into the sensing field before it is detected

Z_d - position uncertainty of the operator in the collaborative workspace, as measured by the presence sensing device resulting from the sensing system measurement tolerance

Z_r - position uncertainty of the robot system, resulting from the accuracy of the robot position measurement system



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Main benefits of speed and separation monitoring collaborative applications :

- allows for the use of standard industrial robots in collaborative applications
- requires fewer limitations on end effector design as well as robot speed and payload
- enables closer, more flexible collaboration than safety-rated monitored stop

ISO / TS 15066 – 2016

Examples of available technology to continuously detect operator position in a SSM application

- programmable laser scanners
- 3D vision safety systems
- 3D radar safety systems

Note : it is the responsibility of the integrator to ensure this technology is third party certified to ensure compliance with applicable safety standards

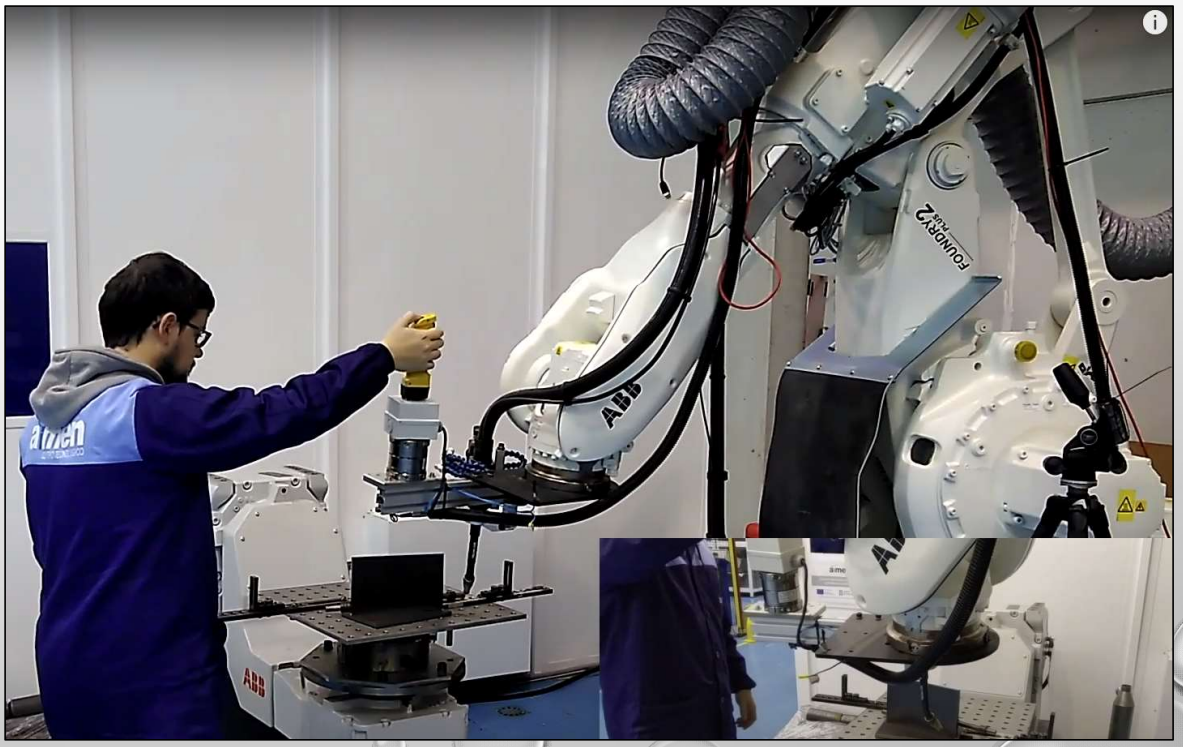
ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Hand Guiding

Description :

- operator transmits motion commands to the robot via a hand guiding device (**not** lead through teaching)
- guiding device must be located as close to the end effector
- must include emergency stop and enabling device capabilities
- does not apply to power and force limiting robot operation



ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Hand Guiding

Operating sequence :

- the robot enters the collaborative workspace and issues a safety-rated monitored stop
- the operator may now enter the collaborative workspace and takes control of the robot motion via the hand guiding device (i.e., they depress the enabling device)
- release of the guiding device initiates a protective stop
- once the operator has exited the collaborative workspace the robot may resume automatic operation

ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Hand Guiding

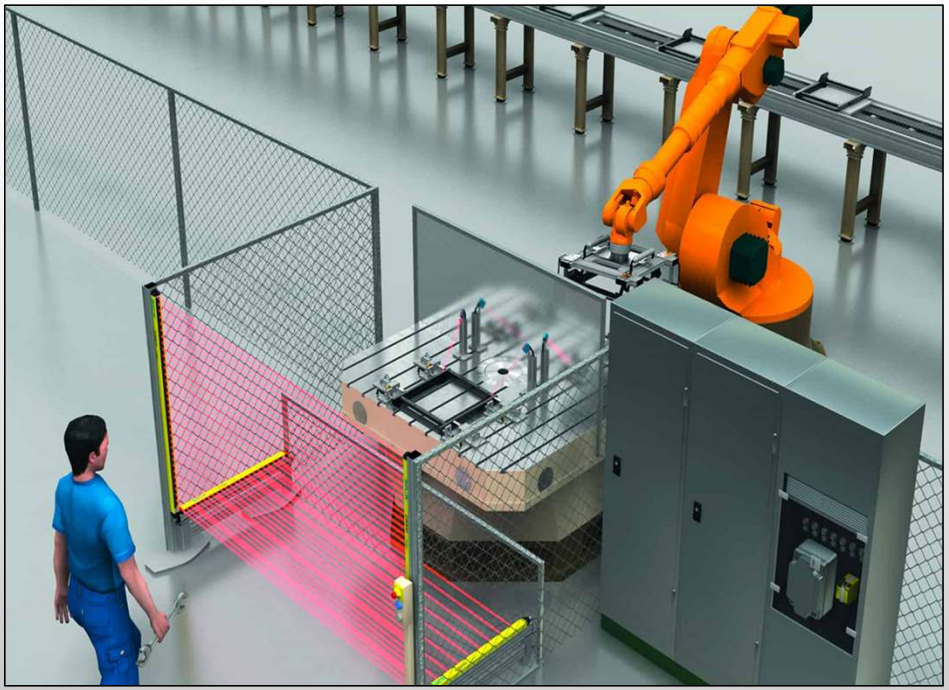
Considerations for guiding device location :

- operator proximity to robot to ensure direct observation of robot motion and any hazards that may arise as a result (e.g., positioning of the guiding device on the end effector or as close to it as possible)
- ensure the process does not require the operator to put themselves in a potentially hazardous location (e.g., directly under the robot arm or between the robot and workpiece)
- operator position must ensure an unobstructed view of the entire collaborative workspace to ensure additional persons do not enter
- the intended motion of the robot shall be intuitive to the operator and controllable from the guiding device

ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Safety Rated Monitored Stop :



ISO / TS 15066 – 2016

ROBOTS AND ROBOTIC DEVICES – COLLABORATIVE ROBOTS

Safety-rated monitored stop

Description :

- used to cease motion of the robot in the collaborative workspace **before** an operator enters
- the robot can operate non-collaboratively if there is no operator in the collaborative workspace
- the operator may enter when the robot system motion has stopped and the safety-rated monitored stop is active
- the robot system motion can continue when the operator has exited the collaborative workspace

Robot Requirements :

- robot motion limiting must comply with 10218-1:2011 (axis limiting requirements)
- robot shall have one or more protective stop functions designed for the connection of external safety devices
- stop functions must be PI=d, cat 3 to comply with 10218-1:2011

ISO / TS 15066 – 2016

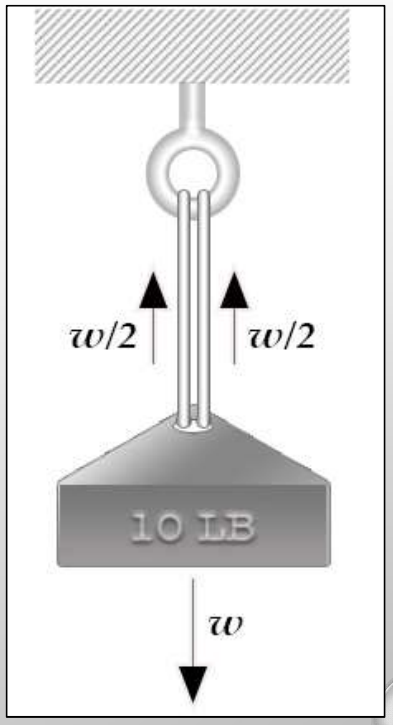
CONTACT FORCE : HOW MUCH IS TOO MUCH ?

Table A2 was created to assist in determining the maximum force values that are permitted in a collaborative application

Key points with respect to the table :

- conducted in Germany at the University of Mainz
- the values are based on pain thresholds, not the onset of injury
- the results are based on a single study *
- testing was conducted on 100 healthy adult subjects (small sample size)
- transient contact derived by multiplying quasi-static values by 2

* **Note** : TS 15066 acknowledges that further studies are required and they may result in changes to these values going forward



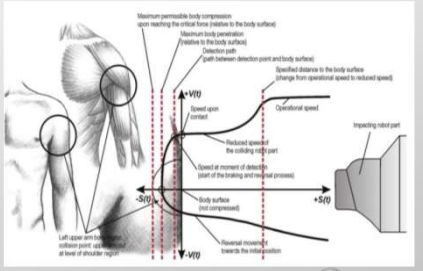
ISO / TS 15066 – 2016

Table A1 excerpt

Table A.1 — Body model descriptions

Body region	Specific body area		Front/Rear
Skull and forehead	1	Middle of forehead	Front
	2	Temple	Front
Face	3	Masticatory muscle	Front
Neck	4	Neck muscle	Rear
	5	Seventh neck vertebra	Rear
Back and shoulders	6	Shoulder joint	Front
	7	Fifth lumbar vertebra	Rear
Chest	8	Sternum	Front
	9	Pectoral muscle	Front
Abdomen	10	Abdominal muscle	Front
Pelvis	11	Pelvic bone	Front
Upper arms and elbow joints	12	Deltoid muscle	Rear
	13	Humerus	Rear
Lower arms and wrist joints	14	Radial bone	Rear
	15	Forearm muscle	Rear
	16	Arm nerve	Front
Hands and fingers	17	Forefinger pad D [a]	Front
	18	Forefinger pad ND [a]	Front
	19	Forefinger end joint D [a]	Rear
	20	Forefinger end joint ND [a]	Rear
	21	Thenar eminence	Front
	22	Palm D [a]	Front
	23	Palm ND [a]	Front
	24	Back of the hand D [a]	Rear
	25	Back of the hand ND [a]	Rear

Body region broken down further into specific body areas



ISO / TS 15066 – 2016

Table A2

Table A.2 — Biomechanical limits

Body region		Specific body area	Quasi-static contact		Transient contact	
			Maximum permissible pressure [a] p_S N/cm²	Maximum permissible force [b] N	Maximum permissible pressure multiplier [c] P_T	Maximum permissible force multiplier [c] F_T
Skull and forehead [d]	*1*	*Middle of forehead*	*130*	*130*	*not applicable*	*not applicable*
	2	*Temple*	*110*		*not applicable*	
Face [d]	*3*	*Masticatory muscle*	*110*	*65*	*not applicable*	*not applicable*
Neck	4	Neck muscle	140	150	2	2
	5	Seventh neck muscle	210		2	
Back and shoulders	6	Shoulder joint	160	210	2	2
	7	Fifth lumbar vertebra	210		2	2
Chest	8	Sternum	120	140	2	2
	9	Pectoral muscle	170		2	
Abdomen	10	Abdominal muscle	140	110	2	2
Pelvis	11	Pelvic bone	210	180	2	2
Upper arms and elbow joints	12	Deltoid muscle	190	150	2	2
	13	Humerus	220		2	
Lower arms and wrist joints	14	Radial bone	190	160	2	2
	15	Forearm muscle	180		2	
	16	Arm nerve	180		2	

Key Point : despite the fact that values have been included for the head neck and face, contact with these areas is not permitted !

Clause 5.5.5.3 states :

Contact exposure to sensitive body regions, including the skull, forehead, larynx, eyes, ears or face SHALL be prevented whenever reasonably practicable

RISK ASSESSMENT

A task based risk assessment is a requirement in almost every current machinery or robotic safety standard. While the risk assessment process is always very important, it is absolutely critical when dealing with human robot collaboration.

But don't complicate the process :

All we are trying to do is determine how likely someone is to come into contact with a hazard and how severely they will be injured. We then use that information to select the appropriate risk reduction measures to reduce the risk to an acceptable level.

RISK ASSESSMENT

Creation of a risk assessment team

- the integrator is responsible for conducting the risk assessment
- strongly encouraged to include the user in the process
    - this will ensure that all of the task and hazard combinations are identified
- the team should be comprised of a variety of stakeholders
    - this can include representation from engineering, maintenance, production, quality, safety / ergo and any external service providers (i.e., industrial cleaning services etc..)

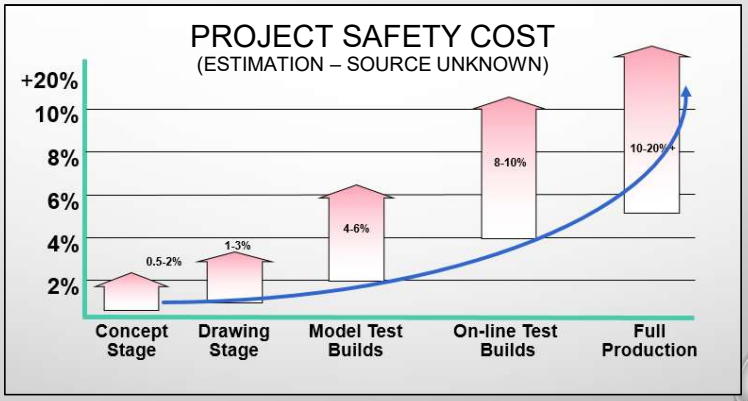
RISK ASSESSMENT

Timing

- the risk assessment should be completed as early in the design stage as possible
- this will ensure that all of the benefits can be fully realized

Concept / Design Stage

- benefits of a team based, design stage task based risk assessment include :
  - enhanced worker safety
  - buy in from stakeholders
  - improved run rates
  - cost down



RISK ASSESSMENT

Identification of tasks

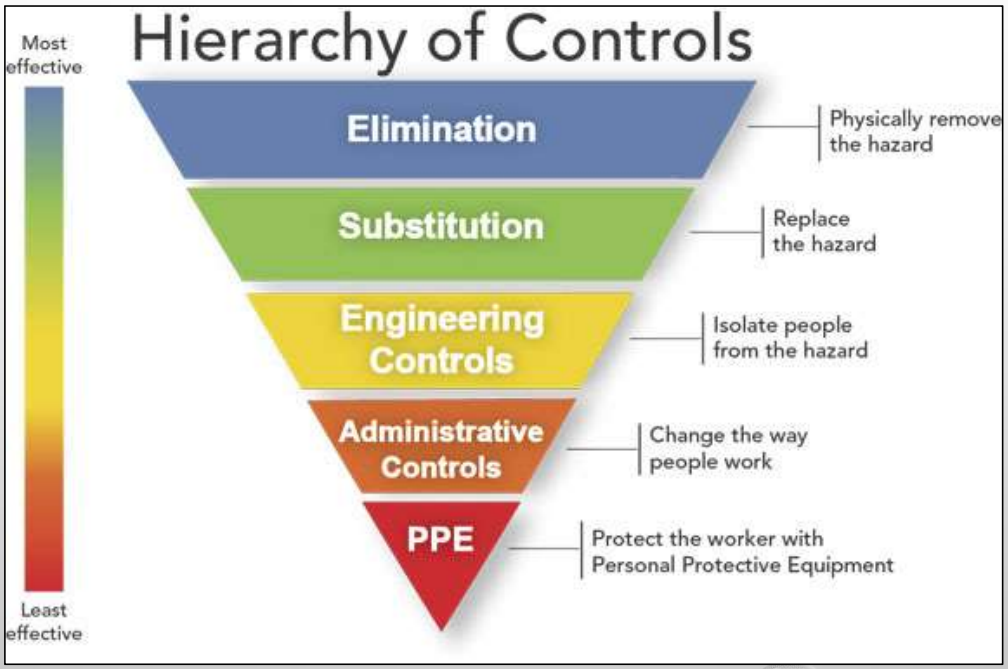
- identification of the tasks performed by the operator, and any other affected stakeholders, is critical to understanding potentially hazardous situations (i.e., task and hazard combinations)

- tasks include, but are not limited to :
  - robot system programming (teaching)
  - parts loading
  - tool or part changes
  - troubleshooting
  - brief operator intervention (i.e., jammed or dropped part)
  - maintenance
  - equipment cleaning

RISK ASSESSMENT

Hazard elimination and risk reduction

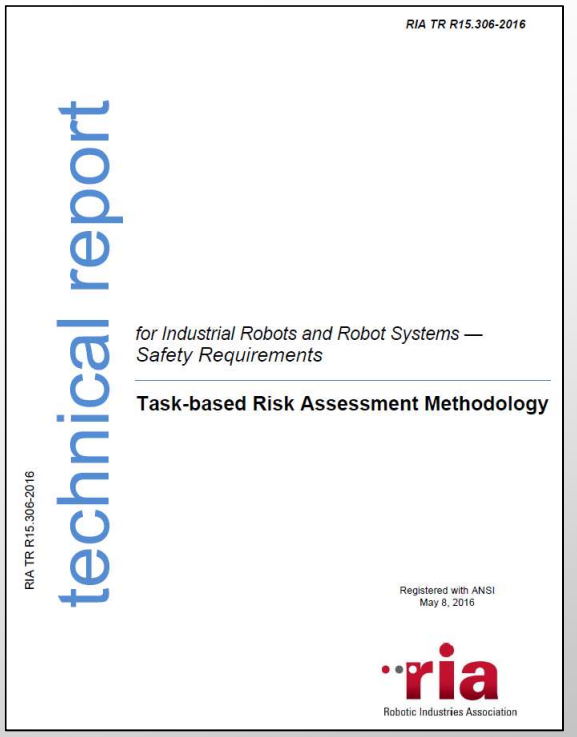
- once all of the hazards have been identified the integrator must follow the hierarch of controls :



RISK ASSESSMENT METHODOLOGY

RIA TR R15.306-2016

- Specific risk scoring system with a link to safety circuit performance level
- Parameters
  - Severity of injury
  - Frequency of exposure
  - Likelihood of avoidance



You can select any methodology as long as it meets the requirements in ISO 12100

RIA TR R15.306-2016 METHODOLOGY

Severity

Factor	Rating	Criteria (Examples) – choose most likely *Read criteria from the top for each factor*
Injury Severity	**Serious S3**	Normally non-reversible; likely will not return to the same job after recovery from incident: – fatality – limb amputation – long term disability – chronic illness **If any of the above are applicable, the rating is SERIOUS**
	Moderate S2	Normally reversible; likely will return to the same job after recovery from incident: – broken bones – severe laceration – short hospitalization – short term disability – lost time (multi-day) – fingertip amputation (not thumb) **If any of the above are applicable, the rating is MODERATE**
	Minor S1	First aid; no recovery required before returning to job: – bruising – small cuts – no loss time (multi-day) – does not require attention by a medical doctor **If any of the above are applicable, the rating is MINOR**

RIA TR R15.306-2016 METHODOLOGY

Exposure

Exposure[1]	**Prevented E0**	– Exposure to hazard(s) is eliminated/ controlled/ limited by inherently safe design measures. – Use of guards prevents exposure or access to the hazard(s) (see Part 2, 5.10). If an interlocked guard is selected, the following bullet must also be met. – If functional safety is used as a risk reduction measure, the implemented functional safety performance (PL) meets or exceeds the required functional safety performance (PL_r). See Part 2, 5.2. **If any of the above are applicable, the rating is PREVENTED**
	High E2	– Typically more than once per day or shift – Frequent or multiple short duration – Situations which could lead to increases in the duration of a task, not to include teaching tasks **If any of the above are applicable, the rating is HIGH**
	Low E1	– Typically less than or once per day or shift – Occasional short durations **If either of the above are applicable, the rating is LOW**

Note 1 : prevented is not an option when assessing initial risk as you must assume no safeguarding is in place

RIA TR R15.306-2016 METHODOLOGY

Avoidance

Avoidance	Not possible A3	– Insufficient clearance to move out of the way and safety-rated reduced speed control is not used – The robot system or cell layout causes the operator to be trapped, with the escape route toward the hazard – Safeguarding is not expected to offer protection from the process hazard (e.g. explosion or eruption hazard) **If any of the above are applicable, the rating is NOT POSSIBLE**
	Not likely A2	– insufficient clearance to move out of the way and safety-rated reduced speed control is used – obstructed path to move to safe area – hazard is moving faster than reduced speed (250 mm/sec) – inadequate warning/reaction time – the hazard is imperceptible **If any of the above are applicable, the rating is NOT LIKELY**
	Likely A1	– sufficient clearance to move out of the way – hazard is incapable of moving greater than reduced speed (250 mm/sec). – adequate warning/reaction time – positioned in a safe location away from the hazard **If any of the above are applicable, the rating is LIKELY**

RIA TR R15.306-2016 METHODOLOGY

Table 2 – Risk level decision matrix

Severity of Injury	Exposure to the Hazard	Avoidance of the Hazard	Risk Level
S1 - Minor	E0 - Prevented		NEGLIGIBLE
	E1 - Low	A1 - Likely	NEGLIGIBLE
		A2/A3 - Not likely/ Not possible	LOW
	E2 - High		LOW
S2 - Moderate	E0 - Prevented		MEDIUM
	E1 - Low		MEDIUM
	E2 - High	A1 - Likely	HIGH
		A2/A3 - Not likely/ Not possible	HIGH
S3 - Serious	E0 - Prevented		LOW
	E1 - Low	A1/A2 - Likely/Not likely	HIGH
	E2 - High	A3 - Not possible	VERY HIGH

The result of the risk decision matrix for almost all industrial robot operations, including collaborative, leads down the path highlighted below.

Even when exposure is low, as it is for robot teaching, the risk level is still high.

This is because the robot can seriously injure you and you cannot avoid it. (i.e., it is moving at a speed > 250 mm / sec)

RIA TR R15.306-2016 METHODOLOGY

Table 5 – Minimum functional safety performance

Risk Level	PL_r	Structure Category
NEGLIGIBLE (see 6.5.3.1)	b	-
LOW	c	2
MEDIUM	d	2
HIGH	d	3
VERY HIGH (see 6.5.3.2)	e	4

This minimum safety performance level satisfies the functional safety requirements for safety-related parts of the control system from 10218-1 (5.4.2) and

RIA TR R15.306-2016 METHODOLOGY

RIA TR R15.306-2016

Line No.	Task Description	Hazards	Initial risk				Risk Reduction Measures	Residual risk				
			Severity S1 - S3	Exposure E1 - E2	Avoidance A1 –A3	Risk level Tbl 2		functional safety performance (if applicable) Table 5	Severity S1 - S3	Exposure E0 - E2	Avoidance A1 –A3	Risk level Tbl 2

Risk Assessment template samples are provided in Annex A (an informative annex)

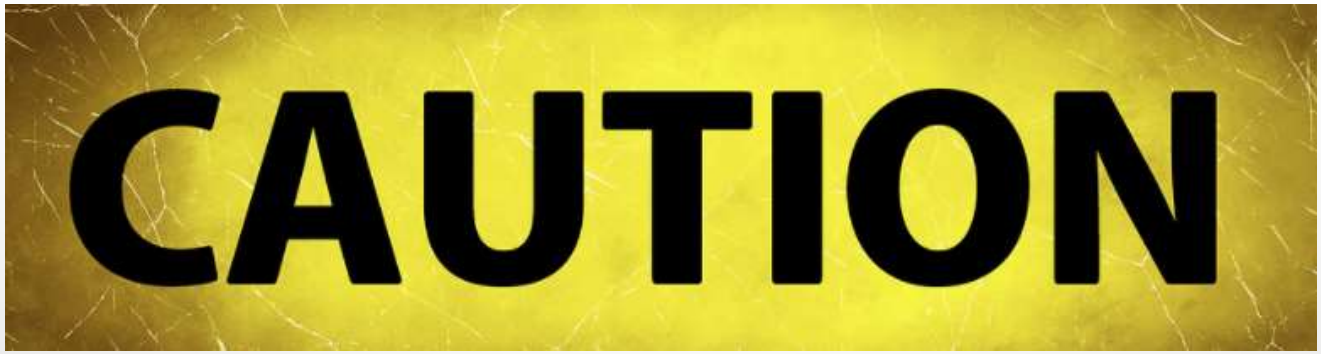
RIA TR R15.306-2016 METHODOLOGY

Cobot Safety Risk Assessment Template - based off RIA TR R15.306-2016															
				Initial Risk					Residual Risk						
Task #	Task Description	Hazard Type	Hazard Description	Severity	Exposure	Avoidance	Risk Rank	Recommentations / Risk Reduction Measures	Severity	Exposure	Avoidance	Risk Rank	Responsibility	Target Completion Date	Actual Completion Date
1															
2															
3															
4															
5															
6															
7															
8															

Cobot Safety has developed a functional excel risk assessment template based off R15.306 that automatically calculates the initial and residual risk rankings.

MOCK RISK ASSESSMENT EXERCISE # 1

Power and Force Limited Robot Polishing Application



The videos and pictures that follow were either provided, or downloaded from the internet, and will be utilized for our Mock Risk Assessments.

All descriptions of the tasks, collaborative workspace, process etc., and the corresponding hazards, have been created by the presenters for training purposes only.

NOTE : these are not intended to be comprehensive risk assessments addressing every task and hazard combination in the collaborative applications.

The primary focus is on the hazards and controls specific to the type of collaborative robot operation being utilized.

MOCK RISK ASSESSMENT EXERCISE # 1

Power and Force Limited Robot Polishing Application

MOCK RISK ASSESSMENT EXERCISE # 1

Power and Force Limited Robot Polishing Application

Task identification :

1. **robot teaching / programming**
2. material / parts loading
3. **buffing parts with power tools**
4. inspection
5. **tool change (polishing pad)**
6. material / parts transfer
7. trouble shooting
8. maintenance

Note : we are only assessing the tasks that have **bold text** in this mock risk assessment

MOCK RISK ASSESSMENT EXERCISE # 1

Robot Teaching / Programming - PFL

- Assessing the initial risk

Task #	Task Description	Hazard Type	Hazard Description	Severity	Exposure	Avoidance	Risk Rank
1	Robot teaching / programming	Struck by	Unintended contact between the operator and robot during programming (transient)	S3 - Serious	E1 - Low	A2 - Not Likely	HIGH (PLd, Cat 3)
			Operator pinched between robot and buffing table during programming (quasi-static)	S3 - Serious	E1 - Low	A2 - Not Likely	HIGH (PLd, Cat 3)

Key Points :

- the initial risk is assessed assuming no safeguards are in place
- this includes the assumption that we are starting with a “traditional” industrial robot
  - features that make it suitable for integration into a collaborative application, in this case power & force limiting, are considered risk reduction measures

MOCK RISK ASSESSMENT EXERCISE # 1

Robot Teaching / Programming - PFL

Applying risk reduction measures and assessing residual risk

Hazard Description	Recommentations / Risk Reduction Measures	Residual Risk			
		Severity	Exposure	Avoidance	Risk Rank
Unintended contact between the operator and robot during programming (transient)	Utilize a robot with power and force limiting capability compliant with ISO 10218-1:2011 Ensure teach pendant is active during programming if required (i.e. the safety-rated limiting functions are NOT active and the risk is NOT reduced by inherently safe design) Ensure all teaching is done at slow speed (250 mm/sec)	S1 - Minor	E1 - Low	A1 - Likely	NEGLIGBLE (PLb, -)
Operator pinched between robot and buffing table during programming (quasi-static)	Design collaborative workspace to minimize unintended contact between the operator and robot system Clearly identify the collaborative workspace (floor markings signage etc..)	S1 - Minor	E1 - Low	A1 - Likely	NEGLIGBLE (PLb, -)

Key Points :

- when reassessing risk, it is critical that you assume all of the risk reduction measures are in place and functioning as intended (including the effectiveness of training and other administrative controls)
- risk assessment is an iterative process. If the risk is not reduced sufficiently reduced then additional risk reduction measures must be implemented. The risk will be reassessed until it is deemed acceptable

MOCK RISK ASSESSMENT EXERCISE # 1

Robot Teaching / Programming - PFL

Assigning responsibility and ensuring completion of the risk reduction measures

Recommentations / Risk Reduction Measures	Residual Risk				Responsibility	Target Completion Date	Actual Completion Date
	Severity	Exposure	Avoidance	Risk Rank			
Utilize a robot with power and force limiting capability compliant with ISO 10218-1:2011	S1 - Minor	E1 - Low	A1 - Likely	NEGLIGBLE (PLb, -)			
Ensure teach pendant is active during programming if required (i.e. the safety-rated limiting functions are not active or the risk is reduced by inherently safe design)							
Ensure all teaching is done at slow speed (250 mm/sec)							
Design collaborative workspace to minimize unintended contact between the operator and robot system	S1 - Minor	E1 - Low	A1 - Likely	NEGLIGBLE (PLb, -)			
Clearly identify the collaborative workspace (floor markings signage etc..)							

Key Points :

- while very straight forward / intuitive, it is critical that all of the risk reduction measures are followed through to completion and documented
- If a risk reduction measure is not completed (e.g., the team later determined it was not required, this should be documented along with a brief explanation)

MOCK RISK ASSESSMENT EXERCISE # 1

Polishing Operation - PFL

Assessing the initial risk

Hazard Type	Hazard Description	Severity	Exposure	Avoidance	Risk Rank
Struck by	Operator intrudes into robot restricted space resulting in unintended contact with robot	S3 - Serious	E1 - Low	A2 - Not Likely	HIGH (PLd, Cat 3)

MOCK RISK ASSESSMENT EXERCISE

Polishing Operation - PFL

Applying risk reduction measures and assessing residual risk

Hazard Description	Recommendation's / Risk Reduction Measures	Residual Risk			
		Severity	Exposure	Avoidance	Risk Rank
Operator intrudes into robot restricted space resulting in unintended contact with robot	Limit the range of motion of the robot (i.e. the restricted space) as much as possible utilizing safety-rated programmable axis limiting	S1 - Minor	E1 - Low	A1 - Likely	NEGLIGBLE (PLb, -)
	Program the robot to minimize the distance between the table and polishing tool to prevent potential contact with the head face or neck				
	Identify potential body part / region most likely to contact robot system				
	Determine permissible force level for each affected body part utilizing table A.2 contained in ISO/TS 15066:2016				
	Verify robot speed is safety-rated and monitired				
	Secure all safety related parameters when programming is complete (i.e. password protected)				
	Validate the power and force limits for the application (i.e. a practical test with a force gauge)				
	Clearly identify the collaborative workspace (floor markings signage etc..)				
	Ensure procedures are developed with respect to change management of the robot safety functions				
	Develop and deliver operator awareness training outlining the potential hazards and corresponding controls required for the application				

MOCK RISK ASSESSMENT EXERCISE

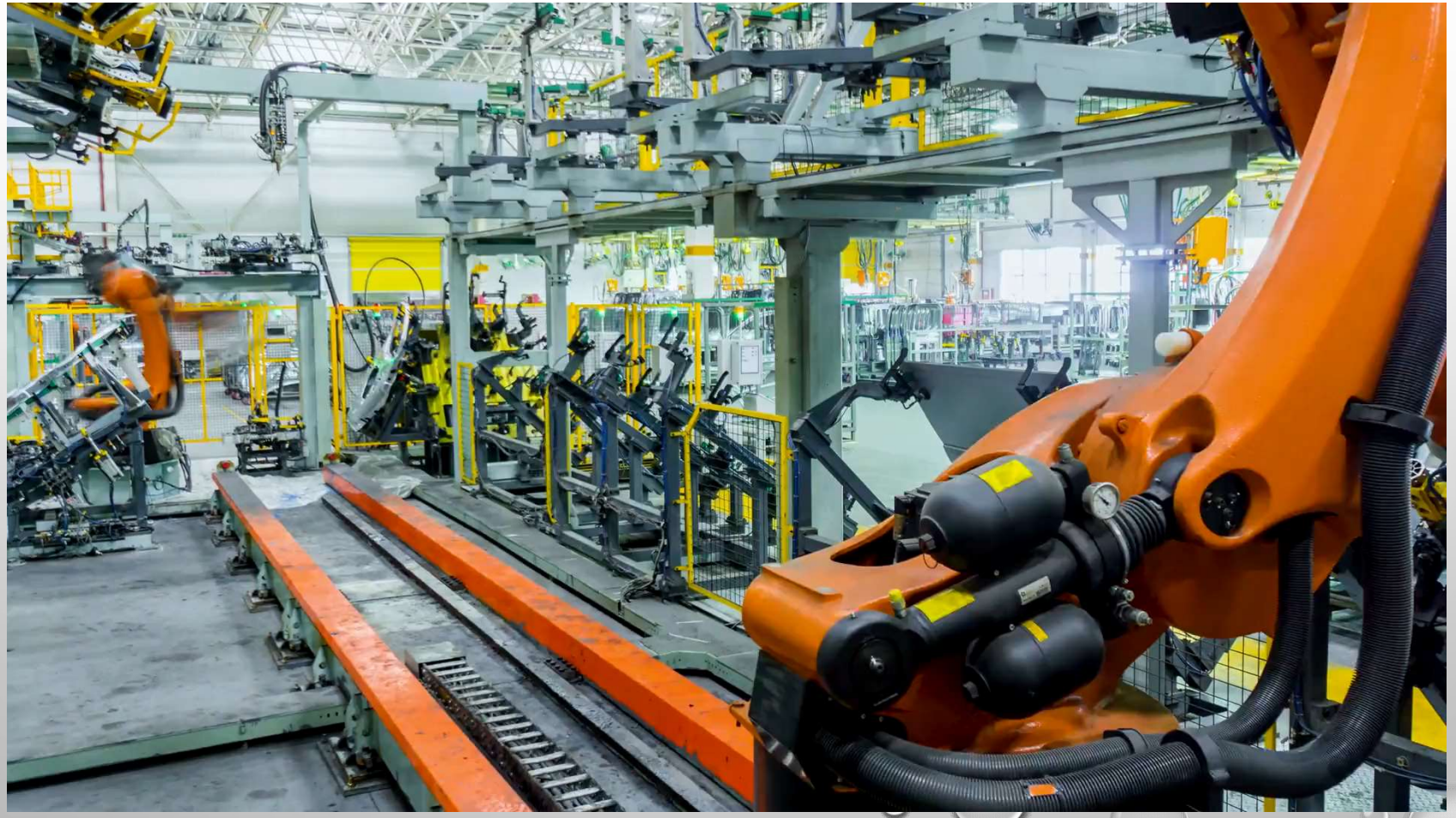
Polishing Operation - PFL

- Assigning responsibility and ensuring completion of the risk reduction measures

Recommendation's / Risk Reduction Measures	Residual Risk				Responsibility	Target Completion Date	Actual Completion Date
	Severity	Exposure	Avoidance	Risk Rank			
Limit the range of motion of the robot (i.e. the restricted space) as much as possible utilizing safety-rated programmable axis limiting	S1 - Minor	E1 - Low	A1 - Likely	NEGLIGBLE (PLb, -)			
Program the robot to minimize the distance between the table and polishing tool to prevent potential contact with the head face or neck							
Identify potential body part / region most likely to contact robot system							
Determine permissible force level for each affected body part utilizing table A.2 contained in ISO/TS 15066:2016							
Verify robot speed is safety-rated and monitired							
Secure all safety related parameters when programming is complete (i.e. password protected)							
Validate the power and force limits for the application (i.e. a practical test with a force gauge)							
Clearly identify the collaborative workspace (floor markings signage etc..)							
Ensure procedures are developed with respect to change management of the robot safety functions							
Develop and deliver operator awareness training outlining the potential hazards and corresponding controls required for the application							

Reminder :
Don't forget to ensure all of the risk reduction measures have been completed and signed off prior to start up !

SPEED AND SEPARATION MONITORING



MOCK RISK ASSESSMENT EXERCISE # 2

Speed and Separation Monitoring Application

Task identification :

1. **robot teaching / programming**
2. **control panel assembly on set jig**
3. inspection
4. trouble shooting
5. maintenance

Note : we are only assessing the tasks that have **bold text** in this mock risk assessment

MOCK RISK ASSESSMENT EXERCISE # 2

Control Panel Assembly by Operator - SSM

- Assessing the initial risk

Task Description	Hazard Type	Hazard Description	Initial Risk			
			Severity	Exposure	Avoidance	Risk Rank
Operator assembles control panel components inside the safegaurded space	Struck against	Operator struck by robot	S3 - Serious	E2 - High	A2 - Not Likely	HIGH (PLd, Cat 3)

MOCK RISK ASSESSMENT EXERCISE # 2

Control Panel Assembly by Operator - SSM

- Applying risk reduction measures and assessing residual risk

Recommendation's / Risk Reduction Measures	Residual Risk			
	Severity	Exposure	Avoidance	Risk Rank
Determine and set the protective separation distance in accordance with the formula provided in ISO/TS 15066:2016 clause 5.5.4.2.3	S1 - Minor	E0 - Prevented	A1 - Likely	NEGLIGBLE (PLb, -)
Ensure the robot initiates a protective stop if any part of the robot system if the protective separation distance is not maintained				
Ensure any hazardous process being performed by the robot system (i.e. rotating tool) cease motion if the protective separation distance is not maintained				
Determine the maximum number of people that can be protected by the safeguarding system and ensure it is never exceeded				
Ensure all operators are detected when entering or exiting the collaborative workspace				
Conduct and document a validation of the safeguarding system prior to operation				
Secure all safety related parameters when programming is complete (i.e. password protected)				
Ensure procedures are developed with respect to change management of the robot safety functions				
Develop and deliver training for operators outlining the specific hazards associated with speed and separation monitoring collaborative robot operation				

POST-TRAINING KNOWLEDGE TRANSFER CONFIRMATION

POST-TRAINING KNOWLEDGE TRANSFER CONFIRMATION

Which CSA Standard applies to Industrial Robot Safety ?

- Z432
- Z460
- Z434
- Z142

Which ISO Standard applies to Industrial Robot Safety ?

- 13855
- 10218
- 13857
- Z142

Which Industrial Robot Safety Standard should I follow in Canada ?

- ISO 10218
- RIA R15.06
- CSA Z434
- The most current industry standard

There is no such thing as a Collaborative Robot or “Cobot” ?
T or F

POST-TRAINING KNOWLEDGE TRANSFER CONFIRMATION

A risk assessment is required for all collaborative applications ?
T or F

The two most common types of collaborative applications are ?

- hand guiding / speed & separation monitoring
- safety rated monitored stop / power & force limited
- speed & separation monitoring / power & force limited
- safety rated monitored stop / hand guiding

Contact with the head, face or neck is permitted in a power and force limited collaborative application ?
T or F

ISO 10218 Parts 1 & 2 will be the base document for the next edition of CSA Z434
T or F

Compliance to the requirements contained in CSA Z434 is optional in BC ?
T or F

BIBLIOGRAPHY

Reference documents :

ISO/TS15066-2016 *Robots and robotic devices – Collaborative robots*

ISO *10218-1 Robots and robotic devices – Safety requirements for industrial robots Part 1 : Robots*

ISO *10218-2 Robots and robotic devices – Safety requirements for industrial robots Part 2 : Robot Systems and Integration*

ISO 13849-1:2006 *Safety of Machinery – Safety related parts of the control systems – Part 1 : General principles for design*

ISO 13850 *Safety of Machinery – Emergency Stop – Principles for design*

ISO 13855 *Safety of Machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body*

ISO 13857 *Safety of Machinery – Safety distances to prevent hazard zones being reached by the upper and lower limbs*

REFERENCE MATERIALS

Provided by :

Advanced Motion and Controls

Universal Robots

Veo Robotics

Inxpect

Fanuc Robotics

Cobot Safety thanks you for the support !!!

COBOT SAFETY PROFESSIONAL SERVICES

- Risk assessment services for new or existing equipment
- Technical Standards and Compliance Training (virtual or in person)
  - Risk assessment
  - Industrial Robot Safety (CSA Z434)
  - Lockout and Other Methods (CSA Z460)
  - Safeguarding of Machinery (CSA Z432)
  - Pre-Start Health & Safety Reviews
- Equipment Safety Compliance Audits

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QUESTIONS