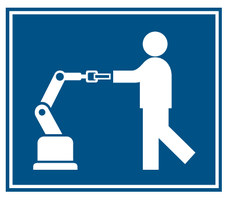
# HRC – Human-robot collaboration
# ISO/TS 15066

PILZ
THE SPIRIT OF SAFETY

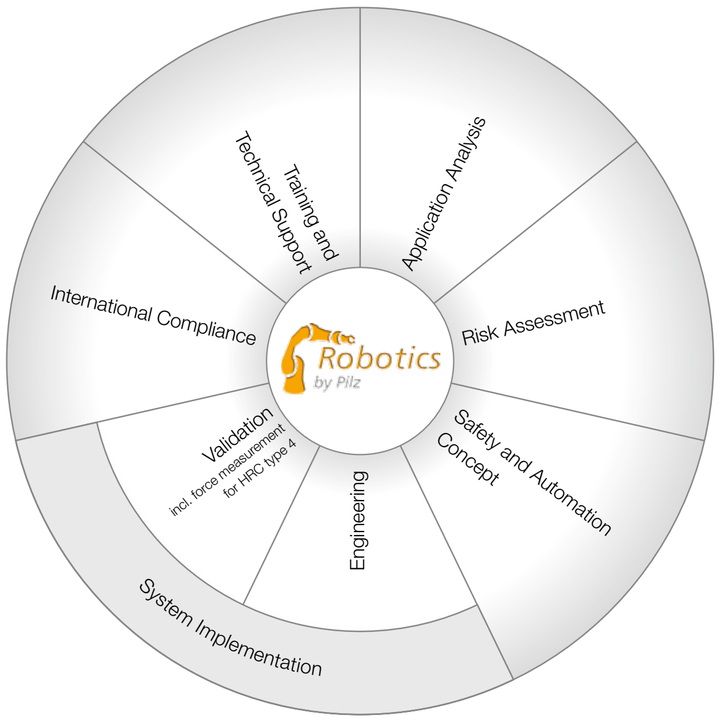
## We automate. And we create. Safe HRC.

Robotics by Pilz

## Lifecycle



**Services throughout the lifecycle of a robot system**
Pilz is here to support you in the implementation of relevant standards and directives: from an optimum safety strategy to a compliant robot application. The final piece of the offering is the range of HRC training courses.




**Risk assessment**
We review your robot application in accordance with the applicable national standards and directives and assess the existing hazards.

**Safety concept**
We develop detailed technical solutions for the safety of your robot application through mechanical, electronic and organisational measures.

**System integration**
The results of the risk assessment and safety concept are implemented to suit the particular requirements through selected safety measures.

**International Compliance**
We ensure conformity with the official requirements, such as CE marking in Europe, or OSHA in the USA, NR-12 in Brazil, KOSHA in Korea, GOST in Russia, or CCC in China.

**Safety design**
A detailed planning of the necessary protective measures reduces or eliminates the danger zones of the application.

**Validation**
Our expert specialist staff review and analyse the risk assessment and safety concept and perform collision measurement in accordance with the limit values laid down in ISO/TS 15066.

**Training and technical support**
Our training courses impart professional expertise relating to the safe application of robots. Our technical support team can be contacted round the clock.

## Determination of the type of collaboration

Do robot and human share a workstation? — Yes → Do human and robot work simultaneously? — Yes → Are there points of contact between human and robot?

- No → **Coexistence**
  The human works at a workstation near a robot's workstation.
  - There is no overlap between the workspaces and no physical contact when used in accordance with its intended purpose.
- No → **Sequential cooperation**
  Human and robot work on the same workpiece sequentially: if the human is working, the robot is stopped. While the robot is working, the worker is not present in the shared workspace.
  - When used in accordance with its intended purpose, there is no physical contact between the human and the robot.
- No → **Parallel cooperation**
  Human and robot work at the same time in the same workspace.
  - Physical contact between human and robot is possible.
- Yes → **Collaboration**
  The closest type of cooperation: man and robot work hand in hand.
  - Physical contact is necessary.

## Reducing risk in human-robot collaboration (HRC)

| Coexistence | Sequential cooperation | Parallel cooperation | Collaboration |
|---|---|---|---|
| 1, 3, 4 | 1, 3, 4 | 3, 4 | Hand-guided robot? Yes → 2, No → 4 |

① Safety-related stop
② Hand guiding
③ Speed and separation monitoring
④ Power and force limiting

**The combination of various methods is possible, such as the combination of method 3 and 4.**

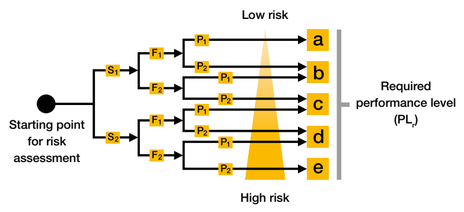
## EN ISO 13849-1

**Applicable for electrical/electronic/programmable electronic/hydraulic/pneumatic/mechanical systems**

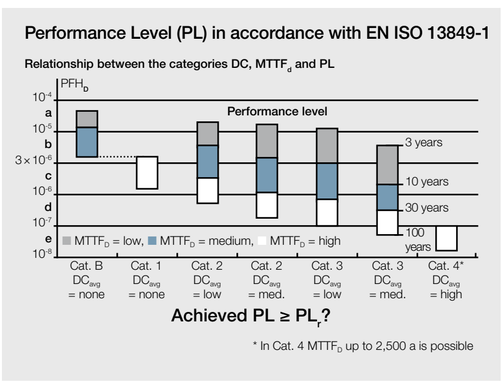
## PL definition for each safety function

### Determination of the required performance level ($PL_r$)

- **S – Severity of injury**
  $S_1$ = Slight (normally reversible injury)
  $S_2$ = Serious (normally irreversible injury including death)
- **F – Frequency and/or duration of exposure to a hazard**
  $F_1$ = Seldom to quite often and/or the exposure time is short
  $F_2$ = Frequent to continuous and/or the exposure time is long
- **P – Possibility of avoiding the hazard**
  $P_1$ = Possible under specific conditions
  $P_2$ = Scarcely possible
- **Probability of occurrence of a hazardous event**
  A low probability can reduce the $PL_r$ by one level.

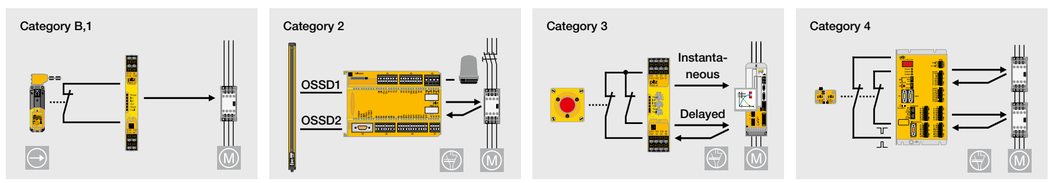



### Probability of a dangerous failure per hour – comparison PL/SIL




Acc. to EN ISO 10218-1/-2 $PL_r$d Cat. 3

### Specification of categories

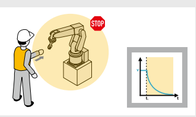



**The solutions illustrated here are provided purely by way of example.**

## Explanations on the options for risk reduction

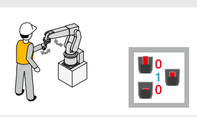
### Methods of human-robot collaboration in accordance with EN ISO 10218-2 and ISO/TS 15066

**1**



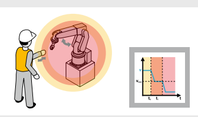
**Method 1 – safety-rated monitored stop**
On entry into the collaboration zone the robot goes into a safe operating stop. Upon leaving the collaboration zone the robot resumes its movement automatically or by a reset. The speed is determined according to the risk assessment.

**2**



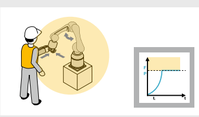
**Method 2 – hand guiding**
The human can only approach the stationary robot. On operation of the enabling device, the robot can be guided manually with safely reduced speed. The speed is determined according to the risk assessment.

**3**



**Method 3 – speed and separation monitoring**
Protective devices are positioned in such a way that people can approach the robot at any time without any risk. Separation of the human and the robot is monitored and the speed is adjusted accordingly. The robot switches off before a collision occurs.

**4**



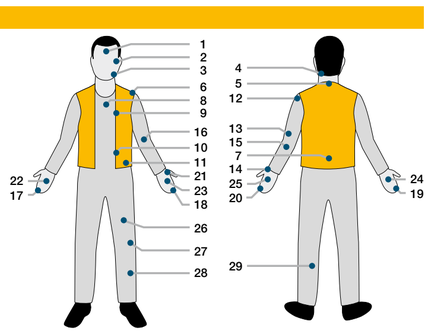
**Method 4 – power and force limiting**
A collision between human and robot is possible when the biomechanical limit values are complied with.

## Method 4

### Biomechanical limit values from ISO/TS 15066

| Body area (body region) | | Specific body area | Quasi-static contact (clamping) Maximum permissible pressure PS (N/cm²) | Quasi-static contact (clamping) Maximum permissible force (N) | Transient contact (impact) Maximum permissible pressure PS (N/cm²) | Transient contact (impact) Maximum permissible force (N) |
|---|---|---|---|---|---|---|
| Skull and forehead | 1 | Middle of forehead | 130 | 130 | 130 | 130 |
| | 2 | Temple | 110 | | 110 | |
| Face | 3 | Masticatory muscle | 110 | 65 | 110 | 65 |
| Neck | 4 | Neck muscle | 140 | 150 | 280 | 300 |
| | 5 | 7th neck vertebra | 210 | | 420 | |
| Back and shoulders | 6 | Shoulder joint | 160 | 210 | 320 | 420 |
| | 7 | 5th lumbar vertebra | 210 | | 420 | |
| Chest | 8 | Sternum | 120 | 140 | 240 | 280 |
| | 9 | Pectoral muscle | 170 | | 340 | |
| Abdomen | 10 | Abdominal muscle | 140 | 110 | 280 | 220 |
| Pelvis | 11 | Pelvic bone | 210 | 180 | 420 | 360 |
| Upper arms and elbow joints | 12 | Deltoid muscle | 190 | 150 | 380 | 300 |
| | 13 | Humerus | 220 | | 440 | |
| Lower arms and wrist joints | 14 | Radial bone | 190 | 160 | 380 | 320 |
| | 15 | Forearm muscle | 180 | | 360 | |
| | 16 | Inside of elbow | 180 | | 360 | |
| Hands and fingers | 17 | Forefinger pad D | 300 | 140 | 600 | 280 |
| | 18 | Forefinger pad ND | 270 | | 540 | |
| | 19 | Forefinger end joint D | 280 | | 560 | |
| | 20 | Forefinger end joint ND | 220 | | 440 | |
| | 21 | Thenar eminence | 200 | | 400 | |
| | 22 | Palm D | 260 | | 520 | |
| | 23 | Palm ND | 260 | | 520 | |
| | 24 | Back of the hand D | 200 | | 400 | |
| | 25 | Back of the hand ND | 190 | | 380 | |
| Thighs and knees | 26 | Thigh muscle | 250 | 220 | 500 | 440 |
| | 27 | Kneecap | 220 | | 440 | |
| Lower legs | 28 | Middle of shin | 220 | 130 | 440 | 260 |
| | 29 | Calf muscle | 210 | | 420 | |

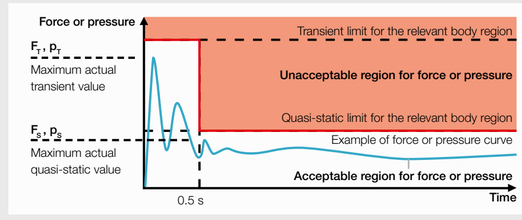
D = dominant ND = non-dominant




| Body region | Damping materials for pressure measurement in accordance with DGUV-FB HM-080 (Shore A) | Spring constants in accordance with ISO/TS 15066 (N/cm³) |
|---|---|---|
| Skull and forehead | 70 | 150 |
| Face | | 75 |
| Hands and fingers | | 75 |
| Neck | | 50 |
| Lower arms and wrist joints | | 40 |
| Chest | | 25 |
| Pelvis | | 25 |
| Lower legs | 30 | 60 |
| Thighs and knees | | 50 |
| Back and shoulders | | 35 |
| Upper arms and elbow joints | | 30 |
| Abdomen | 10 | 10 |

## Validation

### Measurement of force and pressure in accordance with ISO/TS 15066




### Annex G EN ISO 10218-2

**Safety requirements for robot systems and integration in accordance with EN ISO 10218-2**

Table G lists the specific performance requirements that must be considered as essential and be verified and/or validated.

## Lexicon

- **Category (Cat.)**
  Classification of the safety-related parts of a control system in respect of their resistance to faults and their subsequent behaviour in the fault condition, and which is achieved by the structural arrangement of the parts, fault detection and/or by their reliability
- **Collaborative workspace**
  Workspace within the safe-guarded space where the robot and human can perform tasks simultaneously during production operation
- **Common Cause Failure (CCF)**
  Failure due to a common cause
- **$DC_{avg}$**
  Average diagnostic coverage
- **Diagnostic coverage (DC)**
  Measure for the effectiveness of diagnostics; may be determined as the ratio of the failure rate of detected dangerous failures and the failure rate of total dangerous failures
- **Fault**
  State of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources
- **Mission time**
  Period in which the SRP/CS is used
- **$MTTF_D$**
  Average time to dangerous failure
- **Performance Level (PL)**
  Discrete level to specify the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions
- **Performance Level, required ($PL_r$)**
  Performance level (PL) in order to achieve the required risk reduction for each safety function
- **$PFH_D$**
  Probability of dangerous failure per hour
- **Quasi-static contact (clamping)**
  Contact between operator and robot in which the operator's body part is clamped between a fixed interfering contour and the robot
- **Risk**
  Combination of the probability of occurrence of harm and the severity of that harm
- **Robot Collision Measurement (RCMP)**
  Designates the measuring point for collision measurement
- **Safety-related control function (SRCF)**
  Control function implemented by an SRECS with a specified integrity level that is intended to maintain the safe condition of the machine or to prevent an immediate increase of the risk(s)
- **Safety-related part of a control system (SRP/CS)**
  Part of a control system that responds to safety-related input signals and generates safety-related output signals
- **Safety function**
  Function of the machine whose failure can result in an immediate increase of the risk(s)
- **Shore A**
  The Shore hardness is a core value for elastomers and plastics. It states the hardness of the material. The Shore scale ranges from 0 Shore to 100 Shore. A high number means a high degree of hardness.
- **SRECS**
  Safety-Related Electrical Control System
- **Transient contact (impact)**
  Contact between operator and robot in which the operator is not clamped and can retreat
- **Validation**
  Confirmation by examination and by provision of a certificate stating that special requirements for a specific intended use are met
- **Verification**
  Confirmation by examination and by provision of a certificate stating that the requirements of the specification have been met

The measures outlined on this sheet are simplified descriptions and are intended to provide an overview of the standards EN ISO 12100, EN ISO 13849-1 and EN ISO 10218-2. Detailed understanding and correct application of all relevant standards and directives are needed for validation of safety circuits. As a result, we cannot accept any liability for omissions or incomplete information.

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