



CE TECHNICAL DOCUMENTATION

Sample project: CE marking robotic welding cell RSZ-2600

Robotic welding cell RSZ-2600 (assembly of machinery)

Project no.	MUSTER-2026-001-EN
Customer	Beispiel-Ansprechpartner — Muster Maschinenbau GmbH
Location	Plant Musterstadt, Hall 2
Status	Active
As of	18/09/2026

MACHINE DESCRIPTION

Robotic MAG welding cell RSZ-2600 for arc welding of steel assemblies up to 40 kg workpiece weight in series production. Special-purpose machine, single unit. Configuration as an assembly of machinery: (1) Articulated-arm industrial robot, 6 axes, reach 2600 mm, payload 12 kg, supplied by the robot manufacturer as partly completed machinery with a declaration of incorporation in accordance with Annex V Part B and assembly instructions in accordance with Annex XI. ...

Excerpt: the full description is in module 1 under "Intended use".

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1. Risk assessment

according to EN ISO 12100

Robotic welding cell RSZ-2600 (assembly of machinery)

Intended use: automated MAG welding of steel assemblies up to 40 kg workpiece weight in series production. The operator manually places the workpieces at the respective front station of the two-station rotary table, clamps them pneumatically and removes the welded assemblies; the welding process is carried out fully automatically by the robot behind the fixed dividing partition. The cell is intended for stationary use in a production hall (indoors) and may only be operated by instructed skilled personnel in the operating modes Automatic and Set-up. Permitted materials: uncoated structural steels in accordance with the approved welding procedure specification (WPS). Any other use, in particular the welding of coated or galvanised parts, is considered not to be the intended use.

Limits of the machinery: Use limits: workpieces up to 40 kg, maximum dimensions 800 x 600 x 400 mm; workpieces over 15 kg are loaded using a lifting device provided by the operator. MAG welding (process 135) of uncoated structural steel S235 to S355, solid wire 1.0 to 1.2 mm, shielding gas M21 (argon-CO₂ mixture), cycle time approximately 90 seconds.

Spatial limits: floor area of the cell approximately 6.5 x 4.0 m plus an 800 mm maintenance aisle around the safety fence; personnel access only via the loading station with the light curtain and the interlocked maintenance door.

Time limits: designed for two-shift operation (16 h per working day); maintenance intervals in accordance with the operating instructions; intended service life 15 years.

Environmental limits: indoors, +5 to +40 degrees C, relative humidity up to 70 per cent non-condensing, level load-bearing industrial floor, adequate hall ventilation.

Energy limits and interfaces: 400 V AC 50 Hz, connected load 32 kVA; compressed air 5 to 7 bar (nominal value 6 bar); shielding gas supply via operator-side ring main or cylinder bank; welding fume extraction 1800 m³/h with filter cartridge, return of the cleaned air to the hall.

Reasonably foreseeable misuse: Bypassing or manipulating guards: climbing over the safety fence, reaching through or over the light curtain, manipulating the guard locking of the maintenance door or the enabling device. Presence of a second person in the cell in set-up mode outside the set-up operator's field of view. Reaching into the rotary table during rotation, for example to reposition a slipped workpiece. Loading of impermissible workpieces: too heavy, too large, oily, coated or galvanised (increased hazardous substance emission). Manual lifting of workpieces over 15 kg without a lifting device. Operation with a saturated filter cartridge or with the extraction switched off. Cleaning, maintenance and fault-clearing work without isolation and securing against re-energisation (electrical energy, residual pneumatic energy). Operation by uninstructed personnel. Unprotected viewing of the arc by bystanders when the maintenance door is open in set-up mode.

Protection against corruption (security for safety)

Threat analysis according to prEN 50742 (draft) route A as part of this risk assessment; 9 scenarios of the hazard type "Corruption/security" assessed, legal basis per scenario in square brackets (MR (EU) 2023/1230 Annex III No. 1.1.9, 1.2.1, 1.2.6). IEC 62443-3-3 is cited per scenario as the reference for route B. No presumption of conformity as long as there is no OJ reference.

Interface inventory: Network / fieldbus / line integration; Remote access / remote maintenance; USB / removable media; Operator panel (HMI) with user and parameter management; Engineering / programming access

Standards cited without presumption of conformity: EN 149 (filtering half masks to protect against particles; legal framework: Regulation (EU) 2016/425 on personal protective equipment), EN 169 (welding filters), EN 388 (protective gloves against mechanical risks; legal framework: Regulation (EU) 2016/425 on personal protective equipment), EN 407 (protective gloves against thermal risks; legal framework: Regulation (EU) 2016/425 on personal protective equipment), EN 60903 (insulating gloves for live working; legal framework: Regulation (EU) 2016/425 on personal protective equipment), EN ISO 11611 (protective clothing for welding and allied processes; legal framework: Regulation (EU) 2016/425 on personal protective equipment), EN ISO 20345 (safety footwear; legal framework: Regulation (EU) 2016/425 on personal protective equipment), ISO 7010 (registered safety signs). These standards are not listed in the Official Journal of the EU as harmonised standards for the Machinery Directive or the Machinery Regulation and therefore do not confer a presumption of conformity; applying them as recognised state of the art is permitted.

Transport (1 hazard)

No. 28		Environment	Risk before: S 5 · P 2 · RZ 10
Hazard from falling parts during transport and installation of the cell: During crane or forklift truck transport of cell components (safety fence segments, control cabinet, robot base frame), parts may fall due to rigging errors or load pendulation and strike persons.			
Sub-machine: Overall system (transport / installation) · also in: Assembly			
Step 1 · Inherent	All cell components (safety fence segments, control cabinet, robot base frame) are provided with constructively and permanently integrated lifting points designed in accordance with applicable standards (e.g. eye bolts in accordance with DIN 580 or lifting eyes in accordance with DIN 582) with a clearly marked working load limit (WLL) per lifting point. The centre of gravity of each component is constructively positioned or documented by marking on the component such that a stable, pendulation-free load attachment angle of a maximum of 45 degrees to the vertical can be maintained (design based on DGUV Regel 100-500 Chapter 2.8 as a planning reference). This reduces the probability of a rigging error through the design itself.		
Step 2 · Technical	Residual risk from load pendulation and persons present in the hazard area: (1) Technical transport documentation: For each component, a rigging plan (drawing with lifting points, centre of gravity position, selection of lifting accessories and WLL) is to be provided as part of the assembly documents ((EU) 2023/1230 Annex III No. 1.7.4.2, information on transport and handling). (2) Cordoning off the hazard area: During all crane lifts, the area below and to the side of the load is to be secured by physical barriers (barrier tape, barrier fencing) so that no unintended access by persons is possible. (3) Lifting accessories: Selection and use of tested lifting accessories (chains, lifting slings, shackles) with a sufficient WLL and a valid test certificate in accordance with the Ordinance on Industrial Safety and Health (BetrSichV). A safety function within the meaning of EN ISO 13849-1 is not applicable to this transport phase; a PLr is not to be assigned.		
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4.2): (1) Include rigging plans with lifting points, centre of gravity position and WLL per component as part of the assembly instructions chapters. (2) Qualification requirement: crane operations and load rigging may only be carried out by instructed and authorised riggers (in accordance with DGUV Grundsatz 309-007). (3) Warning labelling on each component: warning of suspended load (sign in accordance with DIN EN ISO 7010, warning of suspended load), indication of the mass and the WLL per lifting point directly on the component. (4) PPE specification: safety helmet, safety footwear (S3) and high-visibility vest are mandatory during all transport operations. (5) Note: remaining beneath suspended loads is prohibited.		
Risk after:	5	Residual risk accepted: Yes	

Assembly (4 hazards)

No. 28 Environment		Risk before: S 5 · P 2 · RZ 10
Hazard from falling parts during transport and installation of the cell: During crane or forklift truck transport of cell components (safety fence segments, control cabinet, robot base frame), parts may fall due to rigging errors or load pendulation and strike persons.		
Sub-machine: Overall system (transport / installation) · also in: Transport		
Step 1 · Inherent	All cell components (safety fence segments, control cabinet, robot base frame) are provided with constructively and permanently integrated lifting points designed in accordance with applicable standards (e.g. eye bolts in accordance with DIN 580 or lifting eyes in accordance with DIN 582) with a clearly marked working load limit (WLL) per lifting point. The centre of gravity of each component is constructively positioned or documented by marking on the component such that a stable, pendulation-free load attachment angle of a maximum of 45 degrees to the vertical can be maintained (design based on DGUV Regel 100-500 Chapter 2.8 as a planning reference). This reduces the probability of a rigging error through the design itself.	
Step 2 · Technical	Residual risk from load pendulation and persons present in the hazard area: (1) Technical transport documentation: For each component, a rigging plan (drawing with lifting points, centre of gravity position, selection of lifting accessories and WLL) is to be provided as part of the assembly documents ((EU) 2023/1230 Annex III No. 1.7.4.2, information on transport and handling). (2) Cordoning off the hazard area: During all crane lifts, the area below and to the side of the load is to be secured by physical barriers (barrier tape, barrier fencing) so that no unintended access by persons is possible. (3) Lifting accessories: Selection and use of tested lifting accessories (chains, lifting slings, shackles) with a sufficient WLL and a valid test certificate in accordance with the Ordinance on Industrial Safety and Health (BetrSichV). A safety function within the meaning of EN ISO 13849-1 is not applicable to this transport phase; a PLr is not to be assigned.	
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4.2): (1) Include rigging plans with lifting points, centre of gravity position and WLL per component as part of the assembly instructions chapters. (2) Qualification requirement: crane operations and load rigging may only be carried out by instructed and authorised riggers (in accordance with DGUV Grundsatz 309-007). (3) Warning labelling on each component: warning of suspended load (sign in accordance with DIN EN ISO 7010, warning of suspended load), indication of the mass and the WLL per lifting point directly on the component. (4) PPE specification: safety helmet, safety footwear (S3) and high-visibility vest are mandatory during all transport operations. (5) Note: remaining beneath suspended loads is prohibited.	
Risk after: 5	Residual risk accepted: Yes	

No. 29 EnvironmentRisk before: S 4 · P 2 · **RZ 8**

Hazard from insufficient stability of the cell during installation: if the cell is installed on an uneven or non-load-bearing floor, or if the levelling feet are not secured, the system may tip over or shift; persons in the vicinity may be struck.

Sub-machine: Overall system (installation) · also in: Commissioning

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| Step 1 · Inherent | Constructive assurance of stability by means of an adequately dimensioned, torsionally rigid base frame (welded frame structure or structural steel frame) with a wide base area and low centre of gravity in accordance with EN ISO 12100:2010 section 6.2.5 (stability). Levelling feet with integrated lock nut and anti-rotation device (e.g. square shank in receiver) to be designed constructively so that securing without a special tool is not possible (positive locking rather than friction locking). Fixing bores in the base frame for floor anchoring (heavy-duty anchors) to be provided so that anchoring is possible without reworking. The centre of gravity position and tipping resistance are to be verified by calculation as part of the design (stability verification in accordance with EN ISO 12100:2010 section 6.2.5). |
| Step 2 · Technical | Technical protective measures for the remaining residual risk during assembly and commissioning: (1) Provision of a machine-specific installation plan (dimensional drawing with minimum floor load-bearing capacity, flatness tolerance of the substrate and anchor point positions) as part of the delivery documentation, which is to be approved by the operator before assembly commences. (2) Marking of the levelling feet and anchor points on the base frame by means of permanent markings (arrow or labelling) so that assembly personnel can identify the positions unambiguously. (3) If the system is not permanently anchored: verification of stability without anchoring (tipping resistance verification, ratio of stabilising moments to tipping moments of at least 1.5) in accordance with EN ISO 12100:2010 section 6.2.5. These measures are not safety functions within the meaning of EN ISO 13849-1 and do not require a PLr. |
| Step 3 · Information | Level 3: User information for remaining residual risks: (1) Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): chapter 'Installation and Assembly' with binding specifications for: minimum floor load-bearing capacity (contact pressure in kN/m ² , to be determined and entered by the designer), required flatness of the substrate, prescribed tightening torque of the lock nuts of the levelling feet, obligation to anchor to the floor with specification of the anchor type and embedment depth, and reference to the installation plan. (2) Warning marking on the base frame: warning sign 'Warning: risk of tipping' (ISO 7010) on at least two opposite sides of the base frame, visible during assembly. (3) Qualification requirement: installation and levelling may only be carried out by qualified specialist personnel (industrial mechanics or fitters with experience in machine installation); requirement to be stated in the operating instructions. (4) PPE notice: safety footwear (EN ISO 20345, protection class S3) and protective gloves during assembly; specification in the operating instructions. |

Risk after: **4** Residual risk accepted: Yes

No. 33 MechanicalRisk before: S 4 · P 2 · **RZ 8**

Hazard during disassembly of the cell at the end of its service life: When dismantling protective fence segments, the robot base frame and the control cabinet, hazards arise from heavy components (crushing, falling), residual energy in lines (compressed air, electrical) and sharp edges on sheet-metal parts.

Sub-machine: Overall system (dismantling / disposal)

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| Step 1 · Inherent | Design protective fence segments, the robot base frame and the control cabinet with standardised lifting points (e.g. eyebolt threaded bores in accordance with DIN 580 or integrated crane eyes), so that each component can be rigged individually and in a positionally secured manner without persons having to stand beneath the suspended load. Deburr sheet-metal edges on enclosure parts and protective fence profiles already at the design stage and break them with a radius ≥ 0.5 mm (manufacturing drawing) in order to inherently reduce the risk of cuts. Design pneumatic lines with a de-energised default state upon energy isolation: select valves such that, when the compressed-air supply is switched off, all lines are automatically vented (spring return to venting position in accordance with EN ISO 4414 Section 5.4). |
| Step 2 · Technical | 1. Energy isolation and de-energisation prior to commencing disassembly: Identify the isolating device for electrical energy (main switch with locking facility in accordance with EN 60204-1:2018 Section 5.3) and the shut-off valve with venting function for compressed air (EN ISO 4414:2010 Section 5.4), and lock them in a secured, de-energised state before commencing disassembly (lockout/tagout procedure in accordance with EN ISO 14118:2018). Verify absence of voltage by measurement before opening the control cabinet and line connections. 2. Load handling: For components with an individual weight of more than 25 kg (reference mass in accordance with EN 1005-2:2003+A1:2008), suitable lifting equipment (crane, pallet truck, vacuum lifter) with adequate load capacity and CE marking must be used (lifting points and weights: see Step 3, operating instructions). 3. Safe distance during lifting: Prohibition on remaining beneath suspended loads in accordance with the operating procedure; barrier around the disassembly area. |
| Step 3 · Information | Operating instructions (Chapter Disassembly and Disposal, (EU) 2023/1230 Annex III No. 1.7.4): Step-by-step disassembly instructions with a defined sequence (energy isolation and venting first, then mechanical disassembly); weight data and centre-of-gravity position for each component; specification of lifting points with a diagram; reference to the lockout/tagout procedure in accordance with EN ISO 14118:2018. Warning labelling on the control cabinet and pneumatic distributor: warning of dangerous electrical voltage (ISO 7010 W012) and an information sign indicating possible residual pressure in the pneumatic lines. Qualification requirement: Disassembly to be carried out only by skilled personnel with training in electrical engineering (for work on electrical equipment) and instruction in the handling of lifting equipment. PPE specification: protective gloves against mechanical risks (EN 388), safety footwear (EN ISO 20345), safety helmet when using lifting equipment. |

Risk after: **4** Residual risk accepted: Yes

No. 39 Corruption/securityRisk before: S 4 · P 2 · **RZ 8**

Connection of external devices creates a hazardous situation: A connected external device (infeed unit, robot, test equipment, customer installation, printer) sends unexpected signals, writes to control variables or occupies resources. The machine starts, changes the operating mode or ignores stop conditions because the functions of the external device were not taken into account in the risk assessment. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.2.1 lit. h, 1.2.4.4]

Sub-machine: Interfaces to third-party equipment · also in: Commissioning, Operation

Step 1 · Inherent	Design interfaces to external devices as defined signal interfaces with specified semantics (no enabling of movements by external signals alone), route safety-relevant signals only via safe inputs/outputs, assign the stop and emergency stop chain of the external device unambiguously.
Step 2 · Technical	Whitelist of approved participants and variables, plausibility check of incoming commands, interlock of operating mode changes via external interfaces, diagnostics for missing or unknown participants. Evidence reference Path B: IEC 62443-3-3 SR 1.2, SR 2.1, SR 3.5, SR 5.2, SR 7.7.
Step 3 · Information	Operating instructions and interface description for the integrator (signals, states, requirements for the assembly of machinery in accordance with Annex III No. 1.2.4.4), note that the connection of non-approved devices requires a new risk assessment.

Risk after: **4** Residual risk accepted: Yes

Commissioning (9 hazards)

No. 12	Electrical	Risk before: S 5 · P 2 · RZ 10
Hazard from direct or indirect contact with live parts of the welding power source, the robot control cabinet and the cell control system (400 V AC, 32 kVA): Contact with terminals, cables or the interior of the control cabinet when the cabinet is open without isolation can lead to electric shock with ventricular fibrillation or burns.		
<i>Sub-machine: Electrical installation (control cabinet / welding power source) · also in: Maintenance, Troubleshooting</i>		
Step 1 · Inherent	All live parts inside the control cabinet (terminals, busbars, power terminals of the welding power source) are designed with touch-proof covers (degree of protection at least IP 2X or IPXXB in accordance with EN 60204-1:2018 Section 6.2.2), so that contact with live parts is prevented by the enclosure form itself without the need for a guard. In addition, minimum clearances between live and accessible parts are designed such that the degree of protection IP 2X is maintained even with the cabinet door open (protective caps, insulating covers on terminal strips). This addresses (EU) 2023/1230 Annex III No. 1.5.1 (Electrical energy supply) by analogy, as well as EN 60204-1:2018 Section 6.2.	
Step 2 · Technical	1. Isolation and de-energisation (LOTO): Main switch with lockable zero position in accordance with EN 60204-1:2018 Section 5.3 and EN ISO 14118:2018 (prevention of unexpected start-up / energy isolation). The main switch must disconnect the entire system from the supply on all poles as an isolating device; residual voltage at the capacitors of the welding power source is to be limited to below 60 V DC within 5 s by means of a discharge time or active discharge circuit (requirement from EN 60204-1:2018 Section 5.4). Cabinet door interlock: The doors of the main control cabinets are fitted with a door interlock (key switch or tool-operated fastener) that prevents unauthorised opening (EN 60204-1:2018 Section 6.2.2). 2. Protective equipotential bonding and protective conductor: All control cabinet enclosures, the welding power source and the robot control cabinet are connected via a continuous protective conductor (PE) of adequate cross-section (EN 60204-1:2018 Section 8.2), so that in the event of an insulation fault the fault current is safely dissipated and the protective device (circuit breaker / RCD) trips. 3. Residual current device (RCD): Use of an RCD (Type B, since DC fault currents from frequency inverters and the welding power source are possible) with a tripping current of 30 mA for circuits at which persons are working, in accordance with EN 60204-1:2018 Section 8.3 (insofar as this is feasible on the supply side and compatible with the welding process; otherwise insulation monitoring in accordance with EN 60204-1:2018 Section 8.3 as an alternative). Not a safety function with a PLr requirement; the measures act passively and by design (warning labelling: see Level 3).	
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Document the isolation procedure (LOTO) with a step-by-step instruction, including the discharge time of the capacitors of the welding power source and verification of the absence of voltage using a suitable measuring instrument (voltage tester Category CAT III 600 V). Qualification requirement: Work on the electrical installation may only be carried out by electrically skilled persons (ESP) in accordance with DGUV Vorschrift 3 / BGV A3, or under the supervision of an ESP by electrically instructed persons. PPE specification: Insulating gloves (protection class in accordance with EN 60903 corresponding to the rated voltage of 1000 V), safety goggles (arc flash protection) and antistatic footwear are to be worn when working in an open cabinet. Warning labelling: Warning of dangerous electrical voltage (ISO 7010 W012) to be affixed permanently and clearly visible to all cabinet doors and to the welding power source. Residual risk note in the operating instructions: After operation of the main switch, capacitors in the welding power source and in the frequency inverter of the robot may carry dangerous voltages for a defined period (as specified by the component manufacturer); absence of voltage must always be verified by measurement.	
Risk after:	5 Residual risk accepted: Yes	

No. 29 EnvironmentRisk before: S 4 · P 2 · **RZ 8**

Hazard from insufficient stability of the cell during installation: if the cell is installed on an uneven or non-load-bearing floor, or if the levelling feet are not secured, the system may tip over or shift; persons in the vicinity may be struck.

Sub-machine: Overall system (installation) · also in: Assembly

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| Step 1 · Inherent | Constructive assurance of stability by means of an adequately dimensioned, torsionally rigid base frame (welded frame structure or structural steel frame) with a wide base area and low centre of gravity in accordance with EN ISO 12100:2010 section 6.2.5 (stability). Levelling feet with integrated lock nut and anti-rotation device (e.g. square shank in receiver) to be designed constructively so that securing without a special tool is not possible (positive locking rather than friction locking). Fixing bores in the base frame for floor anchoring (heavy-duty anchors) to be provided so that anchoring is possible without reworking. The centre of gravity position and tipping resistance are to be verified by calculation as part of the design (stability verification in accordance with EN ISO 12100:2010 section 6.2.5). |
| Step 2 · Technical | Technical protective measures for the remaining residual risk during assembly and commissioning: (1) Provision of a machine-specific installation plan (dimensional drawing with minimum floor load-bearing capacity, flatness tolerance of the substrate and anchor point positions) as part of the delivery documentation, which is to be approved by the operator before assembly commences. (2) Marking of the levelling feet and anchor points on the base frame by means of permanent markings (arrow or labelling) so that assembly personnel can identify the positions unambiguously. (3) If the system is not permanently anchored: verification of stability without anchoring (tipping resistance verification, ratio of stabilising moments to tipping moments of at least 1.5) in accordance with EN ISO 12100:2010 section 6.2.5. These measures are not safety functions within the meaning of EN ISO 13849-1 and do not require a PLr. |
| Step 3 · Information | Level 3: User information for remaining residual risks: (1) Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): chapter 'Installation and Assembly' with binding specifications for: minimum floor load-bearing capacity (contact pressure in kN/m ² , to be determined and entered by the designer), required flatness of the substrate, prescribed tightening torque of the lock nuts of the levelling feet, obligation to anchor to the floor with specification of the anchor type and embedment depth, and reference to the installation plan. (2) Warning marking on the base frame: warning sign 'Warning: risk of tipping' (ISO 7010) on at least two opposite sides of the base frame, visible during assembly. (3) Qualification requirement: installation and levelling may only be carried out by qualified specialist personnel (industrial mechanics or fitters with experience in machine installation); requirement to be stated in the operating instructions. (4) PPE notice: safety footwear (EN ISO 20345, protection class S3) and protective gloves during assembly; specification in the operating instructions. |

Risk after: **4** Residual risk accepted: Yes

No. 30 CombinationRisk before: S 5 · P 2 · **RZ 10**

Hazard arising from incorrect parameterisation of the robot control system or the safety control system (e.g. incorrect safety distances, incorrect speed limits in set-up mode, incorrect zone releases): Erroneous parameters may result in safety functions not operating as intended, thereby endangering persons through robot movements or rotary table movements.

Sub-machine: Overall system (control / safety control) · also in: Setting up, Maintenance

- Step 1 · Inherent** Safety-relevant parameters (speed limits, protection zones, zone releases) are stored exclusively in the safety control system (safety PLC) and are protected against unauthorised or inadvertent modification by a hardware key-switch concept or a password-protected, role-based access concept. Parameter sets for safety functions SF-01 to SF-05 are stored in the safety control system as immutable, checksum-protected data records (e.g. CRC-32 or equivalent), so that any unintended modification is automatically detected at system start-up and a safe state is enforced. This principle corresponds to the inherently safe control principle in accordance with EN ISO 12100 Section 6.2.11 (control principles that limit the occurrence of hazards) and reduces the possibility of erroneous parameters becoming effective at all.
- Step 2 · Technical** 1. Validation requirement before release: Every change to safety-relevant parameters requires a documented acceptance test (functional test of all affected safety functions SF-01 to SF-05) carried out by two authorised persons (four-eyes principle) before recommissioning. The safety control system may not release automatic operation until a positive acknowledgement has been given. Basis: EN ISO 13849-2:2012 (validation of safety functions) and EN ISO 11161:2007+A1:2010 Section 5.4 (verification and validation for integrated manufacturing systems). 2. Parameter verification by the safety control system: The safety control system (PLr e for SF-04, PLr d for SF-01, SF-03, SF-05 in accordance with EN ISO 13849-1:2023) checks the consistency of the safety-relevant parameters against stored reference values (checksum comparison) at start-up and cyclically. In the event of a discrepancy, stop category 1 in accordance with EN 60204-1:2018 is triggered and a restart is inhibited (no automatic restart in accordance with EN ISO 14118:2018). 3. Set-up mode SF-05: The safely reduced speed of 250 mm/s (SF-05, PLr d) is limited at hardware level in the safety control system and cannot be overridden by parameters of the robot control system. Monitoring is performed by an SRP/CS in accordance with EN ISO 13849-1:2023, category and PL in accordance with SF-05 (PLr d). 4. Zone release rotary table SF-04: The release of the 180-degree swivel movement (SF-04, PLr e) is performed exclusively via the safety control system on the basis of verified sensor signals; a release caused by erroneous zone parameters in the robot control system alone is excluded by design. 5. Change management: All parameter changes are stored with a time stamp, user identification and predecessor/successor value in a tamper-proof change log (audit trail) of the safety control system. Basis: EN ISO 11161:2007+A1:2010.
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the parameter change procedure with a step-by-step guide, listing of all safety-relevant parameters for each safety function (SF-01 to SF-05), obligation to carry out a validation test after each change, and documentation obligation in the change log. 2. Qualification requirement: Parameter changes to the safety control system may only be carried out by specialist personnel with demonstrated qualification in functional safety (e.g. TÜV certification as Functional Safety Engineer or equivalent) and knowledge of the system. This is to be set out in the operating instructions and in an operating procedure. 3. Warning labelling: A warning sign 'Warning of dangerous electrical voltage or unexpected machine movements' (ISO 7010) and a prohibition sign 'No unauthorised access' (ISO 7010) are to be affixed to the safety control system and the control cabinet. Additionally, an information sign stating: 'Parameter changes by authorised specialist personnel only; subsequent validation test required'. 4. Commissioning checklist: Before every initial commissioning and after every parameter change, a system-specific commissioning checklist is to be completed and signed (basis: EN ISO 11161:2007+A1:2010 Section 5.4).

Risk after: **5** Residual risk accepted: Yes

No. 31 CombinationRisk before: S 5 · P 2 · **RZ 10**

Hazard from differing safety levels of the partial machines from different manufacturers (robot, welding power source, turntable, extraction system): missing or incomplete interface interlocking between the partial machines may result in one partial machine starting up even though another is in an unsafe condition (EN ISO 11161).

Sub-machine: Overall system (system integration) · also in: Operation, Troubleshooting

- Step 1 · Inherent** System architecture with a single, superordinate safety controller (Safety Master) as an inherently safe control principle in accordance with EN ISO 12100 Section 6.2.11: All safety-relevant status signals of the sub-machines (robot operating mode, turning table end position, extraction system operation, welding power source ready) are routed exclusively via the Safety Master. No sub-machine drive receives an enable signal unless the Safety Master has assessed the overall state as safe. Through this centralisation, the possibility of an incomplete interface interlock is constructively reduced to a minimum: there are no parallel, mutually independent enable paths between the sub-machines. The interface definition is carried out in accordance with EN ISO 11161:2007+A1:2010 Section 5 (system integration, responsibilities, interface description) and is documented in the safety concept of the overall installation.
- Step 2 · Technical** Level 2a: Interlock matrix in accordance with EN ISO 11161:2007+A1:2010 Section 6: For each sub-machine combination, a complete state matrix (operating mode x state of the other sub-machines) is created and implemented in the safety controller. Each enable signal is implemented as an AND-combination of all relevant safety states. Level 2b: Safety function SF-04 (enable of the 180-degree pivoting movement of the turning table only when the pivoting area is clear, PLr e in accordance with project specification) ensures that the turning table only pivots when the robot is demonstrably outside the pivoting area. The safety function is designed to PLr e in accordance with EN ISO 13849-1:2023 and validated in accordance with EN ISO 13849-2:2012. Level 2c: Safety function SF-01 (safe stopping upon opening of the maintenance door, stop category 1, PLr d) and SF-02 (safe stopping upon interruption of the light curtain, PLr e) are coordinated across the entire installation: a stop signal from one sub-machine triggers the coordinated stop of all sub-machines via the Safety Master. Stop categories in accordance with EN 60204-1:2018 Section 9.2.2 are to be defined per drive (robot: stop category 1 in accordance with SF-01/SF-03; turning table: stop category 1 in accordance with SF-03). Level 2d: Emergency stop of the overall installation (SF-03, stop category 1, PLr d in accordance with project specification) in accordance with EN ISO 13850:2015 acts on all sub-machines simultaneously via the Safety Master. Emergency stop command devices are arranged at all operator stations and access points. Level 2e: Prevention of unexpected start-up in accordance with EN ISO 14118:2018: After every stop (emergency stop, activation of a protective device, interruption of energy supply), a deliberate restart command is required; automatic restart is excluded. Level 2f: Setting mode with safely reduced speed (SF-05, 250 mm/s, PLr d in accordance with project specification) and enabling device for the robot in accordance with EN ISO 10218-2:2025 Section 5.7.7; in this mode, all other sub-machines (turning table, welding power source) are interlocked and at standstill.
- Step 3 · Information** Operating instructions for the overall installation in accordance with (EU) 2023/1230 Annex III No. 1.7.4: The interface interlock logic (state matrix, enable conditions per sub-machine) is to be documented in full. For each sub-machine, the handover point of safety responsibility (sub-machine manufacturer up to the interface, integrator from the interface onwards) is to be defined in writing in accordance with EN ISO 11161:2007+A1:2010 Section 4.3 and stated in the operating instructions. Qualification requirement: commissioning, parameterisation and modifications to the safety controller may only be carried out by qualified specialist personnel with knowledge of EN ISO 13849-1:2023 and EN ISO 11161. Warning labelling at all operator panels: warning against unexpected start-up of sub-machines (warning sign in accordance with DIN EN ISO 7010, warning against automatic start-up). The operating instructions must describe procedures for fault-finding and commissioning, including the sequence in which sub-machines may be commissioned and the verification steps for checking the interface interlock prior to the first automatic operation.

Risk after: **5** Residual risk accepted: Yes

No. 37 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Unintentional corruption through misconfiguration or operator error: Incorrect recipe or parameter file loaded, roles and passwords not set up (default password active), configuration incompletely restored after a fault. Safety-relevant settings deviate from the approved configuration without being noticed. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.2.1 lit. b, 1.2.1 lit. d, 1.2.1 lit. e]

Sub-machine: HMI / parameterisation · also in: Setting up, Operation

Step 1 · Inherent	Separate safety-relevant settings from process recipes so that a recipe change cannot alter them; hard-limit value ranges in the safety controller (limits derived from the risk assessment, Annex III No. 1.2.1 lit. d).
Step 2 · Technical	Forced password change on commissioning, role model with dual-control approval for safety-relevant changes, comparison of the active configuration with the approved reference (checksum) at start-up with display of any deviation, change log. Evidence reference Path B: IEC 62443-3-3 SR 1.5, SR 2.1, SR 3.4, SR 7.6.
Step 3 · Information	Operating instructions: commissioning checklist (passwords, roles, saving of reference configuration), description of the data designated as safety-relevant, instruction for functional testing after configuration changes.

Risk after: **4** Residual risk accepted: Yes

No. 38 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Failure or disruption of the communication network connection: Network failure, overload (broadcast storm, denial of service), cable break or change of network segment interrupts communication between control components or the safety-oriented communication (PROFIsafe, FSoE). Upon restoration, an unexpected start-up occurs or outdated setpoint values are taken over in an uncontrolled manner. [MR (EU) 2023/1230 Annex III No. 1.2.6, 1.2.1 lit. a, 1.2.3]

Sub-machine: Communication network · also in: Operation

Step 1 · Inherent	Design safety functions such that loss of communication leads to the safe state (watchdog, time monitoring of safe telegrams) and a restart only takes place after a deliberate acknowledgement (Annex III No. 1.2.3). Decouple safety-directed communication from standard communication.
Step 2 · Technical	Network segmentation and load limiting (rate limiting, storm protection at switches), monitoring of network quality with diagnostic message, defined behaviour upon loss of connection in all operating modes tested and documented. Evidence reference Path B: IEC 62443-3-3 SR 7.1, SR 7.2, SR 5.1, SR 5.2.
Step 3 · Information	Operating instructions: requirements for the operator's network (segmentation, permitted participants, no external devices in the safety segment), description of the behaviour upon communication failure and the restart procedure.

Risk after: **4** Residual risk accepted: Yes

No. 39 Corruption/securityRisk before: S 4 · P 2 · **RZ 8**

Connection of external devices creates a hazardous situation: A connected external device (infeed unit, robot, test equipment, customer installation, printer) sends unexpected signals, writes to control variables or occupies resources. The machine starts, changes the operating mode or ignores stop conditions because the functions of the external device were not taken into account in the risk assessment. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.2.1 lit. h, 1.2.4.4]

Sub-machine: Interfaces to third-party equipment · also in: Assembly, Operation

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| Step 1 · Inherent | Design interfaces to external devices as defined signal interfaces with specified semantics (no enabling of movements by external signals alone), route safety-relevant signals only via safe inputs/outputs, assign the stop and emergency stop chain of the external device unambiguously. |
| Step 2 · Technical | Whitelist of approved participants and variables, plausibility check of incoming commands, interlock of operating mode changes via external interfaces, diagnostics for missing or unknown participants. Evidence reference Path B: IEC 62443-3-3 SR 1.2, SR 2.1, SR 3.5, SR 5.2, SR 7.7. |
| Step 3 · Information | Operating instructions and interface description for the integrator (signals, states, requirements for the assembly of machinery in accordance with Annex III No. 1.2.4.4), note that the connection of non-approved devices requires a new risk assessment. |

Risk after: **4** Residual risk accepted: Yes

No. 40 Corruption/securityRisk before: S 3 · P 3 · **RZ 9**

Safety-relevant software not identifiable or labelled: The version status and checksum of the safety software cannot be retrieved at the machine, and safety-relevant software and data are not designated as such. After an intervention, update or device replacement, it cannot be determined whether the machine is still in the inspected state; operation with non-approved software remains undetected. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.1.9 para. 4, 1.7.4.2]

Sub-machine: Software / Documentation · also in: Maintenance, Operation

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| Step 1 · Inherent | Design safety-relevant software as a distinct unit with its own version number and checksum (separate from standard and visualisation software) so that unambiguous identification is technically possible. |
| Step 2 · Technical | Information page on the HMI showing the version and checksum of all safety-relevant software components (always easily accessible without login, Annex III No. 1.1.9 para. 4), labelling of safety-relevant data in file names, menus and exports, comparison with the acceptance report at start-up. Evidence reference Route B: IEC 62443-3-3 SR 3.4. |
| Step 3 · Information | Operating instructions: list of safety-relevant software and data with versions (Annex III No. 1.7.4.2), instructions for retrieving version information, note on the significance for conformity and on the obligation to report deviations. |

Risk after: **3** Residual risk accepted: Yes

No. 43 Corruption/securityRisk before: S 5 · P 2 · **RZ 10**

Unsecured engineering access to the safety controller: The programming access of the safety controller or safety PLC is reachable without a password or with the manufacturer's default credentials; the safety program can be overwritten or placed in a stopped state during operation, and forcing of inputs and outputs is possible. Protective functions are rendered ineffective or actuators are controlled directly. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 2, 1.1.9 para. 3, 1.2.1 lit. a]

Sub-machine: Safety control / engineering · also in: Maintenance, Troubleshooting

Step 1 · Inherent	Programming access to the safety controller physically separated from the process network (dedicated port, inside a locked control cabinet), no forcing of safety-relevant signals in the series state, programme changes only in the secured stop state of the machine.
Step 2 · Technical	Individual password for the safety programme access with mandatory password change at commissioning, write protection and access protection levels of the controller activated, logging of all accesses and programme changes with version and checksum, display of the programme status on the HMI. Evidence reference Route B: IEC 62443-3-3 SR 1.1, SR 1.5, SR 2.1, SR 2.8, SR 3.4, SR 7.7.
Step 3 · Information	Operating instructions: Access protection and password management as an operator obligation, prohibition of programme changes without re-verification and documentation, reference to the requirements for substantial modification.

Risk after: **5** Residual risk accepted: Yes

Setting up (24 hazards)

No. 1		Mechanical	Risk before: S 5 · P 3 · RZ 15	
Crushing and shearing hazard from the turntable during the automatic turning operation: Body parts of the operator (hands, arms) may be drawn in and crushed between the rotating table and the fixed centre wall or the protective fence, in particular when reaching into the turntable during turning to reposition a displaced workpiece (reasonably foreseeable misuse).				
Sub-machine: Turning table (rotary table unit) - also in: Operation, Troubleshooting				
Step 1 · Inherent	Design the gap dimensions between the rotating table edge and the fixed centre wall as well as the protective fence such that no crushing points arise: comply with the minimum distances in accordance with EN ISO 13854:2019 Table 1 (25 mm for fingers, 100 mm for the hand, 120 mm for the arm, 500 mm for the body). If neither the small nor the large gap can be achieved by design, the geometry of the table frame must be configured so that no converging wedge shape is created (parallel or diverging flanks instead of a converging gap). In addition: reduce the mass and pivoting speed of the turntable to the functionally necessary minimum (drive design) in order to limit the kinetic energy acting in the crushing gap.			
Step 2 · Technical	Residual risk after level 1: The swivel area remains a hazard zone that must not be entered while the drive is running. Technical protective measures: 1. Release of the swivel movement only when the swivel area is clear (SF-04, PLr e, EN ISO 13849-1:2023): BWS (light curtain type 4 in accordance with EN 61496-1) monitors the swivel area completely; arrangement and safety distance in accordance with EN ISO 13855:2024. 2. Guard locking of the access door to the turntable area in accordance with EN ISO 14119:2025 with escape release (SF-01, PLr d; stop category 1 in accordance with EN 60204-1:2018). 3. Set-up mode: swivel movement only at safely reduced speed of 250 mm/s and with the enabling device actuated (SF-05, PLr d, stop category 1 in accordance with EN 60204-1:2018). 4. Emergency stop in the operator area in accordance with EN ISO 13850:2015, integrated into SF-03 (PLr d, stop category 1 in accordance with EN 60204-1:2018). 5. Energy isolation prior to interventions: isolating valve with mechanical latching (lockout) in accordance with EN ISO 4414:2010; secure gravitational lowering by means of mechanical support (EN ISO 14118:2018).			
Step 3 · Information	1. Operating instructions: entering the swivel area while the turntable is running or unsecured is prohibited. Before any intervention (e.g. repositioning a workpiece), the system must be completely switched off and secured (lockout/tagout). A separate procedure with an enabling device applies to set-up mode and is described in the operating instructions. 2. Warning signs on the machine: warning signs are affixed to the turntable: "Warning: hand injury hazard", "Warning: rotating parts" and "Entry prohibited during operation" (in accordance with DIN EN ISO 7010). 3. Who may intervene: set-up and fault rectification may only be carried out by trained personnel. Training must be repeated at least once a year and recorded in writing. 4. Personal protective equipment: protective gloves are prohibited at the turntable, as they increase the risk of the hand being drawn in. Safety footwear (protection class S2 or S3) is mandatory throughout the entire system area.			
Risk after: 5		Residual risk accepted: Yes		
		 Warning: crushing		

No. 2 MechanicalRisk before: S 5 · P 3 · **RZ 15**

Crushing and drawing-in hazard from the welding robot (industrial robot) in set-up mode: at reduced speed (jog mode), operators or set-up personnel may be crushed or drawn in between the robot arm and peripheral equipment (safety fence, turning table, welding fixture) by unexpected robot movements.

Sub-machine: Welding robot

Step 1 · Inherent	Speed limitation to a maximum of 250 mm/s (TCP speed) in set-up mode by the robot controller as an inherent design requirement for the robot (EN ISO 10218-1:2025 Sections 5.2.7 and 5.5.3). In addition: minimum distances between the outermost robot positions in set-up mode and fixed peripheral equipment (safety fence, turning table, welding fixture) are to be maximised by design, to the extent that the plant topology permits, in order to geometrically reduce crushing and drawing-in points. Remaining crushing points that fall below a minimum distance of 500 mm (body) or 300 mm (head) in accordance with EN ISO 13854:2019 Table 1 and cannot be resolved by design are passed to Step 2 as residual risk.
Step 2 · Technical	SF-05 'Safely reduced speed 250 mm/s with enabling device in set-up mode', PLr d in accordance with EN ISO 13849-1:2023: The safety function SLS (safely limited speed) is implemented via an SRP/CS PLr d. The enabling device (3-position, panic function) in accordance with EN ISO 10218-2:2025 Section 5.7.7 must be continuously actuated; on release or full depression, stop category 0 is initiated. The set-up person carries the hand-held programmer (HHP) with them; the HHP must have sole authority to enable movement as long as persons are present within the safeguarded space (EN ISO 10218-2:2025 Section 5.7.5). Access to the safeguarded space in set-up mode is only possible via a maintenance door with guard locking in accordance with EN ISO 14119:2025, which is unlocked in set-up mode but forces a change of operating mode to 'set-up' (key switch or coded lock). Isolation of energy before entering the safeguarded space without HHP: safe isolation in accordance with EN ISO 14118:2018 (lockout/tagout preparation). Safety distances to remaining crushing points in accordance with EN ISO 13857:2019 Table 1 to be verified and documented.
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): set-up mode exclusively by instructed and authorised set-up personnel with demonstrated robot operator qualification. Description of permissible body postures and movement areas in set-up mode. Warning marking at the access door: warning of robot movements (ISO 7010, warning sign 'Warning: automatically starting machinery') and note 'Always carry the enabling device'. PPE specification: safety footwear (EN ISO 20345), close-fitting protective clothing (no drawing-in risk from loose clothing). Note in the operating instructions that entering the safeguarded space without an active HHP and without an enabling device is prohibited.

Risk after: **5** Residual risk accepted: Yes

No. 4 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Crushing hazard at the interface between the turning table and the welding robot (transfer area): During the turning operation the loaded fixture moves into the working area of the robot; uncoordinated entry of the robot into the turning area or missing interlock between the turning table movement and the robot enable can lead to collisions and crushing injuries.

Sub-machine: Interface: turning table / welding robot · also in: Operation, Troubleshooting

Step 1 · Inherent	The pivoting radius of the turning table and the working space boundary of the robot (TCP envelope) are coordinated with each other during the design phase such that the maximum pivoting range of the fixture and the minimum robot working space maintain a geometric minimum distance of ≥ 500 mm (safety distance against reaching with the arm in accordance with EN ISO 13857:2019 Table 1, body opening arm) from each other when both movements would be active simultaneously. This minimises the overlap zone by design; complete elimination of the overlap is not possible with this system topology due to functional constraints, so that the remaining residual overlap is safeguarded by Level 2.
Step 2 · Technical	SF-04 'Enable of the 180-degree pivoting movement of the turning table only when the pivoting area is clear' with PLr e in accordance with EN ISO 13849-1:2023 (risk graph: S2/F2/P2). Implementation as an interlocked safety function in the safety PLC: (a) Robot standstill monitoring: the robot must be in a defined rest position (safe position) outside the pivoting zone and must confirm this via a safe feedback signal (e.g. safe output of the robot controller in accordance with EN ISO 10218-2:2025 Sections 5.4.7 and 5.5.8) before the turning table enable is granted. (b) Turning table enable to the robot: as long as the turning table is not in its end position and locked, the robot controller receives no enable signal for the entry area; guard locking of the pivoting movement via a safety drive or mechanical interlock. (c) Guard locking of the maintenance door to the pivoting area in accordance with EN ISO 14119:2025 with escape release, incorporated in SF-01 (PLr d). (d) Emergency stop of the complete system in accordance with EN ISO 13850:2015, incorporated in SF-03 (PLr d), stop category 1 in accordance with EN 60204-1:2018. (e) In set-up mode SF-05 applies: safely reduced speed ≤ 250 mm/s with enabling device (PLr d); the setter may enter the pivoting area only with the enabling device activated and at reduced speed. Safety distance of the fixed guard (safety fence) to the pivoting area to be calculated and documented in accordance with EN ISO 13855:2024 and EN ISO 13857:2019; safety fence to be designed in accordance with EN ISO 14120:2015.
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the interlock logic SF-04 and the permissible operating modes; explicit notice that entering the pivoting area while the system is running is prohibited. Set-up mode: qualification requirement to be documented (only trained specialist personnel with knowledge of the enabling device). Warning labelling at the pivoting area: warning of crushing hazard (ISO 7010, warning sign 'Warning: hand injury' or 'Warning: dangerous area') and prohibition sign 'No entry' (ISO 7010) at all access points. PPE specification in the operating instructions: safety footwear; in set-up mode additionally close-fitting protective clothing (no entanglement risk from loose clothing). Note on residual risk in set-up mode and fault-finding: always keep the enabling device activated, never enter the pivoting area without the enabling device.

Risk after: **5** Residual risk accepted: Yes

No. 5 MechanicalRisk before: S 4 · P 3 · **RZ 12**

Falling of workpieces or fixture parts due to failure of the pneumatic clamping device: In the event of compressed air failure or leakage, the clamping elements open in an uncontrolled manner; workpieces of up to 40 kg may fall from the rotary table and strike persons at the loading station.

Sub-machine: Pneumatic clamping device (rotary table) · also in: Operation, Troubleshooting

Step 1 · Inherent	Use of clamping elements with a spring-force closing principle ("Normally Closed", NC): The clamping force is generated by pre-tensioned springs; compressed air is only required for opening (releasing) the clamping elements. In the event of compressed air failure or leakage, the workpiece remains securely clamped. The spring force is designed for the maximum workpiece weight of 40 kg plus a safety factor in accordance with EN ISO 4414:2010 Section 5.4 (fail-safe principle). Additionally: limitation of the operating pressure to the minimum level required for the opening function, in order to minimise the pneumatic energy stored in the event of a fault (EN ISO 4414:2010 Section 5.3).
Step 2 · Technical	1. Pressure monitoring with safety function: Pressure switch in the supply circuit of the clamping device; if the minimum pressure required for the opening function is not reached, the release of the rotary motion of the rotary table is inhibited (interlocked with SF-04, PLr e in accordance with EN ISO 13849-1:2023). As long as sufficient pressure is not present, the rotary table must not rotate and the loading release is not granted. 2. Mechanical interlock of the rotary motion: Positive locking of the rotary table in the loading position, so that unintended rotation with a clamped or loose workpiece is prevented; the interlock is released only after confirmed clamping force (interlocked with SF-04, PLr e). 3. Enclosure/catch device: Mechanical catch device (e.g. catch rail or deflector plate) below the rotary table, designed for the maximum workpiece weight of 40 kg and the maximum drop height, to keep falling parts away from the loading station; design in accordance with EN ISO 14120:2015. 4. Safety distance at the loading station: Arrangement of the loading station such that the hazard zone below the rotary table is outside the regular area of presence; safety distance to be verified and documented in accordance with EN ISO 13857:2019 Table 1 (upper limbs).
Step 3 · Information	1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the NC clamping principle and the pressure monitoring; prohibition of remaining beneath the rotary table during operation and during fault-finding without secured standstill; procedure in the event of compressed air failure (shut down the machine, restore the compressed air supply, remove the workpiece only after a pressure check). 2. Energy isolation prior to interventions: Instruction for complete pressure relief of the pneumatic system prior to maintenance and servicing work in accordance with EN ISO 4414:2010 Section 5.2 and EN ISO 14118:2018 (prevention of unexpected restart and unexpected energy release); provide a shut-off and exhaust valve with lockout facility. 3. Warning labelling: Attach the warning sign "Warning: overhead load" and the warning sign "Warning: hand injuries" in accordance with DIN EN ISO 7010 to the rotary table and at the loading station. 4. Qualification: Fault-finding and setting-up work to be carried out by trained specialist personnel only; requirements to be specified in the operating instructions. 5. PPE: Prescribe the wearing of safety footwear (EN ISO 20345, protection class S2 or S3) at the loading station as residual risk protection.

Risk after: **4** Residual risk accepted: Yes

No. 6 MechanicalRisk before: S 5 · P 3 · **RZ 15**

Hazard of crushing and impact due to unexpected restart of the turntable or the robot after an emergency stop or after fault clearance: if a coordinated restart prevention system (EN ISO 11161) is absent, individual sub-machines may start up automatically while persons are still present in the hazardous area.

Sub-machine: Overall system (restart coordination) · also in: Troubleshooting, Maintenance

- Step 1 · Inherent** Inherent possibilities exhausted: restart after an emergency stop or after fault clearance is a control-system event that cannot be constructively eliminated by the functional principle of the overall installation (coordinated automatic operation of robot and turntable) without cancelling the machine function. No geometric or energetic measure exists that would prevent the restart itself without abolishing the machine function. Protection must therefore be achieved entirely through Level 2 measures (control system and interlocking).
- Step 2 · Technical** 1. Coordinated restart prevention in accordance with EN ISO 11161:2007+A1:2010 Section 5.6: the overall installation control system shall not release the restart of a sub-machine (turntable, robot) until a deliberate, manual restart command has been issued from a safe position outside all hazardous areas. The restart command shall NOT be triggered automatically following acknowledgement of the emergency stop or following fault clearance. 2. Safety function SF-01 (safe stop, stop category 1 on opening of the maintenance door, PLr d in accordance with EN ISO 13849-1:2023) and SF-03 (emergency stop of the overall installation, stop category 1, PLr d in accordance with EN ISO 13849-1:2023) ensure that all drives are safely brought to a standstill. The restart prevention is implemented as an integral part of safety functions SF-01, SF-03 and SF-04 and is executed at their respective PLr (SF-04: PLr e; SF-01 and SF-03: PLr d in accordance with EN ISO 13849-1:2023). 3. Safety function SF-04 (release of the 180-degree pivoting movement of the turntable only when the pivot area is clear, PLr e in accordance with EN ISO 13849-1:2023): the turntable may only execute its pivoting movement when the pivot area has been detected as clear by a suitable protective device (e.g. light curtain Type 4 in accordance with EN 61496-1, positioned in accordance with EN ISO 13855:2024). This function remains active after restart and prevents start-up in the presence of persons. 4. Safety function SF-05 (safely reduced speed of 250 mm/s with enabling device in set-up mode, PLr d in accordance with EN ISO 13849-1:2023): in set-up mode, restart shall be released exclusively via an enabling device (3-position in accordance with EN ISO 10218-2:2025 Section 5.7.7), so that an unexpected restart at full speed is excluded. 5. De-energisation and energy isolation in accordance with EN ISO 14118:2018: before entering the hazardous area for fault-finding or maintenance, the energy supply to all relevant drives (electrical, pneumatic in accordance with EN ISO 4414:2010) shall be disconnected by means of a lockable isolating device and secured against unintentional re-energisation (lockout/tagout). Residual energy (stored pneumatic energy, gravitational component of the turntable) shall be dissipated or mechanically secured before any intervention. 6. Guard locking of the maintenance door in accordance with EN ISO 14119:2025 with escape release: the guard locking keeps the maintenance door closed as long as hazardous movements have not been safely brought to a standstill (stop category 1 completed). Integration is carried out within the scope of SF-01 (PLr d).
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the restart sequence after an emergency stop and after fault clearance; explicit statement that restart is permissible only after all hazardous areas have been fully vacated and a manual acknowledgement command has been issued from outside. Description of the lockout/tagout procedure in accordance with EN ISO 14118:2018 for all maintenance and fault-finding activities. 2. Warning labelling at all access doors and acknowledgement units: warning of unexpected restart (warning sign 'Warning: automatic start-up' in accordance with DIN EN ISO 7010), notice of the obligation to acknowledge from outside. 3. Qualification requirement: set-up and maintenance activities may only be carried out by instructed specialist personnel who have been trained in the restart procedure and the lockout/tagout method (EN ISO 10218-2:2025 Section 7.5.12). 4. PPE specification: safety footwear (S2/S3) shall be worn when entering the hazardous area for fault-finding or maintenance; additional PPE as determined by the operator's workplace risk assessment.

Risk after: **5** Residual risk accepted: Yes

No. 7 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Missing or uncoordinated emergency stop function between sub-machines (robot, turning table, welding power source, extraction system): an emergency stop at one sub-machine does not necessarily stop all other sub-machines; persons may be endangered by components that continue to run.

Sub-machine: Overall system (emergency stop coordination) · also in: Operation, Troubleshooting

Step 1 · Inherent	Inherent possibilities exhausted: the coordination of several independent controllers necessarily requires a higher-level control logic. A purely constructive measure (geometry, energy limitation, substitution) cannot replace the missing interconnection of the emergency stop circuits. The functional principle of the linked plant necessitates active control coordination.
Step 2 · Technical	Higher-level emergency stop circuit (SF-03) in accordance with EN ISO 13850:2015 and EN ISO 11161:2007+A1:2010: all emergency stop actuating devices of the complete plant are integrated into a common, higher-level safety circuit which, on actuation at any point, brings all sub-machines (robot, turning table, welding power source, extraction system) to a coordinated standstill. Stop category 1 in accordance with EN 60204-1:2018 (controlled stopping, followed by energy disconnection): the robot performs a controlled stop along its path, the turning table brakes actively, the welding power source is de-energised, and the extraction system runs on (not a safety function, but operationally required). Safety function SF-03 is to be designed to PLr d in accordance with EN ISO 13849-1:2023 (Category 3 or 4, depending on architecture). Integration of the robot is carried out via the robot controller in accordance with EN ISO 10218-2:2025 Section 5.3.3 (span of control of the emergency stop, safety interface to the higher-level controller). Emergency stop actuating devices are to be designed in accordance with EN ISO 13850:2015 (mushroom-head pushbutton, yellow background, self-latching, release only by deliberate action). Emergency stop actuating devices are to be positioned such that at least one actuating device is reachable from every operating position without exposure to a hazard (EN ISO 13850:2015 Section 4.4). Restart interlock: after an emergency stop, a manual reset is required before the plant can restart (EN ISO 13850:2015 Section 4.1.4), in order to prevent unexpected restart in accordance with EN ISO 14118:2018.
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the emergency stop topology of the complete plant with a layout plan of all emergency stop actuating devices and the area of effect of each actuating device. Clear instruction that after an emergency stop, the hazard zone of all sub-machines must be inspected before the reset is carried out. Set-up mode and fault-finding: instruction that intervention in the hazard zone is only permissible after all sub-machines have come to a complete standstill and reset protection has been secured (key switch or lock). Qualification requirement: set-up and fault-finding only by instructed specialist personnel who are familiar with the emergency stop topology. Warning marking at all operator panels: information sign indicating the area of effect of the respective emergency stop actuating device (warning of unexpected start-up of adjacent sub-machines, signs in accordance with DIN EN ISO 7010, warning of automatic start-up).

Risk after: **5** Residual risk accepted: Yes

No. 8 MechanicalRisk before: S 3 · P 4 · **RZ 12**

Cutting and puncture hazard from the welding wire (solid wire 1.0 to 1.2 mm) at the welding torch: The wire protruding from the torch acts like a needle; during setting, wire threading or torch cleaning, hands and fingers can be punctured or cut.

Sub-machine: Welding torch / wire feed · also in: Maintenance, Cleaning

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| Step 1 · Inherent | Automatic wire retraction after the end of welding: The wire feed control automatically retracts the wire by a defined amount (e.g. 5 to 10 mm) into the torch after each welding cycle, so that the sharp wire tip is recessed within the contact tip and no longer protrudes freely. This constructively minimises the hazard point (free-standing wire tip) for the setting and cleaning life phases. In addition: selection of a wire feed system that, in inching mode (setting), advances the wire only when the button is continuously pressed (dead man's principle), so that the wire is not advanced in an uncontrolled manner. |
| Step 2 · Technical | 1. Mechanical wire length limitation: An adjustable wire length stop (torch protection cap with a defined opening) is provided at the torch neck, limiting the maximum protruding wire to the minimum dimension necessary for the process. 2. Interlocking of wire feed during cleaning and maintenance: The wire feed function is inhibited by the safety controller as soon as the maintenance door is opened (safety function SF-01, PLr d in accordance with EN ISO 13849-1:2023). 3. Set-up mode with safely reduced speed: In set-up mode, the wire feed is limited to the safely reduced speed in accordance with SF-05 (PLr d), thereby preventing unintentional rapid shooting of the wire. 4. Marking of the hazard point on the torch and wire feed in accordance with DIN EN ISO 7010 (warning of pointed injury hazard). |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Explicit note that the welding wire presents a sharp, pierceable tip even when stationary. Description of the safe procedure for threading wire (wire feed inhibited, cut the wire end cleanly with side cutters, never probe with the bare hand). 2. Warning marking on the torch holder and on the wire feed unit: warning sign 'Warning: hand injuries' in accordance with DIN EN ISO 7010. 3. Qualification requirement: activities on the torch and wire feed (threading wire, cleaning) may only be carried out by instructed specialist personnel; requirement to be documented in the operating instructions. 4. PPE specification: cut-resistant protective gloves (protection class in accordance with EN 388, minimum 2X42 or equivalent) must be worn when threading wire and when cleaning the torch; specification to be included in the operating instructions and on the notice posted at the workplace. 5. Note on safe cutting of the wire tip: before any manual activity on the torch, the wire tip must be cut cleanly and burr-free with a suitable pair of side cutters; the tool is to be made available at the workplace. |

Risk after: **6** Residual risk accepted: Yes

No. 9 MechanicalRisk before: S 4 · P 4 · **RZ 16**

Ergonomic hazard and crushing hazard during manual loading and unloading of workpieces up to 40 kg: Workpieces over 15 kg should be loaded using lifting equipment; in the event of reasonably foreseeable misuse (lifting without lifting equipment), musculoskeletal strain arises together with the risk of losing grip, with the subsequent falling of the workpiece onto feet or hands.

Sub-machine: Loading station (operator station) · also in: Operation

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| Step 1 · Inherent | Inherent limitation of the manually handled workpiece mass to a maximum of 15 kg by dividing heavy workpiece carriers or using sub-pallets, so that no individual part exceeds the limit in accordance with EN 1005-2:2003+A1:2008 (reference value 15 kg for occasional lifting under favourable conditions). Where division is not constructively possible (workpieces 15 kg to 40 kg), a permanently integrated lifting equipment interface (e.g. load eyes, vacuum gripper docking point or balancer interface) is constructively provided at the loading station as an integral part of the workpiece fixture, so that loading without lifting equipment is geometrically impracticable (insertion depth, rigging geometry). |
| Step 2 · Technical | 1. Provision of a suitable lifting aid (balancer, vacuum lifter or jib crane) at the loading station, designed for the maximum workpiece mass of 40 kg with a sufficient operating radius to fully cover the loading zone. The lifting aid must be arranged so that the operator can reach the loading position without re-gripping or releasing the workpiece. 2. Floor marking of the set-down and slewing area of the lifting aid at the loading station, so that the operator is not standing beneath the suspended load during loading. 3. The light curtain at the loading station (SF-02, PLr e) safeguards the hazard zone of the machine opening; it does not protect against the falling of the workpiece itself, but it does limit the area in which hands may be located during loading. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Clear specification of the maximum manual handling mass (15 kg), the obligation to use the lifting aid from 15 kg onwards, and the correct rigging points on the workpiece. Specification of body posture during loading in accordance with EN 1005-2:2003+A1:2008. 2. Warning labelling at the loading station: Warning sign 'Warning of suspended load' and 'Warning of hand injuries' in accordance with DIN EN ISO 7010, as well as mandatory signs 'Wear safety footwear' and 'Use lifting equipment' in accordance with DIN EN ISO 7010 (semantic meaning: obligation to use the lifting aid). Specification of the maximum load in kg directly at the loading station. 3. Qualification requirement: Operators must be instructed in the use of the lifting aid and in ergonomically correct handling before commencing work (documented instruction). 4. PPE specification: Safety footwear S2/S3 with steel toecap and protective gloves (cut-resistant, secure grip) are to be stipulated as minimum PPE for all loading and unloading activities. |

Risk after: **8** Residual risk accepted: Yes

No. 10 MechanicalRisk before: S 3 · P 3 · **RZ 9**

Hazard of tripping, slipping and falling in the area of the loading station and the maintenance aisle due to weld spatter on the floor, cables, hoses (compressed air, shielding gas) and wet areas during cleaning work.

Sub-machine: Loading station / maintenance aisle · also in: Operation, Maintenance, Cleaning, Troubleshooting

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| Step 1 · Inherent | Keep cables and hoses (compressed air, shielding gas) out of the floor area of the loading station and maintenance aisle by means of constructive routing in cable ducts, energy chain systems or ceiling-suspended cable management systems, so that no trip hazards arise. Design connections at the loading station as ceiling pendants or wall-mounted socket panels. Reduce weld-spatter exposure on the floor by means of constructive shielding plates (spatter-protection shields) at the welding station, so that discharge into the operator area is minimised. Provide the floor covering in the loading station and maintenance aisle with an anti-slip surface (assessment group R 11 or higher in accordance with BGR/GUV-R 181, suitability for wet conditions to be verified), so that the slip hazard is inherently reduced. |
| Step 2 · Technical | Limit the residual risk from remaining trip and slip hazards by means of the following technical measures: (1) Floor markings (yellow/black in accordance with ISO 7010) to identify traffic routes and hazardous areas in accordance with (EU) 2023/1230 Annex III No. 1.1.2 and No. 1.6.2. (2) Adequate fixed lighting of the loading station and maintenance aisle in accordance with (EU) 2023/1230 Annex III No. 1.1.4, so that obstacles and wet areas can be detected at an early stage; illuminance to be specified according to the visual task; machine-integrated lighting to be designed in accordance with EN 1837. (3) Drip trays or spatter-protection mats in the immediate welding area that are easy to remove and clean. |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): (1) Reference to the hazard of tripping and slipping due to weld spatter, hoses and wet conditions; prescribe cleaning intervals and cleaning procedures for the floor area. (2) Qualification requirement: all persons entering the loading station and maintenance aisle must have been instructed in the hazards and the traffic-route layout. (3) PPE specification: safety footwear with anti-slip soles (S2 or S3 in accordance with EN ISO 20345) shall be worn when entering the loading station and maintenance aisle. (4) Warning labelling at the access to the loading station and maintenance aisle: affix a warning sign for slip hazard (ISO 7010, warning sign 'Warning: slippery surface') and the mandatory sign 'Wear safety footwear' (ISO 7010, mandatory sign). |

Risk after: **6** Residual risk accepted: Yes

No. 11 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Hazard arising from simultaneous access by several persons to different zones of the cell (EN ISO 11161): a second person is present inside the cell without the setter being aware of this; when the robot or the turntable starts up, the second person is struck.

Sub-machine: Overall system (zone access) · also in: Maintenance, Troubleshooting

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| Step 1 · Inherent | Inherent possibilities exhausted: the functional principle of the overall installation requires accessible zones for set-up, maintenance and fault-finding work. The hazard arises from the simultaneous presence of several persons in different zones, which cannot be resolved by geometry, distance or energy limitation alone without defeating the operational purpose. A reduction of the robot or turntable energy to a level that safely excludes injury is not technically realisable with this type of installation. |
| Step 2 · Technical | 1. Presence-detection concept in accordance with EN ISO 11161:2007+A1:2010 Section 5.6 (access control for assemblies of machinery): a key-transfer or key-interlocking system (key-transfer box) shall be used for each access point to the cell. Each person entering the cell removes a personal key; start-up of the installation is possible only when all keys have been returned. The number of keys corresponds to the maximum permissible number of persons inside the cell. This concept shall be integrated into the safety control system. 2. Zone-specific guard locking at all access doors in accordance with EN ISO 14119:2025 with escape release (escape facility) in accordance with EN ISO 14119:2025 Section 6.9.1, so that persons trapped inside the zone can leave it at any time. 3. The release of start-up (robot and turntable) shall be implemented as a safety function: start-up is possible only when all access doors are closed and locked AND all personal keys are inserted in the key-transfer box. This function shall be assigned to the existing SF-04 (turntable release, PLr e) and SF-01 (standstill on maintenance door, PLr d). Since SF-04 carries the highest requirement level with PLr e, the entire access-control function shall be designed to PLr e in accordance with EN ISO 13849-1:2023. 4. In set-up mode, SF-05 applies (safely reduced speed of 250 mm/s with enabling device, PLr d in accordance with EN ISO 13849-1:2023). The enabling device is person-specific; a second enabling device shall be provided if two persons must work simultaneously in set-up mode, whereby both enabling devices must be actuated simultaneously (AND logic) or start-up remains generally inhibited as long as more than one person is detected inside the cell. 5. Safety distances between the robot working space and areas where persons are present shall be maintained and documented in accordance with EN ISO 13857:2019 Table 1 and EN ISO 10218-2:2025 Sections 5.4.6 and 5.8.9. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the key-transfer concept, the maximum permissible number of persons per zone, the obligation to remove the key before entering and to return the key before start-up. Procedural instruction for multi-person operations (setting up, maintenance, fault-finding) with clear role assignment (responsible person, coordination). 2. Warning signs at all access points: Warning of automatic start-up (warning sign in accordance with DIN EN ISO 7010, warning of dangerous machine parts), notice of key obligation and personnel-tracking concept. 3. Qualification requirement: Setting-up and maintenance personnel must be instructed in the multi-person access concept and the operation of the key-transfer box. The instruction must be documented. 4. PPE specification in the operating instructions: Safety footwear, close-fitting protective clothing (no entanglement risk from loose clothing) when inside the cell. |

Risk after: **5** Residual risk accepted: Yes

No. 13 ElectricalRisk before: S 4 · P 2 · **RZ 8**

Hazard from welding current at the workpiece and at the fixture: the welding circuit carries high currents (typically 100 to 350 A); in the event of a faulty earth connection or damaged insulation, persons who touch the workpiece or the fixture may receive an electric shock.

Sub-machine: Welding power source / fixture · also in: Operation, Troubleshooting

- Step 1 · Inherent** Design the fixture frame and workpiece holders such that touchable conductive surfaces that lie within the welding current circuit are galvanically isolated from the machine frame by constructive insulation (e.g. insulating plates made of Pertinax/glass-fibre epoxy between the fixture base plate and the machine table, as well as insulating clamping jaw inserts). This constructively interrupts the unintentional current path via the frame and touchable external surfaces. In addition: define the earth cable connection point directly on the workpiece or at a designated location on the fixture that is not touchable by the operator, and integrate it by means of shaping (recess, cable routing channel) in such a way that incorrect positioning of the earth clamp is constructively impeded.
- Step 2 · Technical** 1. Welding power source: Procurement of a welding power source with protection class I and degree of protection of at least IP23S in accordance with EN IEC 60974-1 (procurement requirement); integration into the protective conductor chain of the overall installation shall be carried out in accordance with EN 60204-1:2018 Section 8 (protective conductor cross-sections, connection points). 2. Monitoring of the earth connection: If the welding power source or the system control supports an earth current monitoring function, this shall be activated; in the event of interruption or an impermissibly high contact resistance, the welding process is inhibited (safety function in accordance with EN ISO 13849-1:2023, PLr to be determined according to risk graph, as no project-specific SF has been defined for this function). 3. Equipotential bonding: All conductive parts of the fixture that are not deliberately insulated are included in the protective equipotential bonding of the installation (EN 60204-1:2018 Section 8.2). 4. Access restriction during the welding process: The loading station is safeguarded by the light curtain (SF-02, PLr e in accordance with EN ISO 13849-1:2023); during active welding, access to the welding area is prevented by the interlocked maintenance door (SF-01, PLr d) and the enable logic of the turn-over table (SF-04, PLr e), so that contact with live parts in automatic mode is prevented by both constructive and control-engineering means. 5. Cable management: Welding cables and earth cables are routed in enclosed cable ducts or protective conduits (protection against mechanical damage); minimum bending radii as specified by the manufacturer shall be observed; cables shall be secured with strain relief.
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the correct connection of the earth clamp (position, cleaning of the contact surface, permissible clamping areas); notice that touching the workpiece and the fixture during the welding process is prohibited; inspection interval for insulation and cable condition (recommended: daily visual inspection, semi-annual insulation measurement by a qualified electrician). 2. Qualification requirement: Setting up, fault-finding and maintenance on the welding power source and its connections may only be carried out by a qualified electrician or an electrotechnically instructed person under the supervision of a qualified electrician (EN 60204-1:2018 Section 4.2). 3. Warning labelling on the fixture and in the welding area: Attach warning signs 'Warning of electric voltage' and 'Warning of hand injuries from welding spatter' in accordance with DIN EN ISO 7010 at a clearly visible location; attach an information sign 'Check earth clamp before commencing welding'. 4. PPE specification in the operating instructions: When setting up and fault-finding in the welding area, insulating gloves (protection class suitable for low voltage) and welding protective clothing shall be worn.

Risk after: **4** Residual risk accepted: Yes

No. 14 ElectricalRisk before: S 4 · P 2 · **RZ 8**

EMC interference between welding power source and safety controller (robot controller, light curtain evaluation unit, guard locking controller): high-frequency interference pulses from the MAG arc can influence safety functions and lead to spurious triggering or, more critically, to undetected failure of safety functions (EN ISO 11161).

Sub-machine: Overall system (EMC interface) · also in: Operation

- Step 1 · Inherent** Spatial and galvanic separation of welding circuits from safety circuits by design specification: (1) Route the welding current return conductor as a dedicated return conductor close to the workpiece, directly back at the welding table, so that no large-area current loops are created that act as antennas. (2) Route welding current cables and safety signal/control cables in separate cable ducts with a minimum separation of 200 mm (separation distance in accordance with EN 61000-6-2:2019 Annex A as design reference); crossings at right angles only. (3) Earth the welding power source and safety controller on separate equipotential bonding busbars connected with low impedance to the system protective conductor, in order to avoid common impedance paths. These measures reduce coupling at the source without requiring a protective device.
- Step 2 · Technical** For the remaining residual risk of conducted and radiated interference: (1) Execute all safety signal and control cables (light curtain SF-02, guard locking SF-01, rotary release SF-04, emergency stop SF-03) as screened cables; connect the screen at both ends with low impedance to the equipotential bonding busbar. (2) Use mains filters (interference suppression filters) at the supply feed of the safety controller and the light curtain evaluation unit, designed in accordance with EN 61000-6-2:2019 (immunity requirements for industrial environments). (3) Install the robot controller, light curtain evaluation unit and guard locking controller only in control cabinets with continuous shielding (metal enclosures, EMC-compliant cable entries). (4) The safety controller and all components of safety functions SF-01 to SF-05 shall demonstrably comply with the immunity requirements of EN 61000-6-2:2019 (manufacturer's evidence as a procurement requirement). (5) Safety functions SF-01 (PLr d), SF-02 (PLr e), SF-03 (PLr d), SF-04 (PLr e) and SF-05 (PLr d) shall be validated in accordance with EN ISO 13849-1:2023 and EN ISO 13849-2:2012; the validation shall explicitly take into account the influence of EMC on the diagnostic coverage and the MTTFd of the safety functions. (6) Welding power source: procurement only with CE marking and EU declaration of conformity, including compliance with the EMC Directive 2014/30/EU; verify emission levels in accordance with EN 60974-10 (EMC of arc welding equipment) and EN 61000-6-4:2019. (7) Complete installation: carry out an EMC acceptance test in accordance with EN 61000-6-2:2019 in the operating state with the welding process active, in order to verify the immunity of the safety functions under real operating conditions.
- Step 3 · Information** Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): (1) Note that modifications to cable routing (welding current cables, control cables) may only be carried out by qualified skilled personnel with EMC expertise. (2) Maintenance instruction: regular visual inspection of screen terminations, equipotential bonding connections and cable duct separation; define inspection interval. (3) Note that after every replacement of the welding power source, robot controller or safety components, a renewed EMC functional check of the safety functions is required. (4) Qualification requirement: set-up personnel (operating mode Set-up, SF-05 active) shall be instructed in EMC-related fault patterns on safety controllers. (5) Warning label on the control cabinet of the safety controller: warning of electromagnetic fields (ISO 7010, warning sign for electromagnetic field), note on the prescribed cable routing.

Risk after: **4** Residual risk accepted: Yes

No. 15 ThermalRisk before: S 3 · P 4 · **RZ 12**

Burn hazard from hot workpieces and weld seams: Freshly welded assemblies reach several hundred degrees Celsius in the seam area; serious burns may result from removal without suitable protective gloves or from contact with the seam.

Sub-machine: Loading station (removal side) · also in: Operation

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| Step 1 · Inherent | Inherent options exhausted: The operating principle of arc/gas-shielded welding necessarily requires heat input into the workpiece; the resulting seam temperature cannot physically be reduced to a safe level without suppressing the welding process itself. Substitution of the joining process (e.g. adhesive bonding, bolting) is not provided for according to the machine description and would not meet the product requirements. A geometric measure (distance from the seam by means of shaping) cannot be realised constructively at the removal grip point, as the operator must grip the assembly. |
| Step 2 · Technical | 1. Forced cooling time: A control-side lockout period after the end of welding (timer in the system control), during which the release for removal at the loading station (removal side) remains locked. The lockout period is to be determined on the basis of the workpiece geometry and the heat input, and parameterised in the control system. This function is not a safety function within the meaning of EN ISO 13849-1 (no PLr assigned), but a process-related interlock; it reduces the probability of occurrence but does not replace the obligation to use PPE. 2. Warning light / signalling device: Optical indicator (e.g. a red signal light at the removal station) that is active during the cooling lockout period and extinguishes as soon as the release is granted. 3. Thermal shielding: Where structurally feasible, the arrangement of a heat shield (heat protection plate or curtain) between the welding area and the removal station, in order to reduce radiant heat on the operator (design in accordance with EN ISO 13732-1:2008 with regard to contact temperature limits as a design reference for surfaces that may be touched inadvertently). |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Reference to the risk of burns from hot workpieces and weld seams; specification of the required cooling time before removal; obligation to wear heat-protective gloves (PPE Category II, suitable for contact heat in accordance with EN 407, performance level at least contact heat Level 3) and, where applicable, forearm protection. 2. Warning labelling at the removal station: Warning sign 'Warning of hot surface' (ISO 7010) and mandatory sign 'Wear protective gloves' (ISO 7010) to be affixed permanently and clearly visible at the loading station (removal side) ((EU) 2023/1230 Annex III No. 1.7.1). 3. Qualification and instruction: Operators and set-up personnel are to be instructed in the risk of burns, the cooling times and the obligation to use PPE before commencing work; the instruction is to be documented. 4. Provision of PPE: The operating instructions must instruct the operator to provide suitable heat-protective gloves (EN 407) and to monitor their use. |

Risk after: **6** Residual risk accepted: Yes

No. 16 ThermalRisk before: S 4 · P 3 · **RZ 12**

Burn and fire hazard from welding spatter (spark ejection): During MAG welding, spatter is generated at temperatures above 1500 degrees C; it can land on combustible materials (packaging, oils, clothing) in the surrounding area and cause fires or burns.

Sub-machine: Welding robot / welding area · also in: Operation

- Step 1 · Inherent** Welding parameter optimisation to minimise spatter: Use of a low-spatter arc process (e.g. pulsed arc or CMT-type short arc) instead of the conventional short arc, to the extent permitted by the joining task. By specifically reducing the transferred spatter energy and quantity, the probability of ignition-capable spatter reaching combustible materials is reduced by design. Additionally: position the welding area such that no combustible operating materials (oils, lubricants, packaging) are stored or routed within the spatter protection radius defined by the plant planning (minimum 1 m, to be specified on a project-specific basis). Lines carrying combustible media shall be routed out of the spatter area or provided with non-combustible shields.
- Step 2 · Technical** 1. Fixed/movable guard (welding booth/spatter protection walls): Complete spatial enclosure of the welding area by means of non-combustible, welding-spatter-resistant partition walls (e.g. steel sheet or certified welding protection curtain material) in accordance with EN ISO 14120:2015. The enclosure prevents spatter from escaping into the general working area. Openings (workpiece entry/exit) shall be closed by overlapping welding protection curtains (non-combustible, tested in accordance with the relevant product standard). 2. Extraction system in the welding area: capture of welding fumes and particles directly at the point of origin in accordance with EN ISO 21904-1:2020, in order to extract glowing particles and reduce the thermal load on the surrounding area. 3. Secure the exclusion zone around the welding booth (minimum 1 m) by structural means: permanent floor marking and, where possible, physical barriers; no storage or depositing areas within the zone. 4. Fire protection: provide a bracket for a fire extinguisher (CO2 or powder, no water due to the electrical installation) at the cell; provision and inspection of extinguishing agents are the responsibility of the operator (note in the operating instructions, Stage 3). 5. Safety functions: the protective devices of the welding booth (access doors, maintenance openings) shall be integrated into the safety controller. For the release of welding operation, SF-04 (PLr e) or SF-01 (PLr d) applies in accordance with the project's own functional safety module, to the extent that the booth doors are integrated into these safety functions as access guards.
- Step 3 · Information** 1. Operating instructions (pursuant to (EU) 2023/1230 Annex III No. 1.7.4): Reference to the spatter protection radius and prohibition of storing combustible materials in the welding area. Specification of the permissible welding parameter ranges (current, voltage, wire feed) to minimise spatter ejection. Instructions for the regular cleaning of spatter from machine surfaces and the welding area (reduction of fire load). Procedural instructions for the event of fire (alerting, first-response extinguishing, evacuation). 2. Warning labelling on the welding enclosure: Warning of fire hazard caused by welding spatter (warning sign in accordance with DIN EN ISO 7010, warning of flammable materials, semantic meaning: 'Warning of fire hazard caused by welding spatter'). Warning of hot surfaces in the welding area (semantic meaning: 'Warning of hot surface', in accordance with DIN EN ISO 7010). Mandatory sign: 'Wear welding protective clothing' (in accordance with DIN EN ISO 7010). 3. Qualification requirement: Setters and operators must be trained in the operation of the welding system and in the handling of fire protection equipment. Setters require a qualification as a welding specialist or equivalent documented instruction. 4. PPE specification: During setting mode (life phases involving personal exposure in the welding area), the following PPE must be worn: flame-retardant welding protective clothing (in accordance with EN ISO 11611), welding protective gloves (in accordance with EN 12477), welding protective screen or helmet with an appropriate protection level. In automatic mode with the enclosure closed, no welder PPE is required; however, entering the welding area during operation is prohibited (operating instructions).

Risk after: **4** Residual risk accepted: Yes

No. 17 ThermalRisk before: S 3 · P 3 · **RZ 9**

Risk of burns from the hot welding torch and torch neck: The torch neck and the contact tip are strongly heated after the welding process; when changing the torch, during cleaning or during set-up without a cooling period, hands and fingers may be burned.

Sub-machine: Welding torch · also in: Maintenance, Cleaning

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| Step 1 · Inherent | Use of active torch cooling (water-cooled torch instead of an air-cooled torch), provided the welding process permits this: The continuous water cooling limits the thermal energy in the torch neck and at the contact tip by design to a significantly lower temperature level. Additionally: The torch holder and the change system are designed such that the operator, when changing the torch, touches only thermally decoupled grip areas (plastic or ceramic handle, no direct metal contact with the torch neck). Design in accordance with EN ISO 13732-1:2008 (contact temperature limits for metal: pain threshold approx. 48 °C, burn threshold depending on contact time and material). |
| Step 2 · Technical | 1. Technical cooling-time interlock (if a temperature sensor is fitted or can be retrofitted at the burner neck): release of manual access to the burner only after the temperature falls below a defined limit value; integration into the safety control system as a safety function (PLr to be determined by EN ISO 13849-1 risk graph). 2. Fixed/movable guard: the welding cell is fitted with a protective enclosure in accordance with EN ISO 14120:2015; access to the burner for maintenance and cleaning is provided exclusively via the secured maintenance door (SF-01, PLr d). Unintentional access to the hot burner during automatic operation is thereby constructively excluded. 3. Provision of a burner rest with a thermally insulated receptacle (ceramic or silicone pad) immediately at the welding station, so that the burner is placed down in a defined manner after the process and is not set down on conductive metal surfaces. |
| Step 3 · Information | 1. Operating instructions: state the cooling time after the end of welding explicitly before any torch change, cleaning or set-up work on the burner (adopt the reference value from the burner manufacturer's specifications); include a procedure for torch changes with the step 'wait for cooling time or check temperature'. 2. Warning labelling: permanently and clearly affix the warning sign 'Warning: hot surface' (ISO 7010) to the burner area and to the maintenance door. 3. Qualification: only instructed persons may carry out torch changes and cleaning; instruction covers the risk of burns, cooling times and correct use of PPE. 4. PPE specification: heat-protection gloves (suitable for contact heat, protection class in accordance with EN 407) are mandatory during torch changes, cleaning and set-up work on the burner; this requirement shall be stated in the operating instructions and indicated by the mandatory sign 'Wear protective gloves' (ISO 7010) at the maintenance door. |

Risk after: **3** Residual risk accepted: Yes

No. 18 RadiationRisk before: S 4 · P 3 · **RZ 12**

Hazard from optical radiation of the MAG arc (UV, visible, IR): the arc emits intense ultraviolet, visible and infrared radiation; unprotected viewing of the arc (including through an open maintenance door in set-up mode) can cause eye injuries (keratoconjunctivitis, retinal damage) and skin burns.

Sub-machine: Welding robot / welding area · also in: Operation

- Step 1 · Inherent** Inherent possibilities exhausted: the functional principle of MAG welding necessarily requires an open arc with high radiation intensity; current, voltage and arc energy cannot be reduced to a level at which the radiation hazard is eliminated without interrupting the welding process. Geometric relocation of the hazard point is not possible in a robot welding system with changing welding positions.
- Step 2 · Technical** Level 2, technical protective measures: 1. Enclosure of the welding area: Complete fixed guard (welding protection booth) made of radiation-opaque walls and viewing panels in accordance with EN ISO 14120:2015; wall material and coating (matt black, light-absorbing surface) to be designed such that no relevant UV/IR reflection escapes to the outside. Viewing windows, where provided, to be fitted with welding protection glass of the appropriate protection level in accordance with DIN EN 169 (suitability to be verified). 2. Maintenance door / access door to the welding area: The maintenance door shall be equipped with guard locking in accordance with EN ISO 14119:2025 (interlock with guard locking, escape release in accordance with EN ISO 14119:2025 Section 6.9.1). The safety function "SF-01 Safe stop (stop category 1) upon opening of the maintenance door" shall be implemented with PLr d in accordance with EN ISO 13849-1:2023: opening the door stops the welding process (arc extinguishes) and brings the robot to a safe standstill before persons can reach the radiation area. Safety distance between the door and the welding area to be calculated in accordance with EN ISO 13855:2024. 3. Set-up mode with the maintenance door open: In set-up mode, welding (arc ignition) with the maintenance door open shall be interlocked at control level (welding enable only when the protective enclosure is closed and locked). The function "SF-05 Safely reduced speed 250 mm/s with enabling device in set-up mode" (PLr d) applies to robot movements; a separate control interlock prevents arc ignition in set-up mode when the door is open. The PLr of this welding-enable inhibit function shall be determined in accordance with EN ISO 13849-1:2023 (risk graph, S2/F/P). 4. Radiation protection at interfaces to adjacent stations: At transfer areas (e.g. the turning table opening), radiation protection curtains or labyrinth shields made of welding-suitable, UV-absorbing material shall be provided so that no direct radiation passage into adjacent working areas is possible.
- Step 3 · Information** Level 3, user information: 1. Operating instructions: Note on the radiation hazard from the MAG arc (UV, visible, IR) in accordance with (EU) 2023/1230 Annex III No. 1.7.4.1 and No. 1.7.4.2; statement that arc ignition with the protective enclosure open is inhibited at control level; description of the PPE requirements for set-up and maintenance activities in the vicinity of the welding area. 2. Qualification requirement: Set-up and maintenance personnel must have knowledge of the radiation hazard associated with arc welding; instruction in accordance with OStrV (occupational health and safety law, operator obligation) is to be identified in the operating instructions as an operator obligation. 3. PPE specification: For activities where a residual risk from stray radiation (e.g. reflections during set-up in the immediate vicinity) cannot be completely excluded: welding protection goggles or welding protection shield with an appropriate protection level (protection level in accordance with DIN EN 169, suitability to be verified), UV-resistant protective clothing and protective gloves. 4. Warning labelling: Warning of optical radiation / arc radiation at all access doors and openings of the welding protection booth; mandatory signs "Wear eye protection" and "Wear protective clothing" in accordance with DIN EN ISO 7010 to be affixed at all access points. Sign selection by meaning: warning of harmful optical radiation, obligation to wear eye protection and body protection. 5. Emission data: Information on the optical radiation of the arc in the operating instructions in accordance with (EU) 2023/1230 Annex III No. 1.5.10 and 1.7.4.2; the basis is the manufacturer's data for the welding power source and the assessment of radiation emission in accordance with EN 12198 (radiation from machinery).

Risk after: **4** Residual risk accepted: Yes

No. 19 RadiationRisk before: S 4 · P 2 · **RZ 8**

Hazard from electromagnetic fields (EMF) generated by the welding power source and the welding cables: High welding currents generate strong magnetic fields; persons with active implants (cardiac pacemakers, insulin pumps) may be endangered by the fields.

Sub-machine: Welding power source / welding cables · also in: Operation, Maintenance

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| Step 1 · Inherent | Route and bundle the welding cables (current conductor and return conductor) so that the forward and return conductors are brought into close spatial proximity (twisted or parallel-routed cable pairs with minimum distance between them): The magnetic fields of both conductors partially cancel each other out, which significantly reduces the resultant field strength in the surrounding area. Keep cables as short as technically possible and avoid unnecessary coiling or routing in loops, as loops increase field strength. Install the welding power source in a separate switchgear area or ancillary room with a structural distance from regular areas of presence, to the extent permitted by the machine concept. |
| Step 2 · Technical | Secure access to the welding area (welding cell) during operation by means of the existing fixed guard (safety fence in accordance with EN ISO 14120:2015), so that persons cannot enter the immediate vicinity of the active welding cables during automatic operation. Design access doors with guard locking in accordance with EN ISO 14119:2025 (SF-01, PLr d), which permits entry only after the welding current has been switched off. During setting-up mode and during maintenance work in the vicinity of cables: switch off the welding current before entering the hazard zone and secure it against being switched on again (energy isolation and standstill in accordance with EN ISO 14118:2018). Ensure a minimum distance from the welding area for persons with implants by means of structural measures (e.g. cordoning off the immediate vicinity outside the safety fence openings), to the extent that presence outside the cell is possible. Note: The suitability of additional EMF shielding measures (e.g. magnetically shielding cable ducts) is to be assessed on a project-specific basis. |
| Step 3 · Information | Operating instructions: Explicit statement that operation of the welding machine generates strong electromagnetic fields. Persons with active or passive metallic implants (cardiac pacemakers, insulin pumps, cochlear implants, metal implants) must not enter the immediate vicinity of the welding cables and the welding power source. Before commencing setting-up or maintenance activities in the vicinity of cables, the welding current must be switched off. Qualification requirement: Setting-up and maintenance personnel must be instructed regarding the EMF hazard; persons with known implants must be excluded from activities in the immediate vicinity of active welding cables. Warning labelling: Attach the warning sign for magnetic fields (warning sign in accordance with DIN EN ISO 7010, sign W006 "Warning: magnetic field") at the accesses to the welding cell and on the welding power source. Additionally, attach prohibition signs for persons with cardiac pacemakers (P007 in accordance with DIN EN ISO 7010) at all accesses. EMF emissions are to be described qualitatively in the operating instructions; the basis for assessment is the manufacturer's data for the welding power source in accordance with EN IEC 62822-2 (assessment of arc welding equipment with regard to EMF exposure of persons). |

Risk after: **4** Residual risk accepted: Yes

No. 20 Substances/materialsRisk before: S 4 · P 4 · **RZ 16**

Hazard from inhaling welding fumes and vapours (metal oxides, manganese, iron oxides): MAG welding of structural steel generates harmful particles and gases; when extraction is inadequate (saturated filter cartridge, system switched off), concentrations in the operator's breathing zone exceed the workplace exposure limits.

Sub-machine: Overall system (extraction / welding area) · also in: Operation, Maintenance, Cleaning

- Step 1 · Inherent** Substitution of the welding consumable: Use of solid-wire electrodes with a demonstrably reduced manganese content (low-Mn alloy, e.g. Mn content < 1.0 % in accordance with the safety data sheet) instead of flux-cored wire electrodes or high-manganese wires, to the extent that the welding task (structural steel, weld quality) permits this. In addition: optimisation of welding parameters (arc voltage, wire feed speed, shielding gas composition) to a low-fume setting in accordance with the welding power source manufacturer's recommendation, in order to minimise fume generation at source. Both measures genuinely reduce the emitted pollutant mass and thereby reduce the severity of exposure.
- Step 2 · Technical** Technical ventilation and extraction in accordance with EN ISO 21904-1:2020 (welding fume extraction): Source extraction directly at the welding point (extraction nozzle or integrated torch extraction) with a volumetric flow rate that ensures the capture velocity at the point of generation. The extraction system must be equipped with filter monitoring (differential-pressure switch) that triggers an alarm when the filter cartridge is saturated and inhibits welding operation via the machine control system (safety function: operating enable only when extraction is running, PLr to be determined in accordance with EN ISO 13849-1 risk graph). Enclosure of the welding area (welding booth/housing) in accordance with EN ISO 14120:2015, to the extent compatible with the turntable concept, in order to minimise fume escape into the operator area. Ambient air monitoring for welding fume concentration at the loading station is recommended as an additional operator measure.
- Step 3 · Information** Operating instructions (in accordance with (EU) 2023/1230 Annex III No. 1.7.4): Specification of the welding fume types emitted and reference to the workplace exposure limits to be observed in accordance with TRGS 900 and TRGS 528; instruction for regular inspection and replacement of filter cartridges (maintenance interval in accordance with manufacturer's specification EN ISO 21904-1:2020); prohibition of welding operation when the extraction system has failed or is switched off. Warning signs at the welding area: warning of harmful vapours and fumes (ISO 7010, warning sign), obligation to wear respiratory protection (ISO 7010, mandatory sign 'Wear respiratory protection') as residual risk marking. PPE requirement: respiratory protection of at least FFP2 (preferably FFP3 or powered air-purifying respirator) for setting-up, maintenance and cleaning work in the welding area when the enclosure is open or the extraction system is switched off. Qualification requirement: operators and setting-up personnel must be instructed in the hazards of welding fumes and the correct operation of the extraction system (TRGS 528 Section 5).

Risk after: **6** Residual risk accepted: Yes

No. 24 NoiseRisk before: S 3 · P 4 · **RZ 12**

Hazard from noise during the MAG welding process and from the rotary table drive: The welding process (arc noise, spatter) and mechanical drives generate relevant sound pressure levels at the loading station; during continuous operation (two-shift operation, 16 h), the daily noise exposure level LEX,8h may reach or exceed the action values of the LärmVibrationsArbSchV.

Sub-machine: Overall system (welding area / turning table) · also in: Operation

Step 1 · Inherent	Noise reduction at source by constructive measures: (1) Welding process optimisation: selection of low-emission welding parameters (pulsed arc instead of short arc where technically feasible in terms of the process), as the short arc generates higher spatter and noise emissions. (2) Drive encapsulation and structure-borne noise isolation of the rotary table drive: elastic mounting of the drive motor and gearbox on the machine frame in order to reduce structure-borne noise transmission to radiating surfaces. (3) Machine frame using sound-absorbing or damped profiles (e.g. sheet metal cladding lined with bituminous damping mats) instead of undamped steel sheet surfaces, in order to reduce sound radiation. Measurement and declaration of noise emission values will be carried out in Stage 2 and Stage 3.
Step 2 · Technical	For the residual risk remaining after Stage 1: (1) Acoustic shielding of the welding area by means of a sound-absorbing partition wall or welding protection wall between the welding area and the loading station, to the extent permitted by the machine function (rotary table loading). Design in accordance with EN ISO 11161:2007+A1:2010 (integration into the overall installation) and taking into account the safety distances in accordance with EN ISO 13857:2019. (2) Encapsulation or cladding of the rotary table drive with sound-absorbing material, provided that maintenance accessibility is ensured (cladding to be designed as a fixed/movable guard in accordance with EN ISO 14120:2015). (3) Noise measurement at the loading station in accordance with EN ISO 11202:2010 under representative operating conditions (two-shift operation, MAG welding active, rotary table in operation) in order to determine the actual LEX,8h as the basis for the operator's obligations under the LärmVibrationsArbSchV. Note: No safety function in accordance with EN ISO 13849-1 is affected; PLr determination does not apply to this hazard.
Step 3 · Information	Residual risk information for the operating instructions and labelling: (1) Operating instructions (MR (EU) 2023/1230 Annex III No. 1.7.4.2 u)): Statement of the measured emission sound pressure level LpA at the loading station in accordance with EN ISO 11202:2010 and EN ISO 4871:2009 (with measurement uncertainty K); where LpA exceeds 80 dB(A), additional statement of the sound power level LWA in accordance with EN ISO 3746:2010. Note on the operator's obligations under LärmVibrationsArbSchV (risk assessment, noise reduction programme from the upper action value LEX,8h 85 dB(A), obligation to provide hearing protection from 80 dB(A), obligation to wear hearing protection from 85 dB(A)). (2) Warning labelling at the loading station: Warning sign 'Warning: loud noise' and mandatory sign 'Wear hearing protection' in accordance with DIN EN ISO 7010, to be affixed in a clearly visible location. (3) Qualification and instruction: Operating personnel are to be instructed by the operator on the noise hazard, the action values and the correct use of hearing protection. (4) PPE specification: Suitable hearing protection (earmuffs or earplugs) with a sufficient attenuation value (SNR) corresponding to the measured LEX,8h is to be provided by the operator; selection in accordance with EN 458.

Risk after: **6** Residual risk accepted: Yes

No. 27 ErgonomicRisk before: S 2 · P 3 · **RZ 6**

Insufficient lighting at the loading station and in the maintenance walkway: inadequate illuminance makes it difficult to load and unload workpieces safely and to carry out maintenance work, and increases the risk of errors and accidents.

Sub-machine: Loading station / maintenance aisle · also in: Operation, Maintenance, Cleaning

Step 1 · Inherent	Machine-integrated workplace lighting at the loading station and in the maintenance walkway to be provided as part of the design: luminaires are permanently integrated into the machine structure (e.g. built into the enclosure frame or protective housing) so that the illuminance at the loading station and in the maintenance walkway is permanently ensured independently of the hall lighting. The design is carried out in accordance with EN ISO 12100:2010 section 6.2.6 (ergonomic design) in conjunction with EN 1837 (machine-integrated lighting); reference values: 500 lx at the loading station, 200 lx in the maintenance walkway, with the respective visual task being the determining factor. The constructive integration eliminates dependence on external lighting sources that may be inadequate.
Step 2 · Technical	Residual risk from failure or shadowing of the integrated luminaires: monitoring of the operational readiness of the workplace lighting by the machine control system (notification in the event of lamp failure). In addition, maintenance walkway areas to be marked with retroreflective floor markings (trip hazards, aisle boundaries) in accordance with DIN EN ISO 7010 (sign W007, warning of trip hazard, at relevant locations). A safety function within the meaning of EN ISO 13849-1 is not required for lighting monitoring; in the event of a lighting failure, work is to be discontinued (level 3).
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): specification of the required minimum illuminance at the loading station and in the maintenance walkway; notice that work is to be discontinued in the event of failure of the integrated lighting until the lighting has been restored. Warning marking in accordance with DIN EN ISO 7010 on the maintenance walkway door: notice of restricted visibility in the event of lamp failure. Qualification requirement: maintenance personnel must be instructed in checking the lighting function before commencing work. Use suitable portable luminaires for brief inspections in the event of a lighting failure; resume regular work only after the lighting has been restored.

Risk after: **2** Residual risk accepted: Yes

No. 30 CombinationRisk before: S 5 · P 2 · **RZ 10**

Hazard arising from incorrect parameterisation of the robot control system or the safety control system (e.g. incorrect safety distances, incorrect speed limits in set-up mode, incorrect zone releases): Erroneous parameters may result in safety functions not operating as intended, thereby endangering persons through robot movements or rotary table movements.

Sub-machine: Overall system (control / safety control) · also in: Commissioning, Maintenance

- Step 1 · Inherent** Safety-relevant parameters (speed limits, protection zones, zone releases) are stored exclusively in the safety control system (safety PLC) and are protected against unauthorised or inadvertent modification by a hardware key-switch concept or a password-protected, role-based access concept. Parameter sets for safety functions SF-01 to SF-05 are stored in the safety control system as immutable, checksum-protected data records (e.g. CRC-32 or equivalent), so that any unintended modification is automatically detected at system start-up and a safe state is enforced. This principle corresponds to the inherently safe control principle in accordance with EN ISO 12100 Section 6.2.11 (control principles that limit the occurrence of hazards) and reduces the possibility of erroneous parameters becoming effective at all.
- Step 2 · Technical** 1. Validation requirement before release: Every change to safety-relevant parameters requires a documented acceptance test (functional test of all affected safety functions SF-01 to SF-05) carried out by two authorised persons (four-eyes principle) before recommissioning. The safety control system may not release automatic operation until a positive acknowledgement has been given. Basis: EN ISO 13849-2:2012 (validation of safety functions) and EN ISO 11161:2007+A1:2010 Section 5.4 (verification and validation for integrated manufacturing systems). 2. Parameter verification by the safety control system: The safety control system (PLr e for SF-04, PLr d for SF-01, SF-03, SF-05 in accordance with EN ISO 13849-1:2023) checks the consistency of the safety-relevant parameters against stored reference values (checksum comparison) at start-up and cyclically. In the event of a discrepancy, stop category 1 in accordance with EN 60204-1:2018 is triggered and a restart is inhibited (no automatic restart in accordance with EN ISO 14118:2018). 3. Set-up mode SF-05: The safely reduced speed of 250 mm/s (SF-05, PLr d) is limited at hardware level in the safety control system and cannot be overridden by parameters of the robot control system. Monitoring is performed by an SRP/CS in accordance with EN ISO 13849-1:2023, category and PL in accordance with SF-05 (PLr d). 4. Zone release rotary table SF-04: The release of the 180-degree swivel movement (SF-04, PLr e) is performed exclusively via the safety control system on the basis of verified sensor signals; a release caused by erroneous zone parameters in the robot control system alone is excluded by design. 5. Change management: All parameter changes are stored with a time stamp, user identification and predecessor/successor value in a tamper-proof change log (audit trail) of the safety control system. Basis: EN ISO 11161:2007+A1:2010.
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the parameter change procedure with a step-by-step guide, listing of all safety-relevant parameters for each safety function (SF-01 to SF-05), obligation to carry out a validation test after each change, and documentation obligation in the change log. 2. Qualification requirement: Parameter changes to the safety control system may only be carried out by specialist personnel with demonstrated qualification in functional safety (e.g. TÜV certification as Functional Safety Engineer or equivalent) and knowledge of the system. This is to be set out in the operating instructions and in an operating procedure. 3. Warning labelling: A warning sign 'Warning of dangerous electrical voltage or unexpected machine movements' (ISO 7010) and a prohibition sign 'No unauthorised access' (ISO 7010) are to be affixed to the safety control system and the control cabinet. Additionally, an information sign stating: 'Parameter changes by authorised specialist personnel only; subsequent validation test required'. 4. Commissioning checklist: Before every initial commissioning and after every parameter change, a system-specific commissioning checklist is to be completed and signed (basis: EN ISO 11161:2007+A1:2010 Section 5.4).

Risk after: **5** Residual risk accepted: Yes

No. 32 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Hazard from reaching over or under the light curtain at the loading station (reasonably foreseeable misuse): Persons reach around the side of the light curtain or under the light curtain into the turning area without the protective function being triggered; the turntable or the robot may start up and trap hands or arms.

Sub-machine: Loading station (light curtain interface) · also in: Operation

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| Step 1 · Inherent | Inherent possibilities exhausted: The loading station requires a permanently open access opening for manual workpiece infeed. Complete geometric closure of this opening by design would render the machine non-functional. Minimum distances in accordance with EN ISO 13854:2019 cannot constructively prevent lateral bypassing of a light curtain as long as the opening must remain available for operator access. Limitation of force or energy at the turntable or robot to a non-hazardous level (Step 1) is not technically feasible at the masses and torques involved without impairing the function. |
| Step 2 · Technical | 1. Safety distance and under-reach guarding: Position the light curtain (Type 4 in accordance with EN 61496-1, SF-02, PLr e) such that the lowest beam is no more than 300 mm above the floor (under-reach limit value in accordance with EN ISO 13857:2019 Table 3 for reaching under fixed/movable guards). If the floor clearance cannot be reduced to ≤ 300 mm by design, a fixed under-reach protection bar (fixed guard in accordance with EN ISO 14120:2015) must be fitted flush below the lowest beam so that reaching under is not possible. 2. Lateral flank guarding: Fixed guards (side panels or channel guides) in accordance with EN ISO 14120:2015 must be fitted on both sides of the light curtain to constructively prevent lateral bypassing. The depth of these flanks must be determined in accordance with EN ISO 13857:2019 Table 1 (safety distance as a function of opening width) so that the hazard zone cannot be reached from the lateral direction. 3. Light curtain specification: The light curtain must be selected as Type 4 in accordance with EN 61496-1 and integrated into safety function SF-02 (PLr e). The safety distance between the light curtain and the nearest hazard zone must be calculated and maintained in accordance with EN ISO 13855:2024 (reaching through at a detection capability of up to 40 mm in accordance with clause 8.3.2, resolution ≤ 14 mm for finger detection or ≤ 30 mm for hand detection). Integration into the control system is carried out in accordance with EN ISO 13849-1:2023, PLr e (SF-02). 4. Muting function (if provided): If a muting function is provided for workpiece transport, it must be designed to PLr e in accordance with EN ISO 13849-1:2023 and may only be activated for defined workpiece profiles. Muting sensors must be arranged so that a body part cannot be detected as a workpiece. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Explicit statement that lateral bypassing or reaching under the light curtain is prohibited and overrides safety function SF-02. Description of the correct loading action (insert workpiece from the front through the light curtain). Note on the hazard posed by the turntable and the robot when the protective function has not been triggered. 2. Warning signs (DIN EN ISO 7010): Warning of hand injuries (crushing/entanglement) to be affixed on both sides of the flank panels and on the light curtain frame. Prohibition sign 'Do not reach into the hazard zone' at the access opening. 3. Qualification requirement: In setting-up mode (SF-05, PLr d, safely reduced speed 250 mm/s with enabling device) only instructed specialist personnel who are familiar with the function and limitations of the light curtain may work. This requirement must be recorded in the operating instructions and in the instruction documentation. 4. PPE: Protective gloves provide no protection against crushing and entanglement hazards from the turntable or robot and are not suitable as a protective measure for this hazard. This notice must be included in the operating instructions to avoid incorrect assumptions. |

Risk after: **5** Residual risk accepted: Yes

No. 36 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Manipulation of safety-relevant parameters via the network: Unauthorised write access via fieldbus, OPC UA or MES interface alters safety-relevant parameters (e.g. muting times, monitoring of the safety door, speed, force or energy limits). The protective function becomes ineffective or the machine operates outside the limits defined in the risk assessment. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.1.9 para. 3, 1.2.1 lit. a, 1.2.1 lit. d]

Sub-machine: Control / network · also in: Operation

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| Step 1 · Inherent | Safety-relevant parameters are to be held only in the safety controller and must not be writable via the process network under any circumstances (write access physically or architecturally separated, safety network segmented from standard communication). Limit values derived from the risk assessment are to be stored as constants in the safety program, not as recipe data. |
| Step 2 · Technical | Authentication and authorisation for every write access (roles, no default passwords), integrity checking of safety-relevant configuration (checksum/CRC with release procedure), plausibility checking of incoming values against the permissible limits, logging of every parameter change with timestamp and user. Evidence reference Path B: IEC 62443-3-3 SR 1.1, SR 2.1, SR 3.4, SR 3.5, SR 5.1, SR 2.8. |
| Step 3 · Information | Operating instructions: network requirements for the operator (segmentation, firewall, no direct internet connection of the controller), list of safety-relevant parameters with a note that changes are only permissible by authorised personnel and with a subsequent functional check of the safety functions. |

Risk after: **4** Residual risk accepted: Yes

No. 37 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Unintentional corruption through misconfiguration or operator error: Incorrect recipe or parameter file loaded, roles and passwords not set up (default password active), configuration incompletely restored after a fault. Safety-relevant settings deviate from the approved configuration without being noticed. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.2.1 lit. b, 1.2.1 lit. d, 1.2.1 lit. e]

Sub-machine: HMI / parameterisation · also in: Operation, Commissioning

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| Step 1 · Inherent | Separate safety-relevant settings from process recipes so that a recipe change cannot alter them; hard-limit value ranges in the safety controller (limits derived from the risk assessment, Annex III No. 1.2.1 lit. d). |
| Step 2 · Technical | Forced password change on commissioning, role model with dual-control approval for safety-relevant changes, comparison of the active configuration with the approved reference (checksum) at start-up with display of any deviation, change log. Evidence reference Path B: IEC 62443-3-3 SR 1.5, SR 2.1, SR 3.4, SR 7.6. |
| Step 3 · Information | Operating instructions: commissioning checklist (passwords, roles, saving of reference configuration), description of the data designated as safety-relevant, instruction for functional testing after configuration changes. |

Risk after: **4** Residual risk accepted: Yes

Operation (29 hazards)

No. 1 Mechanical		Risk before: S 5 · P 3 · RZ 15
Crushing and shearing hazard from the turntable during the automatic turning operation: Body parts of the operator (hands, arms) may be drawn in and crushed between the rotating table and the fixed centre wall or the protective fence, in particular when reaching into the turntable during turning to reposition a displaced workpiece (reasonably foreseeable misuse).		
<i>Sub-machine: Turning table (rotary table unit) · also in: Setting up, Troubleshooting</i>		
Step 1 · Inherent	Design the gap dimensions between the rotating table edge and the fixed centre wall as well as the protective fence such that no crushing points arise: comply with the minimum distances in accordance with EN ISO 13854:2019 Table 1 (25 mm for fingers, 100 mm for the hand, 120 mm for the arm, 500 mm for the body). If neither the small nor the large gap can be achieved by design, the geometry of the table frame must be configured so that no converging wedge shape is created (parallel or diverging flanks instead of a converging gap). In addition: reduce the mass and pivoting speed of the turntable to the functionally necessary minimum (drive design) in order to limit the kinetic energy acting in the crushing gap.	
Step 2 · Technical	Residual risk after level 1: The swivel area remains a hazard zone that must not be entered while the drive is running. Technical protective measures: 1. Release of the swivel movement only when the swivel area is clear (SF-04, PLr e, EN ISO 13849-1:2023): BWS (light curtain type 4 in accordance with EN 61496-1) monitors the swivel area completely; arrangement and safety distance in accordance with EN ISO 13855:2024. 2. Guard locking of the access door to the turntable area in accordance with EN ISO 14119:2025 with escape release (SF-01, PLr d; stop category 1 in accordance with EN 60204-1:2018). 3. Set-up mode: swivel movement only at safely reduced speed of 250 mm/s and with the enabling device actuated (SF-05, PLr d, stop category 1 in accordance with EN 60204-1:2018). 4. Emergency stop in the operator area in accordance with EN ISO 13850:2015, integrated into SF-03 (PLr d, stop category 1 in accordance with EN 60204-1:2018). 5. Energy isolation prior to interventions: isolating valve with mechanical latching (lockout) in accordance with EN ISO 4414:2010; secure gravitational lowering by means of mechanical support (EN ISO 14118:2018).	
Step 3 · Information	1. Operating instructions: entering the swivel area while the turntable is running or unsecured is prohibited. Before any intervention (e.g. repositioning a workpiece), the system must be completely switched off and secured (lockout/tagout). A separate procedure with an enabling device applies to set-up mode and is described in the operating instructions. 2. Warning signs on the machine: warning signs are affixed to the turntable: "Warning: hand injury hazard", "Warning: rotating parts" and "Entry prohibited during operation" (in accordance with DIN EN ISO 7010). 3. Who may intervene: set-up and fault rectification may only be carried out by trained personnel. Training must be repeated at least once a year and recorded in writing. 4. Personal protective equipment: protective gloves are prohibited at the turntable, as they increase the risk of the hand being drawn in. Safety footwear (protection class S2 or S3) is mandatory throughout the entire system area.	
Risk after: 5 Residual risk accepted: Yes		 Warning: crushing

No. 3 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Impact and crushing hazard from the welding robot during automatic operation in the event of unauthorised access: persons who climb over the protective fence or tamper with the maintenance door are struck by the robot axis moving at full speed and force or are pressed against fixed parts.

Sub-machine: Welding robot

Step 1 · Inherent Inherent possibilities exhausted: the functional principle of the welding robot requires the free, rapid movement of the robot arm with full payload within the working space. Limiting force or speed to a level that is harmless to persons (impact force below the pain threshold) is technically incompatible with the required process parameters in automatic operation and would prevent the welding process. Geometric resolution of the hazard zone by shaping alone is not possible with a 6-axis industrial robot.

Step 2 · Technical 1. Fixed guard (protective fence): fixed guard in accordance with EN ISO 14120:2015 around the entire robot working space. Minimum height and mesh size in accordance with EN ISO 13857:2019 Table 1 (upper body access) to be designed so that climbing over without aids is not possible; safety distance to be calculated in accordance with EN ISO 13855:2024. Design to be such that reaching under or through into the hazard zone is not possible (EN ISO 13857:2019 Tables 2 and 4). 2. Interlocked maintenance door with guard locking (SF-01): the maintenance door is provided with an interlocked guard with guard locking in accordance with EN ISO 14119:2025. Opening the door triggers SF-01 'Safe stop, stop category 1'. The guard locking keeps the door closed until the robot has come to a safe standstill. Escape release to be provided in accordance with EN ISO 14119:2025 section 6.9.1. PLR d in accordance with project definition SF-01; integration into the safety control system in accordance with EN ISO 13849-1:2023. 3. Tamper protection of the protective devices: interlocking devices in accordance with EN ISO 14119:2025 section 8 to be designed against tampering (bypassing); coding level and fastening concept to be documented. In addition: protective fence panels to be fastened so that they can only be released using a tool (no quick-release fasteners), so that unauthorised opening without a tool is not possible. 4. Emergency stop devices (SF-03): emergency stop pushbuttons on the outside of the protective fence and at the maintenance door in accordance with EN ISO 13850:2015, integrated into SF-03 'Emergency stop of the entire system, stop category 1', PLR d in accordance with project definition SF-03. 5. Protection against unexpected restart: energy isolation and restart prevention in accordance with EN ISO 14118:2018 to be ensured; restart after door opening only by deliberate acknowledgement at an operator panel located outside the hazard zone. 6. Set-up mode (SF-05): in set-up mode, robot movement only at safely reduced speed of 250 mm/s and with enabling device in accordance with SF-05, PLR d; integration in accordance with EN ISO 10218-2:2025 sections 5.5.6 and 5.7.7 and EN ISO 13849-1:2023.

Step 3 · Information 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the access rules for the robot working space, prohibition of climbing over the protective fence, procedure for energy isolation prior to entry (lockout/tagout in accordance with EN ISO 14118:2018), qualification requirements for operators and set-up personnel (robot safety instruction in accordance with EN ISO 10218-2:2025). 2. Warning marking on the protective fence and at the maintenance door in accordance with DIN EN ISO 7010: warning of the robot working space (warning of automatically starting machinery), prohibition sign 'No entry for unauthorised persons'. Marking to be affixed so that it is clearly visible and permanent. 3. Instruction: operating personnel and set-up personnel are to be instructed before initial commissioning and thereafter at regular intervals. Unauthorised access is to be prevented by organisational measures (access control, key-operated switch for operating mode selection in accordance with EN ISO 10218-2:2025 section 5.7.2). 4. Residual risk notice in the operating instructions: despite all protective measures, a residual risk exists in the event of tampering with the protective devices; notice of the criminal law and liability consequences of tampering.

Risk after: **5** Residual risk accepted: Yes

No. 4 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Crushing hazard at the interface between the turning table and the welding robot (transfer area): During the turning operation the loaded fixture moves into the working area of the robot; uncoordinated entry of the robot into the turning area or missing interlock between the turning table movement and the robot enable can lead to collisions and crushing injuries.

Sub-machine: Interface: turning table / welding robot · also in: Setting up, Troubleshooting

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| Step 1 · Inherent | The pivoting radius of the turning table and the working space boundary of the robot (TCP envelope) are coordinated with each other during the design phase such that the maximum pivoting range of the fixture and the minimum robot working space maintain a geometric minimum distance of ≥ 500 mm (safety distance against reaching with the arm in accordance with EN ISO 13857:2019 Table 1, body opening arm) from each other when both movements would be active simultaneously. This minimises the overlap zone by design; complete elimination of the overlap is not possible with this system topology due to functional constraints, so that the remaining residual overlap is safeguarded by Level 2. |
| Step 2 · Technical | SF-04 'Enable of the 180-degree pivoting movement of the turning table only when the pivoting area is clear' with PLr e in accordance with EN ISO 13849-1:2023 (risk graph: S2/F2/P2). Implementation as an interlocked safety function in the safety PLC: (a) Robot standstill monitoring: the robot must be in a defined rest position (safe position) outside the pivoting zone and must confirm this via a safe feedback signal (e.g. safe output of the robot controller in accordance with EN ISO 10218-2:2025 Sections 5.4.7 and 5.5.8) before the turning table enable is granted. (b) Turning table enable to the robot: as long as the turning table is not in its end position and locked, the robot controller receives no enable signal for the entry area; guard locking of the pivoting movement via a safety drive or mechanical interlock. (c) Guard locking of the maintenance door to the pivoting area in accordance with EN ISO 14119:2025 with escape release, incorporated in SF-01 (PLr d). (d) Emergency stop of the complete system in accordance with EN ISO 13850:2015, incorporated in SF-03 (PLr d), stop category 1 in accordance with EN 60204-1:2018. (e) In set-up mode SF-05 applies: safely reduced speed ≤ 250 mm/s with enabling device (PLr d); the setter may enter the pivoting area only with the enabling device activated and at reduced speed. Safety distance of the fixed guard (safety fence) to the pivoting area to be calculated and documented in accordance with EN ISO 13855:2024 and EN ISO 13857:2019; safety fence to be designed in accordance with EN ISO 14120:2015. |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the interlock logic SF-04 and the permissible operating modes; explicit notice that entering the pivoting area while the system is running is prohibited. Set-up mode: qualification requirement to be documented (only trained specialist personnel with knowledge of the enabling device). Warning labelling at the pivoting area: warning of crushing hazard (ISO 7010, warning sign 'Warning: hand injury' or 'Warning: dangerous area') and prohibition sign 'No entry' (ISO 7010) at all access points. PPE specification in the operating instructions: safety footwear; in set-up mode additionally close-fitting protective clothing (no entanglement risk from loose clothing). Note on residual risk in set-up mode and fault-finding: always keep the enabling device activated, never enter the pivoting area without the enabling device. |

Risk after: **5** Residual risk accepted: Yes

No. 5 MechanicalRisk before: S 4 · P 3 · **RZ 12**

Falling of workpieces or fixture parts due to failure of the pneumatic clamping device: In the event of compressed air failure or leakage, the clamping elements open in an uncontrolled manner; workpieces of up to 40 kg may fall from the rotary table and strike persons at the loading station.

Sub-machine: Pneumatic clamping device (rotary table) · also in: Setting up, Troubleshooting

Step 1 · Inherent	Use of clamping elements with a spring-force closing principle ("Normally Closed", NC): The clamping force is generated by pre-tensioned springs; compressed air is only required for opening (releasing) the clamping elements. In the event of compressed air failure or leakage, the workpiece remains securely clamped. The spring force is designed for the maximum workpiece weight of 40 kg plus a safety factor in accordance with EN ISO 4414:2010 Section 5.4 (fail-safe principle). Additionally: limitation of the operating pressure to the minimum level required for the opening function, in order to minimise the pneumatic energy stored in the event of a fault (EN ISO 4414:2010 Section 5.3).
Step 2 · Technical	1. Pressure monitoring with safety function: Pressure switch in the supply circuit of the clamping device; if the minimum pressure required for the opening function is not reached, the release of the rotary motion of the rotary table is inhibited (interlocked with SF-04, PLr e in accordance with EN ISO 13849-1:2023). As long as sufficient pressure is not present, the rotary table must not rotate and the loading release is not granted. 2. Mechanical interlock of the rotary motion: Positive locking of the rotary table in the loading position, so that unintended rotation with a clamped or loose workpiece is prevented; the interlock is released only after confirmed clamping force (interlocked with SF-04, PLr e). 3. Enclosure/catch device: Mechanical catch device (e.g. catch rail or deflector plate) below the rotary table, designed for the maximum workpiece weight of 40 kg and the maximum drop height, to keep falling parts away from the loading station; design in accordance with EN ISO 14120:2015. 4. Safety distance at the loading station: Arrangement of the loading station such that the hazard zone below the rotary table is outside the regular area of presence; safety distance to be verified and documented in accordance with EN ISO 13857:2019 Table 1 (upper limbs).
Step 3 · Information	1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the NC clamping principle and the pressure monitoring; prohibition of remaining beneath the rotary table during operation and during fault-finding without secured standstill; procedure in the event of compressed air failure (shut down the machine, restore the compressed air supply, remove the workpiece only after a pressure check). 2. Energy isolation prior to interventions: Instruction for complete pressure relief of the pneumatic system prior to maintenance and servicing work in accordance with EN ISO 4414:2010 Section 5.2 and EN ISO 14118:2018 (prevention of unexpected restart and unexpected energy release); provide a shut-off and exhaust valve with lockout facility. 3. Warning labelling: Attach the warning sign "Warning: overhead load" and the warning sign "Warning: hand injuries" in accordance with DIN EN ISO 7010 to the rotary table and at the loading station. 4. Qualification: Fault-finding and setting-up work to be carried out by trained specialist personnel only; requirements to be specified in the operating instructions. 5. PPE: Prescribe the wearing of safety footwear (EN ISO 20345, protection class S2 or S3) at the loading station as residual risk protection.

Risk after: **4** Residual risk accepted: Yes

No. 7 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Missing or uncoordinated emergency stop function between sub-machines (robot, turning table, welding power source, extraction system): an emergency stop at one sub-machine does not necessarily stop all other sub-machines; persons may be endangered by components that continue to run.

Sub-machine: Overall system (emergency stop coordination) · also in: Setting up, Troubleshooting

Step 1 · Inherent	Inherent possibilities exhausted: the coordination of several independent controllers necessarily requires a higher-level control logic. A purely constructive measure (geometry, energy limitation, substitution) cannot replace the missing interconnection of the emergency stop circuits. The functional principle of the linked plant necessitates active control coordination.
Step 2 · Technical	Higher-level emergency stop circuit (SF-03) in accordance with EN ISO 13850:2015 and EN ISO 11161:2007+A1:2010: all emergency stop actuating devices of the complete plant are integrated into a common, higher-level safety circuit which, on actuation at any point, brings all sub-machines (robot, turning table, welding power source, extraction system) to a coordinated standstill. Stop category 1 in accordance with EN 60204-1:2018 (controlled stopping, followed by energy disconnection): the robot performs a controlled stop along its path, the turning table brakes actively, the welding power source is de-energised, and the extraction system runs on (not a safety function, but operationally required). Safety function SF-03 is to be designed to PLr d in accordance with EN ISO 13849-1:2023 (Category 3 or 4, depending on architecture). Integration of the robot is carried out via the robot controller in accordance with EN ISO 10218-2:2025 Section 5.3.3 (span of control of the emergency stop, safety interface to the higher-level controller). Emergency stop actuating devices are to be designed in accordance with EN ISO 13850:2015 (mushroom-head pushbutton, yellow background, self-latching, release only by deliberate action). Emergency stop actuating devices are to be positioned such that at least one actuating device is reachable from every operating position without exposure to a hazard (EN ISO 13850:2015 Section 4.4). Restart interlock: after an emergency stop, a manual reset is required before the plant can restart (EN ISO 13850:2015 Section 4.1.4), in order to prevent unexpected restart in accordance with EN ISO 14118:2018.
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the emergency stop topology of the complete plant with a layout plan of all emergency stop actuating devices and the area of effect of each actuating device. Clear instruction that after an emergency stop, the hazard zone of all sub-machines must be inspected before the reset is carried out. Set-up mode and fault-finding: instruction that intervention in the hazard zone is only permissible after all sub-machines have come to a complete standstill and reset protection has been secured (key switch or lock). Qualification requirement: set-up and fault-finding only by instructed specialist personnel who are familiar with the emergency stop topology. Warning marking at all operator panels: information sign indicating the area of effect of the respective emergency stop actuating device (warning of unexpected start-up of adjacent sub-machines, signs in accordance with DIN EN ISO 7010, warning of automatic start-up).

Risk after: **5** Residual risk accepted: Yes

No. 9 MechanicalRisk before: S 4 · P 4 · **RZ 16**

Ergonomic hazard and crushing hazard during manual loading and unloading of workpieces up to 40 kg: Workpieces over 15 kg should be loaded using lifting equipment; in the event of reasonably foreseeable misuse (lifting without lifting equipment), musculoskeletal strain arises together with the risk of losing grip, with the subsequent falling of the workpiece onto feet or hands.

Sub-machine: Loading station (operator station) · also in: Setting up

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| Step 1 · Inherent | Inherent limitation of the manually handled workpiece mass to a maximum of 15 kg by dividing heavy workpiece carriers or using sub-pallets, so that no individual part exceeds the limit in accordance with EN 1005-2:2003+A1:2008 (reference value 15 kg for occasional lifting under favourable conditions). Where division is not constructively possible (workpieces 15 kg to 40 kg), a permanently integrated lifting equipment interface (e.g. load eyes, vacuum gripper docking point or balancer interface) is constructively provided at the loading station as an integral part of the workpiece fixture, so that loading without lifting equipment is geometrically impracticable (insertion depth, rigging geometry). |
| Step 2 · Technical | 1. Provision of a suitable lifting aid (balancer, vacuum lifter or jib crane) at the loading station, designed for the maximum workpiece mass of 40 kg with a sufficient operating radius to fully cover the loading zone. The lifting aid must be arranged so that the operator can reach the loading position without re-gripping or releasing the workpiece. 2. Floor marking of the set-down and slewing area of the lifting aid at the loading station, so that the operator is not standing beneath the suspended load during loading. 3. The light curtain at the loading station (SF-02, PLr e) safeguards the hazard zone of the machine opening; it does not protect against the falling of the workpiece itself, but it does limit the area in which hands may be located during loading. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Clear specification of the maximum manual handling mass (15 kg), the obligation to use the lifting aid from 15 kg onwards, and the correct rigging points on the workpiece. Specification of body posture during loading in accordance with EN 1005-2:2003+A1:2008. 2. Warning labelling at the loading station: Warning sign 'Warning of suspended load' and 'Warning of hand injuries' in accordance with DIN EN ISO 7010, as well as mandatory signs 'Wear safety footwear' and 'Use lifting equipment' in accordance with DIN EN ISO 7010 (semantic meaning: obligation to use the lifting aid). Specification of the maximum load in kg directly at the loading station. 3. Qualification requirement: Operators must be instructed in the use of the lifting aid and in ergonomically correct handling before commencing work (documented instruction). 4. PPE specification: Safety footwear S2/S3 with steel toecap and protective gloves (cut-resistant, secure grip) are to be stipulated as minimum PPE for all loading and unloading activities. |

Risk after: **8** Residual risk accepted: Yes

No. 10 MechanicalRisk before: S 3 · P 3 · **RZ 9**

Hazard of tripping, slipping and falling in the area of the loading station and the maintenance aisle due to weld spatter on the floor, cables, hoses (compressed air, shielding gas) and wet areas during cleaning work.

Sub-machine: Loading station / maintenance aisle · also in: Setting up, Maintenance, Cleaning, Troubleshooting

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| Step 1 · Inherent | Keep cables and hoses (compressed air, shielding gas) out of the floor area of the loading station and maintenance aisle by means of constructive routing in cable ducts, energy chain systems or ceiling-suspended cable management systems, so that no trip hazards arise. Design connections at the loading station as ceiling pendants or wall-mounted socket panels. Reduce weld-spatter exposure on the floor by means of constructive shielding plates (spatter-protection shields) at the welding station, so that discharge into the operator area is minimised. Provide the floor covering in the loading station and maintenance aisle with an anti-slip surface (assessment group R 11 or higher in accordance with BGR/GUV-R 181, suitability for wet conditions to be verified), so that the slip hazard is inherently reduced. |
| Step 2 · Technical | Limit the residual risk from remaining trip and slip hazards by means of the following technical measures: (1) Floor markings (yellow/black in accordance with ISO 7010) to identify traffic routes and hazardous areas in accordance with (EU) 2023/1230 Annex III No. 1.1.2 and No. 1.6.2. (2) Adequate fixed lighting of the loading station and maintenance aisle in accordance with (EU) 2023/1230 Annex III No. 1.1.4, so that obstacles and wet areas can be detected at an early stage; illuminance to be specified according to the visual task; machine-integrated lighting to be designed in accordance with EN 1837. (3) Drip trays or spatter-protection mats in the immediate welding area that are easy to remove and clean. |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): (1) Reference to the hazard of tripping and slipping due to weld spatter, hoses and wet conditions; prescribe cleaning intervals and cleaning procedures for the floor area. (2) Qualification requirement: all persons entering the loading station and maintenance aisle must have been instructed in the hazards and the traffic-route layout. (3) PPE specification: safety footwear with anti-slip soles (S2 or S3 in accordance with EN ISO 20345) shall be worn when entering the loading station and maintenance aisle. (4) Warning labelling at the access to the loading station and maintenance aisle: affix a warning sign for slip hazard (ISO 7010, warning sign 'Warning: slippery surface') and the mandatory sign 'Wear safety footwear' (ISO 7010, mandatory sign). |

Risk after: **6** Residual risk accepted: Yes

No. 13 ElectricalRisk before: S 4 · P 2 · **RZ 8**

Hazard from welding current at the workpiece and at the fixture: the welding circuit carries high currents (typically 100 to 350 A); in the event of a faulty earth connection or damaged insulation, persons who touch the workpiece or the fixture may receive an electric shock.

Sub-machine: Welding power source / fixture · also in: Setting up, Troubleshooting

- Step 1 · Inherent** Design the fixture frame and workpiece holders such that touchable conductive surfaces that lie within the welding current circuit are galvanically isolated from the machine frame by constructive insulation (e.g. insulating plates made of Pertinax/glass-fibre epoxy between the fixture base plate and the machine table, as well as insulating clamping jaw inserts). This constructively interrupts the unintentional current path via the frame and touchable external surfaces. In addition: define the earth cable connection point directly on the workpiece or at a designated location on the fixture that is not touchable by the operator, and integrate it by means of shaping (recess, cable routing channel) in such a way that incorrect positioning of the earth clamp is constructively impeded.
- Step 2 · Technical** 1. Welding power source: Procurement of a welding power source with protection class I and degree of protection of at least IP23S in accordance with EN IEC 60974-1 (procurement requirement); integration into the protective conductor chain of the overall installation shall be carried out in accordance with EN 60204-1:2018 Section 8 (protective conductor cross-sections, connection points). 2. Monitoring of the earth connection: If the welding power source or the system control supports an earth current monitoring function, this shall be activated; in the event of interruption or an impermissibly high contact resistance, the welding process is inhibited (safety function in accordance with EN ISO 13849-1:2023, PLr to be determined according to risk graph, as no project-specific SF has been defined for this function). 3. Equipotential bonding: All conductive parts of the fixture that are not deliberately insulated are included in the protective equipotential bonding of the installation (EN 60204-1:2018 Section 8.2). 4. Access restriction during the welding process: The loading station is safeguarded by the light curtain (SF-02, PLr e in accordance with EN ISO 13849-1:2023); during active welding, access to the welding area is prevented by the interlocked maintenance door (SF-01, PLr d) and the enable logic of the turn-over table (SF-04, PLr e), so that contact with live parts in automatic mode is prevented by both constructive and control-engineering means. 5. Cable management: Welding cables and earth cables are routed in enclosed cable ducts or protective conduits (protection against mechanical damage); minimum bending radii as specified by the manufacturer shall be observed; cables shall be secured with strain relief.
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the correct connection of the earth clamp (position, cleaning of the contact surface, permissible clamping areas); notice that touching the workpiece and the fixture during the welding process is prohibited; inspection interval for insulation and cable condition (recommended: daily visual inspection, semi-annual insulation measurement by a qualified electrician). 2. Qualification requirement: Setting up, fault-finding and maintenance on the welding power source and its connections may only be carried out by a qualified electrician or an electrotechnically instructed person under the supervision of a qualified electrician (EN 60204-1:2018 Section 4.2). 3. Warning labelling on the fixture and in the welding area: Attach warning signs 'Warning of electric voltage' and 'Warning of hand injuries from welding spatter' in accordance with DIN EN ISO 7010 at a clearly visible location; attach an information sign 'Check earth clamp before commencing welding'. 4. PPE specification in the operating instructions: When setting up and fault-finding in the welding area, insulating gloves (protection class suitable for low voltage) and welding protective clothing shall be worn.

Risk after: **4** Residual risk accepted: Yes

No. 14 ElectricalRisk before: S 4 · P 2 · **RZ 8**

EMC interference between welding power source and safety controller (robot controller, light curtain evaluation unit, guard locking controller): high-frequency interference pulses from the MAG arc can influence safety functions and lead to spurious triggering or, more critically, to undetected failure of safety functions (EN ISO 11161).

Sub-machine: Overall system (EMC interface) · also in: Setting up

- Step 1 · Inherent** Spatial and galvanic separation of welding circuits from safety circuits by design specification: (1) Route the welding current return conductor as a dedicated return conductor close to the workpiece, directly back at the welding table, so that no large-area current loops are created that act as antennas. (2) Route welding current cables and safety signal/control cables in separate cable ducts with a minimum separation of 200 mm (separation distance in accordance with EN 61000-6-2:2019 Annex A as design reference); crossings at right angles only. (3) Earth the welding power source and safety controller on separate equipotential bonding busbars connected with low impedance to the system protective conductor, in order to avoid common impedance paths. These measures reduce coupling at the source without requiring a protective device.
- Step 2 · Technical** For the remaining residual risk of conducted and radiated interference: (1) Execute all safety signal and control cables (light curtain SF-02, guard locking SF-01, rotary release SF-04, emergency stop SF-03) as screened cables; connect the screen at both ends with low impedance to the equipotential bonding busbar. (2) Use mains filters (interference suppression filters) at the supply feed of the safety controller and the light curtain evaluation unit, designed in accordance with EN 61000-6-2:2019 (immunity requirements for industrial environments). (3) Install the robot controller, light curtain evaluation unit and guard locking controller only in control cabinets with continuous shielding (metal enclosures, EMC-compliant cable entries). (4) The safety controller and all components of safety functions SF-01 to SF-05 shall demonstrably comply with the immunity requirements of EN 61000-6-2:2019 (manufacturer's evidence as a procurement requirement). (5) Safety functions SF-01 (PLr d), SF-02 (PLr e), SF-03 (PLr d), SF-04 (PLr e) and SF-05 (PLr d) shall be validated in accordance with EN ISO 13849-1:2023 and EN ISO 13849-2:2012; the validation shall explicitly take into account the influence of EMC on the diagnostic coverage and the MTTFd of the safety functions. (6) Welding power source: procurement only with CE marking and EU declaration of conformity, including compliance with the EMC Directive 2014/30/EU; verify emission levels in accordance with EN 60974-10 (EMC of arc welding equipment) and EN 61000-6-4:2019. (7) Complete installation: carry out an EMC acceptance test in accordance with EN 61000-6-2:2019 in the operating state with the welding process active, in order to verify the immunity of the safety functions under real operating conditions.
- Step 3 · Information** Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): (1) Note that modifications to cable routing (welding current cables, control cables) may only be carried out by qualified skilled personnel with EMC expertise. (2) Maintenance instruction: regular visual inspection of screen terminations, equipotential bonding connections and cable duct separation; define inspection interval. (3) Note that after every replacement of the welding power source, robot controller or safety components, a renewed EMC functional check of the safety functions is required. (4) Qualification requirement: set-up personnel (operating mode Set-up, SF-05 active) shall be instructed in EMC-related fault patterns on safety controllers. (5) Warning label on the control cabinet of the safety controller: warning of electromagnetic fields (ISO 7010, warning sign for electromagnetic field), note on the prescribed cable routing.

Risk after: **4** Residual risk accepted: Yes

No. 15 ThermalRisk before: S 3 · P 4 · **RZ 12**

Burn hazard from hot workpieces and weld seams: Freshly welded assemblies reach several hundred degrees Celsius in the seam area; serious burns may result from removal without suitable protective gloves or from contact with the seam.

Sub-machine: Loading station (removal side) · also in: Setting up

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| Step 1 · Inherent | Inherent options exhausted: The operating principle of arc/gas-shielded welding necessarily requires heat input into the workpiece; the resulting seam temperature cannot physically be reduced to a safe level without suppressing the welding process itself. Substitution of the joining process (e.g. adhesive bonding, bolting) is not provided for according to the machine description and would not meet the product requirements. A geometric measure (distance from the seam by means of shaping) cannot be realised constructively at the removal grip point, as the operator must grip the assembly. |
| Step 2 · Technical | 1. Forced cooling time: A control-side lockout period after the end of welding (timer in the system control), during which the release for removal at the loading station (removal side) remains locked. The lockout period is to be determined on the basis of the workpiece geometry and the heat input, and parameterised in the control system. This function is not a safety function within the meaning of EN ISO 13849-1 (no PLr assigned), but a process-related interlock; it reduces the probability of occurrence but does not replace the obligation to use PPE. 2. Warning light / signalling device: Optical indicator (e.g. a red signal light at the removal station) that is active during the cooling lockout period and extinguishes as soon as the release is granted. 3. Thermal shielding: Where structurally feasible, the arrangement of a heat shield (heat protection plate or curtain) between the welding area and the removal station, in order to reduce radiant heat on the operator (design in accordance with EN ISO 13732-1:2008 with regard to contact temperature limits as a design reference for surfaces that may be touched inadvertently). |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Reference to the risk of burns from hot workpieces and weld seams; specification of the required cooling time before removal; obligation to wear heat-protective gloves (PPE Category II, suitable for contact heat in accordance with EN 407, performance level at least contact heat Level 3) and, where applicable, forearm protection. 2. Warning labelling at the removal station: Warning sign 'Warning of hot surface' (ISO 7010) and mandatory sign 'Wear protective gloves' (ISO 7010) to be affixed permanently and clearly visible at the loading station (removal side) ((EU) 2023/1230 Annex III No. 1.7.1). 3. Qualification and instruction: Operators and set-up personnel are to be instructed in the risk of burns, the cooling times and the obligation to use PPE before commencing work; the instruction is to be documented. 4. Provision of PPE: The operating instructions must instruct the operator to provide suitable heat-protective gloves (EN 407) and to monitor their use. |

Risk after: **6** Residual risk accepted: Yes

No. 16 ThermalRisk before: S 4 · P 3 · **RZ 12**

Burn and fire hazard from welding spatter (spark ejection): During MAG welding, spatter is generated at temperatures above 1500 degrees C; it can land on combustible materials (packaging, oils, clothing) in the surrounding area and cause fires or burns.

Sub-machine: Welding robot / welding area · also in: Setting up

- Step 1 · Inherent** Welding parameter optimisation to minimise spatter: Use of a low-spatter arc process (e.g. pulsed arc or CMT-type short arc) instead of the conventional short arc, to the extent permitted by the joining task. By specifically reducing the transferred spatter energy and quantity, the probability of ignition-capable spatter reaching combustible materials is reduced by design. Additionally: position the welding area such that no combustible operating materials (oils, lubricants, packaging) are stored or routed within the spatter protection radius defined by the plant planning (minimum 1 m, to be specified on a project-specific basis). Lines carrying combustible media shall be routed out of the spatter area or provided with non-combustible shields.
- Step 2 · Technical** 1. Fixed/movable guard (welding booth/spatter protection walls): Complete spatial enclosure of the welding area by means of non-combustible, welding-spatter-resistant partition walls (e.g. steel sheet or certified welding protection curtain material) in accordance with EN ISO 14120:2015. The enclosure prevents spatter from escaping into the general working area. Openings (workpiece entry/exit) shall be closed by overlapping welding protection curtains (non-combustible, tested in accordance with the relevant product standard). 2. Extraction system in the welding area: capture of welding fumes and particles directly at the point of origin in accordance with EN ISO 21904-1:2020, in order to extract glowing particles and reduce the thermal load on the surrounding area. 3. Secure the exclusion zone around the welding booth (minimum 1 m) by structural means: permanent floor marking and, where possible, physical barriers; no storage or depositing areas within the zone. 4. Fire protection: provide a bracket for a fire extinguisher (CO2 or powder, no water due to the electrical installation) at the cell; provision and inspection of extinguishing agents are the responsibility of the operator (note in the operating instructions, Stage 3). 5. Safety functions: the protective devices of the welding booth (access doors, maintenance openings) shall be integrated into the safety controller. For the release of welding operation, SF-04 (PLr e) or SF-01 (PLr d) applies in accordance with the project's own functional safety module, to the extent that the booth doors are integrated into these safety functions as access guards.
- Step 3 · Information** 1. Operating instructions (pursuant to (EU) 2023/1230 Annex III No. 1.7.4): Reference to the spatter protection radius and prohibition of storing combustible materials in the welding area. Specification of the permissible welding parameter ranges (current, voltage, wire feed) to minimise spatter ejection. Instructions for the regular cleaning of spatter from machine surfaces and the welding area (reduction of fire load). Procedural instructions for the event of fire (alerting, first-response extinguishing, evacuation). 2. Warning labelling on the welding enclosure: Warning of fire hazard caused by welding spatter (warning sign in accordance with DIN EN ISO 7010, warning of flammable materials, semantic meaning: 'Warning of fire hazard caused by welding spatter'). Warning of hot surfaces in the welding area (semantic meaning: 'Warning of hot surface', in accordance with DIN EN ISO 7010). Mandatory sign: 'Wear welding protective clothing' (in accordance with DIN EN ISO 7010). 3. Qualification requirement: Setters and operators must be trained in the operation of the welding system and in the handling of fire protection equipment. Setters require a qualification as a welding specialist or equivalent documented instruction. 4. PPE specification: During setting mode (life phases involving personal exposure in the welding area), the following PPE must be worn: flame-retardant welding protective clothing (in accordance with EN ISO 11611), welding protective gloves (in accordance with EN 12477), welding protective screen or helmet with an appropriate protection level. In automatic mode with the enclosure closed, no welder PPE is required; however, entering the welding area during operation is prohibited (operating instructions).

Risk after: **4** Residual risk accepted: Yes

No. 18 RadiationRisk before: S 4 · P 3 · **RZ 12**

Hazard from optical radiation of the MAG arc (UV, visible, IR): the arc emits intense ultraviolet, visible and infrared radiation; unprotected viewing of the arc (including through an open maintenance door in set-up mode) can cause eye injuries (keratoconjunctivitis, retinal damage) and skin burns.

Sub-machine: Welding robot / welding area · also in: Setting up

- Step 1 · Inherent** Inherent possibilities exhausted: the functional principle of MAG welding necessarily requires an open arc with high radiation intensity; current, voltage and arc energy cannot be reduced to a level at which the radiation hazard is eliminated without interrupting the welding process. Geometric relocation of the hazard point is not possible in a robot welding system with changing welding positions.
- Step 2 · Technical** Level 2, technical protective measures: 1. Enclosure of the welding area: Complete fixed guard (welding protection booth) made of radiation-opaque walls and viewing panels in accordance with EN ISO 14120:2015; wall material and coating (matt black, light-absorbing surface) to be designed such that no relevant UV/IR reflection escapes to the outside. Viewing windows, where provided, to be fitted with welding protection glass of the appropriate protection level in accordance with DIN EN 169 (suitability to be verified). 2. Maintenance door / access door to the welding area: The maintenance door shall be equipped with guard locking in accordance with EN ISO 14119:2025 (interlock with guard locking, escape release in accordance with EN ISO 14119:2025 Section 6.9.1). The safety function "SF-01 Safe stop (stop category 1) upon opening of the maintenance door" shall be implemented with PLr d in accordance with EN ISO 13849-1:2023: opening the door stops the welding process (arc extinguishes) and brings the robot to a safe standstill before persons can reach the radiation area. Safety distance between the door and the welding area to be calculated in accordance with EN ISO 13855:2024. 3. Set-up mode with the maintenance door open: In set-up mode, welding (arc ignition) with the maintenance door open shall be interlocked at control level (welding enable only when the protective enclosure is closed and locked). The function "SF-05 Safely reduced speed 250 mm/s with enabling device in set-up mode" (PLr d) applies to robot movements; a separate control interlock prevents arc ignition in set-up mode when the door is open. The PLr of this welding-enable inhibit function shall be determined in accordance with EN ISO 13849-1:2023 (risk graph, S2/F/P). 4. Radiation protection at interfaces to adjacent stations: At transfer areas (e.g. the turning table opening), radiation protection curtains or labyrinth shields made of welding-suitable, UV-absorbing material shall be provided so that no direct radiation passage into adjacent working areas is possible.
- Step 3 · Information** Level 3, user information: 1. Operating instructions: Note on the radiation hazard from the MAG arc (UV, visible, IR) in accordance with (EU) 2023/1230 Annex III No. 1.7.4.1 and No. 1.7.4.2; statement that arc ignition with the protective enclosure open is inhibited at control level; description of the PPE requirements for set-up and maintenance activities in the vicinity of the welding area. 2. Qualification requirement: Set-up and maintenance personnel must have knowledge of the radiation hazard associated with arc welding; instruction in accordance with OStrV (occupational health and safety law, operator obligation) is to be identified in the operating instructions as an operator obligation. 3. PPE specification: For activities where a residual risk from stray radiation (e.g. reflections during set-up in the immediate vicinity) cannot be completely excluded: welding protection goggles or welding protection shield with an appropriate protection level (protection level in accordance with DIN EN 169, suitability to be verified), UV-resistant protective clothing and protective gloves. 4. Warning labelling: Warning of optical radiation / arc radiation at all access doors and openings of the welding protection booth; mandatory signs "Wear eye protection" and "Wear protective clothing" in accordance with DIN EN ISO 7010 to be affixed at all access points. Sign selection by meaning: warning of harmful optical radiation, obligation to wear eye protection and body protection. 5. Emission data: Information on the optical radiation of the arc in the operating instructions in accordance with (EU) 2023/1230 Annex III No. 1.5.10 and 1.7.4.2; the basis is the manufacturer's data for the welding power source and the assessment of radiation emission in accordance with EN 12198 (radiation from machinery).

Risk after: **4** Residual risk accepted: Yes

No. 19 RadiationRisk before: S 4 · P 2 · **RZ 8**

Hazard from electromagnetic fields (EMF) generated by the welding power source and the welding cables: High welding currents generate strong magnetic fields; persons with active implants (cardiac pacemakers, insulin pumps) may be endangered by the fields.

Sub-machine: Welding power source / welding cables · also in: Setting up, Maintenance

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| Step 1 · Inherent | Route and bundle the welding cables (current conductor and return conductor) so that the forward and return conductors are brought into close spatial proximity (twisted or parallel-routed cable pairs with minimum distance between them): The magnetic fields of both conductors partially cancel each other out, which significantly reduces the resultant field strength in the surrounding area. Keep cables as short as technically possible and avoid unnecessary coiling or routing in loops, as loops increase field strength. Install the welding power source in a separate switchgear area or ancillary room with a structural distance from regular areas of presence, to the extent permitted by the machine concept. |
| Step 2 · Technical | Secure access to the welding area (welding cell) during operation by means of the existing fixed guard (safety fence in accordance with EN ISO 14120:2015), so that persons cannot enter the immediate vicinity of the active welding cables during automatic operation. Design access doors with guard locking in accordance with EN ISO 14119:2025 (SF-01, PLr d), which permits entry only after the welding current has been switched off. During setting-up mode and during maintenance work in the vicinity of cables: switch off the welding current before entering the hazard zone and secure it against being switched on again (energy isolation and standstill in accordance with EN ISO 14118:2018). Ensure a minimum distance from the welding area for persons with implants by means of structural measures (e.g. cordoning off the immediate vicinity outside the safety fence openings), to the extent that presence outside the cell is possible. Note: The suitability of additional EMF shielding measures (e.g. magnetically shielding cable ducts) is to be assessed on a project-specific basis. |
| Step 3 · Information | Operating instructions: Explicit statement that operation of the welding machine generates strong electromagnetic fields. Persons with active or passive metallic implants (cardiac pacemakers, insulin pumps, cochlear implants, metal implants) must not enter the immediate vicinity of the welding cables and the welding power source. Before commencing setting-up or maintenance activities in the vicinity of cables, the welding current must be switched off. Qualification requirement: Setting-up and maintenance personnel must be instructed regarding the EMF hazard; persons with known implants must be excluded from activities in the immediate vicinity of active welding cables. Warning labelling: Attach the warning sign for magnetic fields (warning sign in accordance with DIN EN ISO 7010, sign W006 "Warning: magnetic field") at the accesses to the welding cell and on the welding power source. Additionally, attach prohibition signs for persons with cardiac pacemakers (P007 in accordance with DIN EN ISO 7010) at all accesses. EMF emissions are to be described qualitatively in the operating instructions; the basis for assessment is the manufacturer's data for the welding power source in accordance with EN IEC 62822-2 (assessment of arc welding equipment with regard to EMF exposure of persons). |

Risk after: **4** Residual risk accepted: Yes

No. 20 Substances/materialsRisk before: S 4 · P 4 · **RZ 16**

Hazard from inhaling welding fumes and vapours (metal oxides, manganese, iron oxides): MAG welding of structural steel generates harmful particles and gases; when extraction is inadequate (saturated filter cartridge, system switched off), concentrations in the operator's breathing zone exceed the workplace exposure limits.

Sub-machine: Overall system (extraction / welding area) · also in: Setting up, Maintenance, Cleaning

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| Step 1 · Inherent | Substitution of the welding consumable: Use of solid-wire electrodes with a demonstrably reduced manganese content (low-Mn alloy, e.g. Mn content < 1.0 % in accordance with the safety data sheet) instead of flux-cored wire electrodes or high-manganese wires, to the extent that the welding task (structural steel, weld quality) permits this. In addition: optimisation of welding parameters (arc voltage, wire feed speed, shielding gas composition) to a low-fume setting in accordance with the welding power source manufacturer's recommendation, in order to minimise fume generation at source. Both measures genuinely reduce the emitted pollutant mass and thereby reduce the severity of exposure. |
| Step 2 · Technical | Technical ventilation and extraction in accordance with EN ISO 21904-1:2020 (welding fume extraction): Source extraction directly at the welding point (extraction nozzle or integrated torch extraction) with a volumetric flow rate that ensures the capture velocity at the point of generation. The extraction system must be equipped with filter monitoring (differential-pressure switch) that triggers an alarm when the filter cartridge is saturated and inhibits welding operation via the machine control system (safety function: operating enable only when extraction is running, PLr to be determined in accordance with EN ISO 13849-1 risk graph). Enclosure of the welding area (welding booth/housing) in accordance with EN ISO 14120:2015, to the extent compatible with the turntable concept, in order to minimise fume escape into the operator area. Ambient air monitoring for welding fume concentration at the loading station is recommended as an additional operator measure. |
| Step 3 · Information | Operating instructions (in accordance with (EU) 2023/1230 Annex III No. 1.7.4): Specification of the welding fume types emitted and reference to the workplace exposure limits to be observed in accordance with TRGS 900 and TRGS 528; instruction for regular inspection and replacement of filter cartridges (maintenance interval in accordance with manufacturer's specification EN ISO 21904-1:2020); prohibition of welding operation when the extraction system has failed or is switched off. Warning signs at the welding area: warning of harmful vapours and fumes (ISO 7010, warning sign), obligation to wear respiratory protection (ISO 7010, mandatory sign 'Wear respiratory protection') as residual risk marking. PPE requirement: respiratory protection of at least FFP2 (preferably FFP3 or powered air-purifying respirator) for setting-up, maintenance and cleaning work in the welding area when the enclosure is open or the extraction system is switched off. Qualification requirement: operators and setting-up personnel must be instructed in the hazards of welding fumes and the correct operation of the extraction system (TRGS 528 Section 5). |

Risk after: **6** Residual risk accepted: Yes

No. 21

Substances/materials

Risk before: S 4 · P 2 · **RZ 8**

Hazard from shielding gas (argon-CO₂ mixture M21) in the event of leakage: Shielding gas is heavier than air (CO₂ content) and may accumulate near floor level; in the event of larger leakages in poorly ventilated areas, there is a risk of asphyxiation due to oxygen displacement.

Sub-machine: Shielding gas supply / piping system · also in: Maintenance, Troubleshooting

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| Step 1 · Inherent | Pressure limitation in the piping system: Limit the operating pressure of the shielding gas supply to the minimum level required for the welding process (pressure regulator directly at the withdrawal point of the cylinder battery or at the supply connection). A lower system pressure reduces the quantity of gas escaping in the event of a fault and thus the potential for accumulation. Additionally: design the pipe routing and connection points so that leakages are constructively minimised: use of cutting ring fittings or press fittings instead of hose clamps on fixed pipe sections; reduce hose lengths to the minimum operationally necessary; no routing of pipes near floor level in pits or enclosed chambers (route near the ceiling where possible). These measures address the energy source (stored pressurised gas) and the hazard location (accumulation zone) directly. |
| Step 2 · Technical | 1. Automatic shut-off of the gas supply: Solenoid valve (de-energised closed) in the shielding gas supply line, which automatically shuts off the gas supply upon machine stop, emergency stop (SF-03) and during operating pauses; additionally, a manual shut-off valve outside the cell. 2. Leak monitoring: Plausibility check of gas consumption via the machine control system (indication when gas flow occurs without an active welding process, as a leakage indicator); daily visual inspection of hose connections as a maintenance requirement. 3. Installation of the shielding gas supply (cylinder battery or withdrawal station) in a ventilated area of the hall, not in pits, basements or confined recesses. If installed in poorly ventilated areas, the operator is required to provide an oxygen warning device (note in the operating instructions). A safety function with a PLr requirement is not necessary for this hazard; the risk is controlled by means of shut-off, installation location and ventilation. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Note on the risk of asphyxiation due to oxygen displacement in the event of larger leaks in poorly ventilated areas; requirement for adequate hall ventilation at the installation site; work on the gas supply only with the line shut off and depressurised (EN ISO 14118:2018). 2. Qualification: Work on compressed gas lines and fittings only by instructed specialist personnel; instruction in accordance with DGUV Regel 100-500 Chapter 2.26 and TRGS 528 (operator's obligation). 3. Warning labelling: Note on the risk of asphyxiation in poorly ventilated areas at the gas supply installation site; prohibition sign 'No entry for unauthorised persons' on locked supply areas (DIN EN ISO 7010). 4. When working in confined or poorly ventilated areas (e.g. cylinder changes in recesses): use a portable oxygen warning device; no lone working. |

Risk after: **4**

Residual risk accepted: Yes

No. 24

Noise

Risk before: S 3 · P 4 · **RZ 12**

Hazard from noise during the MAG welding process and from the rotary table drive: The welding process (arc noise, spatter) and mechanical drives generate relevant sound pressure levels at the loading station; during continuous operation (two-shift operation, 16 h), the daily noise exposure level LEX,8h may reach or exceed the action values of the LärmVibrationsArbSchV.

Sub-machine: Overall system (welding area / turning table) · also in: Setting up

- Step 1 · Inherent** Noise reduction at source by constructive measures: (1) Welding process optimisation: selection of low-emission welding parameters (pulsed arc instead of short arc where technically feasible in terms of the process), as the short arc generates higher spatter and noise emissions. (2) Drive encapsulation and structure-borne noise isolation of the rotary table drive: elastic mounting of the drive motor and gearbox on the machine frame in order to reduce structure-borne noise transmission to radiating surfaces. (3) Machine frame using sound-absorbing or damped profiles (e.g. sheet metal cladding lined with bituminous damping mats) instead of undamped steel sheet surfaces, in order to reduce sound radiation. Measurement and declaration of noise emission values will be carried out in Stage 2 and Stage 3.
- Step 2 · Technical** For the residual risk remaining after Stage 1: (1) Acoustic shielding of the welding area by means of a sound-absorbing partition wall or welding protection wall between the welding area and the loading station, to the extent permitted by the machine function (rotary table loading). Design in accordance with EN ISO 11161:2007+A1:2010 (integration into the overall installation) and taking into account the safety distances in accordance with EN ISO 13857:2019. (2) Encapsulation or cladding of the rotary table drive with sound-absorbing material, provided that maintenance accessibility is ensured (cladding to be designed as a fixed/movable guard in accordance with EN ISO 14120:2015). (3) Noise measurement at the loading station in accordance with EN ISO 11202:2010 under representative operating conditions (two-shift operation, MAG welding active, rotary table in operation) in order to determine the actual LEX,8h as the basis for the operator's obligations under the LärmVibrationsArbSchV. Note: No safety function in accordance with EN ISO 13849-1 is affected; PLr determination does not apply to this hazard.
- Step 3 · Information** Residual risk information for the operating instructions and labelling: (1) Operating instructions (MR (EU) 2023/1230 Annex III No. 1.7.4.2 u)): Statement of the measured emission sound pressure level LpA at the loading station in accordance with EN ISO 11202:2010 and EN ISO 4871:2009 (with measurement uncertainty K); where LpA exceeds 80 dB(A), additional statement of the sound power level LWA in accordance with EN ISO 3746:2010. Note on the operator's obligations under LärmVibrationsArbSchV (risk assessment, noise reduction programme from the upper action value LEX,8h 85 dB(A), obligation to provide hearing protection from 80 dB(A), obligation to wear hearing protection from 85 dB(A)). (2) Warning labelling at the loading station: Warning sign 'Warning: loud noise' and mandatory sign 'Wear hearing protection' in accordance with DIN EN ISO 7010, to be affixed in a clearly visible location. (3) Qualification and instruction: Operating personnel are to be instructed by the operator on the noise hazard, the action values and the correct use of hearing protection. (4) PPE specification: Suitable hearing protection (earmuffs or earplugs) with a sufficient attenuation value (SNR) corresponding to the measured LEX,8h is to be provided by the operator; selection in accordance with EN 458.

Risk after: **6** Residual risk accepted: Yes

No. 27 ErgonomicRisk before: S 2 · P 3 · **RZ 6**

Insufficient lighting at the loading station and in the maintenance walkway: inadequate illuminance makes it difficult to load and unload workpieces safely and to carry out maintenance work, and increases the risk of errors and accidents.

Sub-machine: Loading station / maintenance aisle · also in: Setting up, Maintenance, Cleaning

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| Step 1 · Inherent | Machine-integrated workplace lighting at the loading station and in the maintenance walkway to be provided as part of the design: luminaires are permanently integrated into the machine structure (e.g. built into the enclosure frame or protective housing) so that the illuminance at the loading station and in the maintenance walkway is permanently ensured independently of the hall lighting. The design is carried out in accordance with EN ISO 12100:2010 section 6.2.6 (ergonomic design) in conjunction with EN 1837 (machine-integrated lighting); reference values: 500 lx at the loading station, 200 lx in the maintenance walkway, with the respective visual task being the determining factor. The constructive integration eliminates dependence on external lighting sources that may be inadequate. |
| Step 2 · Technical | Residual risk from failure or shadowing of the integrated luminaires: monitoring of the operational readiness of the workplace lighting by the machine control system (notification in the event of lamp failure). In addition, maintenance walkway areas to be marked with retroreflective floor markings (trip hazards, aisle boundaries) in accordance with DIN EN ISO 7010 (sign W007, warning of trip hazard, at relevant locations). A safety function within the meaning of EN ISO 13849-1 is not required for lighting monitoring; in the event of a lighting failure, work is to be discontinued (level 3). |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): specification of the required minimum illuminance at the loading station and in the maintenance walkway; notice that work is to be discontinued in the event of failure of the integrated lighting until the lighting has been restored. Warning marking in accordance with DIN EN ISO 7010 on the maintenance walkway door: notice of restricted visibility in the event of lamp failure. Qualification requirement: maintenance personnel must be instructed in checking the lighting function before commencing work. Use suitable portable luminaires for brief inspections in the event of a lighting failure; resume regular work only after the lighting has been restored. |

Risk after: **2** Residual risk accepted: Yes

No. 31 CombinationRisk before: S 5 · P 2 · **RZ 10**

Hazard from differing safety levels of the partial machines from different manufacturers (robot, welding power source, turntable, extraction system): missing or incomplete interface interlocking between the partial machines may result in one partial machine starting up even though another is in an unsafe condition (EN ISO 11161).

Sub-machine: Overall system (system integration) · also in: Commissioning, Troubleshooting

- Step 1 · Inherent** System architecture with a single, superordinate safety controller (Safety Master) as an inherently safe control principle in accordance with EN ISO 12100 Section 6.2.11: All safety-relevant status signals of the sub-machines (robot operating mode, turning table end position, extraction system operation, welding power source ready) are routed exclusively via the Safety Master. No sub-machine drive receives an enable signal unless the Safety Master has assessed the overall state as safe. Through this centralisation, the possibility of an incomplete interface interlock is constructively reduced to a minimum: there are no parallel, mutually independent enable paths between the sub-machines. The interface definition is carried out in accordance with EN ISO 11161:2007+A1:2010 Section 5 (system integration, responsibilities, interface description) and is documented in the safety concept of the overall installation.
- Step 2 · Technical** Level 2a: Interlock matrix in accordance with EN ISO 11161:2007+A1:2010 Section 6: For each sub-machine combination, a complete state matrix (operating mode x state of the other sub-machines) is created and implemented in the safety controller. Each enable signal is implemented as an AND-combination of all relevant safety states. Level 2b: Safety function SF-04 (enable of the 180-degree pivoting movement of the turning table only when the pivoting area is clear, PLr e in accordance with project specification) ensures that the turning table only pivots when the robot is demonstrably outside the pivoting area. The safety function is designed to PLr e in accordance with EN ISO 13849-1:2023 and validated in accordance with EN ISO 13849-2:2012. Level 2c: Safety function SF-01 (safe stopping upon opening of the maintenance door, stop category 1, PLr d) and SF-02 (safe stopping upon interruption of the light curtain, PLr e) are coordinated across the entire installation: a stop signal from one sub-machine triggers the coordinated stop of all sub-machines via the Safety Master. Stop categories in accordance with EN 60204-1:2018 Section 9.2.2 are to be defined per drive (robot: stop category 1 in accordance with SF-01/SF-03; turning table: stop category 1 in accordance with SF-03). Level 2d: Emergency stop of the overall installation (SF-03, stop category 1, PLr d in accordance with project specification) in accordance with EN ISO 13850:2015 acts on all sub-machines simultaneously via the Safety Master. Emergency stop command devices are arranged at all operator stations and access points. Level 2e: Prevention of unexpected start-up in accordance with EN ISO 14118:2018: After every stop (emergency stop, activation of a protective device, interruption of energy supply), a deliberate restart command is required; automatic restart is excluded. Level 2f: Setting mode with safely reduced speed (SF-05, 250 mm/s, PLr d in accordance with project specification) and enabling device for the robot in accordance with EN ISO 10218-2:2025 Section 5.7.7; in this mode, all other sub-machines (turning table, welding power source) are interlocked and at standstill.
- Step 3 · Information** Operating instructions for the overall installation in accordance with (EU) 2023/1230 Annex III No. 1.7.4: The interface interlock logic (state matrix, enable conditions per sub-machine) is to be documented in full. For each sub-machine, the handover point of safety responsibility (sub-machine manufacturer up to the interface, integrator from the interface onwards) is to be defined in writing in accordance with EN ISO 11161:2007+A1:2010 Section 4.3 and stated in the operating instructions. Qualification requirement: commissioning, parameterisation and modifications to the safety controller may only be carried out by qualified specialist personnel with knowledge of EN ISO 13849-1:2023 and EN ISO 11161. Warning labelling at all operator panels: warning against unexpected start-up of sub-machines (warning sign in accordance with DIN EN ISO 7010, warning against automatic start-up). The operating instructions must describe procedures for fault-finding and commissioning, including the sequence in which sub-machines may be commissioned and the verification steps for checking the interface interlock prior to the first automatic operation.

Risk after: **5** Residual risk accepted: Yes

No. 32 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Hazard from reaching over or under the light curtain at the loading station (reasonably foreseeable misuse): Persons reach around the side of the light curtain or under the light curtain into the turning area without the protective function being triggered; the turntable or the robot may start up and trap hands or arms.

Sub-machine: Loading station (light curtain interface) · also in: Setting up

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| Step 1 · Inherent | Inherent possibilities exhausted: The loading station requires a permanently open access opening for manual workpiece infeed. Complete geometric closure of this opening by design would render the machine non-functional. Minimum distances in accordance with EN ISO 13854:2019 cannot constructively prevent lateral bypassing of a light curtain as long as the opening must remain available for operator access. Limitation of force or energy at the turntable or robot to a non-hazardous level (Step 1) is not technically feasible at the masses and torques involved without impairing the function. |
| Step 2 · Technical | 1. Safety distance and under-reach guarding: Position the light curtain (Type 4 in accordance with EN 61496-1, SF-02, PLr e) such that the lowest beam is no more than 300 mm above the floor (under-reach limit value in accordance with EN ISO 13857:2019 Table 3 for reaching under fixed/movable guards). If the floor clearance cannot be reduced to ≤ 300 mm by design, a fixed under-reach protection bar (fixed guard in accordance with EN ISO 14120:2015) must be fitted flush below the lowest beam so that reaching under is not possible. 2. Lateral flank guarding: Fixed guards (side panels or channel guides) in accordance with EN ISO 14120:2015 must be fitted on both sides of the light curtain to constructively prevent lateral bypassing. The depth of these flanks must be determined in accordance with EN ISO 13857:2019 Table 1 (safety distance as a function of opening width) so that the hazard zone cannot be reached from the lateral direction. 3. Light curtain specification: The light curtain must be selected as Type 4 in accordance with EN 61496-1 and integrated into safety function SF-02 (PLr e). The safety distance between the light curtain and the nearest hazard zone must be calculated and maintained in accordance with EN ISO 13855:2024 (reaching through at a detection capability of up to 40 mm in accordance with clause 8.3.2, resolution ≤ 14 mm for finger detection or ≤ 30 mm for hand detection). Integration into the control system is carried out in accordance with EN ISO 13849-1:2023, PLr e (SF-02). 4. Muting function (if provided): If a muting function is provided for workpiece transport, it must be designed to PLr e in accordance with EN ISO 13849-1:2023 and may only be activated for defined workpiece profiles. Muting sensors must be arranged so that a body part cannot be detected as a workpiece. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Explicit statement that lateral bypassing or reaching under the light curtain is prohibited and overrides safety function SF-02. Description of the correct loading action (insert workpiece from the front through the light curtain). Note on the hazard posed by the turntable and the robot when the protective function has not been triggered. 2. Warning signs (DIN EN ISO 7010): Warning of hand injuries (crushing/entanglement) to be affixed on both sides of the flank panels and on the light curtain frame. Prohibition sign 'Do not reach into the hazard zone' at the access opening. 3. Qualification requirement: In setting-up mode (SF-05, PLr d, safely reduced speed 250 mm/s with enabling device) only instructed specialist personnel who are familiar with the function and limitations of the light curtain may work. This requirement must be recorded in the operating instructions and in the instruction documentation. 4. PPE: Protective gloves provide no protection against crushing and entanglement hazards from the turntable or robot and are not suitable as a protective measure for this hazard. This notice must be included in the operating instructions to avoid incorrect assumptions. |

Risk after: **5** Residual risk accepted: Yes

No. 34 ThermalRisk before: S 3 · P 3 · **RZ 9**

Fire hazard in the welding fume extraction system (filter fire): Sparks and glowing particles drawn in by the process can accumulate in the filter cartridge and ignite a smouldering fire or filter fire, including in a time-delayed manner after the end of a shift. Fire smoke can spread via the pipework system and the air recirculation into the hall.

also in: Maintenance

Step 1 · Inherent	Spark reduction at the point of origin through constructive design of the welding parameters and the extraction geometry: Position the extraction nozzle as close as technically possible to the welding point (maximise the capture rate) so that sparks have already cooled before they reach the filter cartridge. In addition, provide a pre-spark separator (baffle plate/cyclone separator) as an integrated component directly upstream of the filter cartridge, which separates coarse particles and sparks by inertia before they come into contact with the filter medium. This component is a constructive part of the extraction system, not a downstream protective device. Design in accordance with EN ISO 21904-1:2020 (requirements for welding fume extraction systems), which specifies spark separation as a constructive requirement for the system.
Step 2 · Technical	The remaining residual risk of a filter fire is limited by the following technical protective measures: 1. Thermal monitoring of the filter cartridge: temperature sensor (thermostat or thermocouple) in the filter housing with a trigger threshold; upon exceedance, automatic shutdown of the extraction fan and closing of a motorised shut-off damper in the pipework system to prevent the supply of oxygen. Integration into the machine control system; PLr to be determined in accordance with EN ISO 13849-1 (risk graph). 2. Extinguishing device at the filter housing: at least one closable extinguishing agent inlet opening (extinguishing lance) on the housing; optionally an automatic extinguishing device (CO ₂ or water spray), selection to be agreed with the operator's fire protection concept. 3. Motorised shut-off damper in the air recirculation duct to the hall: automatic closure upon fire alarm to prevent the spread of smoke into the hall. Integration into the building management system or machine control system. 4. Smoke and CO detectors in the filter housing and in the exhaust air duct as a redundant detection level, with alarm forwarding to a permanently staffed location or to a fire alarm control panel (operator's responsibility, to be agreed with the building fire protection concept). 5. Run-on time of the extraction fan after the end of welding: programme a minimum run-on time of 10 minutes at the control system level so that glowing particles still present in the pipework are fully transported into the separator and cooled before the system is shut down. Design of the run-on time based on the pipework length and the volumetric flow rate.
Step 3 · Information	Operating instructions (in accordance with (EU) 2023/1230 Annex III No. 1.7.4): - Reference to the fire hazard from sparks and glowing particles in the filter system; description of the damage mechanism including time-delayed ignition. - The prescribed run-on time of the extraction fan after the end of welding (minimum value from the design) as a binding operating instruction. - Maintenance intervals for filter cartridges, pre-spark separators and temperature sensors; specification of the loading level at which the filter cartridge is to be replaced (manufacturer's specification EN ISO 21904-1:2020). - Prohibition on operating the extraction system with a defective temperature sensor or deactivated extinguishing system. - Procedure in the event of a fire alarm: vacate the installation immediately, alert the fire brigade, do not attempt to deal with the filter housing independently (opening it can fan a smouldering fire). - Note that after the end of a shift, a visual inspection of the filter housing (temperature, odour) is to be carried out before the building is vacated. Warning labelling on the extraction system (DIN EN ISO 7010): - Warning of fire hazard (warning of flammable substances/sparks) on the filter housing and maintenance opening. - Prohibition sign 'Do not open in the event of a fire alarm' on the maintenance door of the filter housing. Qualification and instruction: - Operating personnel and maintenance personnel are to be instructed before commencing work and thereafter at least annually on the fire hazard, the function of the protective devices and the correct behaviour in the event of a fire (operator's obligation). - Maintenance work on the filter system only by instructed personnel wearing appropriate PPE (protective gloves, and where applicable respiratory protection during filter replacement due to welding fume exposure).

Risk after: **3** Residual risk accepted: Yes

No. 35 ErgonomicRisk before: S 3 · P 5 · **RZ 15**

Hazard from constrained postures and repetitive movements during loading and unloading of workpieces: The operator repeatedly performs gripping, lifting and clamping movements at a cycle of approximately 90 seconds; unfavourable body postures (bending, stretching) with varying workpiece geometries place strain on the spine, shoulders and wrists.

Step 1 · Inherent	Height-adjustable loading station (lift table or height-adjustable workpiece support), designed for the body height range P5 to P95 of the operating population in accordance with EN 1005-2:2003+A1:2008 Section 5 (working height for assembly/handling: approximately 900 to 1100 mm above standing surface, individually adjustable). Design the workpiece carrier or clamping fixture so that all gripping points are within the recommended gripping zone (elbow height ± 150 mm, horizontal reach max. 400 mm in front of the body), without bending or stretching. Assess workpiece weight and handling frequency in accordance with EN 1005-2 Section 6: if the product of mass and frequency exceeds the limit value of the standard, the workpiece mass must be reduced by dividing the batch or by constructive weight reduction (Step 1 measure). Design the grip geometry of the clamping fixture for a neutral wrist position (no ulnar/radial deviation, no forced pronation) in accordance with EN ISO 12100:2010 Section 6.2.6.
Step 2 · Technical	To the extent that, after Step 1, a residual force or residual frequency remains that exceeds the limit value in accordance with EN 1005-2: use of a handling assistant (balancer, vacuum lifter or collaborative lightweight robot) for workpieces above the mass threshold determined in accordance with EN 1005-2. Design and integration of the handling assistant in accordance with EN ISO 10218-2:2025 (if a collaborative robot) or in accordance with EN ISO 4414:2010 (if a pneumatic vacuum lifter). Support cycle time and break scheduling via the machine control system (enforced micro-breaks or cycle buffers), where the process permits. Ensure illumination at the loading station of at least 500 lx (visual task: workpiece positioning) in order to avoid poor postures caused by inadequate visibility.
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Specification of the workpiece mass/masses and the assessed postural load in accordance with EN 1005-2; instructions on the correct adjustment of the working height with a setting guide. Ergonomic instruction for operators: correct lifting technique, use of the handling assistant, recognition of overload signals. Reference in the operating instructions to the operator's obligation regarding occupational health surveillance in accordance with ArbMedVV (offer of health surveillance for activities involving heavy physical work). Warning labelling at the loading station: information sign 'Maximum handling mass [X] kg' (ISO 7010 M-sign, semantic meaning: observe handling weight) and reference to the obligation to use the handling assistant above the stated mass threshold. Qualification requirement: Operators must be instructed in ergonomically correct operation and in the adjustment of the lift table.

Risk after: **6** Residual risk accepted: Yes

No. 36 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Manipulation of safety-relevant parameters via the network: Unauthorised write access via fieldbus, OPC UA or MES interface alters safety-relevant parameters (e.g. muting times, monitoring of the safety door, speed, force or energy limits). The protective function becomes ineffective or the machine operates outside the limits defined in the risk assessment. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.1.9 para. 3, 1.2.1 lit. a, 1.2.1 lit. d]

Sub-machine: Control / network · also in: Setting up

Step 1 · Inherent	Safety-relevant parameters are to be held only in the safety controller and must not be writable via the process network under any circumstances (write access physically or architecturally separated, safety network segmented from standard communication). Limit values derived from the risk assessment are to be stored as constants in the safety program, not as recipe data.
Step 2 · Technical	Authentication and authorisation for every write access (roles, no default passwords), integrity checking of safety-relevant configuration (checksum/CRC with release procedure), plausibility checking of incoming values against the permissible limits, logging of every parameter change with timestamp and user. Evidence reference Path B: IEC 62443-3-3 SR 1.1, SR 2.1, SR 3.4, SR 3.5, SR 5.1, SR 2.8.
Step 3 · Information	Operating instructions: network requirements for the operator (segmentation, firewall, no direct internet connection of the controller), list of safety-relevant parameters with a note that changes are only permissible by authorised personnel and with a subsequent functional check of the safety functions.

Risk after: **4** Residual risk accepted: Yes

No. 37 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Unintentional corruption through misconfiguration or operator error: Incorrect recipe or parameter file loaded, roles and passwords not set up (default password active), configuration incompletely restored after a fault. Safety-relevant settings deviate from the approved configuration without being noticed. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.2.1 lit. b, 1.2.1 lit. d, 1.2.1 lit. e]

Sub-machine: HMI / parameterisation · also in: Setting up, Commissioning

Step 1 · Inherent	Separate safety-relevant settings from process recipes so that a recipe change cannot alter them; hard-limit value ranges in the safety controller (limits derived from the risk assessment, Annex III No. 1.2.1 lit. d).
Step 2 · Technical	Forced password change on commissioning, role model with dual-control approval for safety-relevant changes, comparison of the active configuration with the approved reference (checksum) at start-up with display of any deviation, change log. Evidence reference Path B: IEC 62443-3-3 SR 1.5, SR 2.1, SR 3.4, SR 7.6.
Step 3 · Information	Operating instructions: commissioning checklist (passwords, roles, saving of reference configuration), description of the data designated as safety-relevant, instruction for functional testing after configuration changes.

Risk after: **4** Residual risk accepted: Yes

No. 38 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Failure or disruption of the communication network connection: Network failure, overload (broadcast storm, denial of service), cable break or change of network segment interrupts communication between control components or the safety-oriented communication (PROFIsafe, FSoE). Upon restoration, an unexpected start-up occurs or outdated setpoint values are taken over in an uncontrolled manner. [MR (EU) 2023/1230 Annex III No. 1.2.6, 1.2.1 lit. a, 1.2.3]

Sub-machine: Communication network · also in: Commissioning

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| Step 1 · Inherent | Design safety functions such that loss of communication leads to the safe state (watchdog, time monitoring of safe telegrams) and a restart only takes place after a deliberate acknowledgement (Annex III No. 1.2.3). Decouple safety-directed communication from standard communication. |
| Step 2 · Technical | Network segmentation and load limiting (rate limiting, storm protection at switches), monitoring of network quality with diagnostic message, defined behaviour upon loss of connection in all operating modes tested and documented. Evidence reference Path B: IEC 62443-3-3 SR 7.1, SR 7.2, SR 5.1, SR 5.2. |
| Step 3 · Information | Operating instructions: requirements for the operator's network (segmentation, permitted participants, no external devices in the safety segment), description of the behaviour upon communication failure and the restart procedure. |

Risk after: **4** Residual risk accepted: Yes

No. 39 Corruption/securityRisk before: S 4 · P 2 · **RZ 8**

Connection of external devices creates a hazardous situation: A connected external device (infeed unit, robot, test equipment, customer installation, printer) sends unexpected signals, writes to control variables or occupies resources. The machine starts, changes the operating mode or ignores stop conditions because the functions of the external device were not taken into account in the risk assessment. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.2.1 lit. h, 1.2.4.4]

Sub-machine: Interfaces to third-party equipment · also in: Assembly, Commissioning

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| Step 1 · Inherent | Design interfaces to external devices as defined signal interfaces with specified semantics (no enabling of movements by external signals alone), route safety-relevant signals only via safe inputs/outputs, assign the stop and emergency stop chain of the external device unambiguously. |
| Step 2 · Technical | Whitelist of approved participants and variables, plausibility check of incoming commands, interlock of operating mode changes via external interfaces, diagnostics for missing or unknown participants. Evidence reference Path B: IEC 62443-3-3 SR 1.2, SR 2.1, SR 3.5, SR 5.2, SR 7.7. |
| Step 3 · Information | Operating instructions and interface description for the integrator (signals, states, requirements for the assembly of machinery in accordance with Annex III No. 1.2.4.4), note that the connection of non-approved devices requires a new risk assessment. |

Risk after: **4** Residual risk accepted: Yes

No. 40 Corruption/securityRisk before: S 3 · P 3 · **RZ 9**

Safety-relevant software not identifiable or labelled: The version status and checksum of the safety software cannot be retrieved at the machine, and safety-relevant software and data are not designated as such. After an intervention, update or device replacement, it cannot be determined whether the machine is still in the inspected state; operation with non-approved software remains undetected. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.1.9 para. 4, 1.7.4.2]

Sub-machine: Software / Documentation · also in: Commissioning, Maintenance

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| Step 1 · Inherent | Design safety-relevant software as a distinct unit with its own version number and checksum (separate from standard and visualisation software) so that unambiguous identification is technically possible. |
| Step 2 · Technical | Information page on the HMI showing the version and checksum of all safety-relevant software components (always easily accessible without login, Annex III No. 1.1.9 para. 4), labelling of safety-relevant data in file names, menus and exports, comparison with the acceptance report at start-up. Evidence reference Route B: IEC 62443-3-3 SR 3.4. |
| Step 3 · Information | Operating instructions: list of safety-relevant software and data with versions (Annex III No. 1.7.4.2), instructions for retrieving version information, note on the significance for conformity and on the obligation to report deviations. |

Risk after: **3** Residual risk accepted: Yes

No. 41 Corruption/securityRisk before: S 3 · P 3 · **RZ 9**

Missing or incomplete records of interventions (logging): Interventions in safety-relevant hardware, software or configuration are not recorded, or are recorded without a timestamp and originator; logs overwrite themselves after a short period or are open to manipulation. Unauthorised interventions remain undetected and the audit trail is not available upon request by the authorities. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 2, 1.1.9 para. 5, 1.2.1 lit. f]

Sub-machine: Control / logging · also in: Maintenance, Troubleshooting

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| Step 1 · Inherent | Provide event logging as a fixed function of the control system (not deactivatable by the operator), with a non-volatile memory of sufficient capacity. |
| Step 2 · Technical | Logging of safety-relevant events with timestamp, user identity and content of the change (log-on, parameter and configuration change, software upload with version and checksum, opening of safety-relevant assemblies, remote-access sessions), protection against deletion and modification, export in readable form, retention of uploads and associated data for up to five years after uploading (Annex III No. 1.2.1 lit. f). Evidence reference Route B: IEC 62443-3-3 SR 2.8, SR 2.9, SR 2.11, SR 3.9, SR 6.1. |
| Step 3 · Information | Operating instructions: Access to and export of logs, operator's retention obligations when the machine is transferred, procedure in the event of a regulatory request, note on storage capacity and time synchronisation. |

Risk after: **3** Residual risk accepted: Yes

No. 42 Corruption/securityRisk before: S 3 · P 3 · **RZ 9**

Falsified production or recipe data from MES or cloud: Order and recipe data taken from MES, ERP or cloud platform (e.g. energy, force, speed or tool data) are falsified, outdated or intended for the wrong machine. The machine operates with specifications outside the safe limits or with an incorrect tool and material reference. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.2.1 lit. b, 1.2.1 lit. d]

Sub-machine: MES / cloud data connection

Step 1 · Inherent Limit safety boundaries independently of transferred recipe data in the safety controller; recipe data shall control process parameters only within these limits (Annex III No. 1.2.1 lit. d).

Step 2 · Technical Integrity and origin verification of transferred data sets (signature or checksum, machine and tool assignment), plausibility check against permissible ranges with rejection and notification, release step by authorised personnel for new recipes, log of transferred data sets. Evidence reference Route B: IEC 62443-3-3 SR 3.1, SR 3.4, SR 3.5, SR 1.2.

Step 3 · Information Operating instructions: responsibility of the operator for data quality, description of the checks and notifications, instructions in the event of rejected data sets.

Risk after: **3** Residual risk accepted: Yes

No. 44 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Unauthorised or faulty remote access via the remote maintenance gateway: Via the IPsec VPN connection of the remote maintenance gateway, an unauthorised person with stolen credentials or an authorised technician at the wrong moment intervenes in the cell controller: program or parameter change, acknowledgement of faults or starting of movements while persons are at the loading station or in the maintenance walkway. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.1.9 para. 3, 1.2.1 lit. a, 1.2.1 lit. d]

Sub-machine: Remote maintenance gateway / cell controller · also in: Maintenance, Troubleshooting

Step 1 · Inherent Remote access designed so that it cannot trigger hazardous movements or bypass safety functions: the remote maintenance gateway only reaches the standard controller and the operator panel; the safety PLC has no remote access path. Movement commands and acknowledgement of faults are only possible from control positions with a view of the danger zone (Annex III No. 1.2.2).

Step 2 · Technical Remote maintenance disabled on delivery; a session can only be enabled on site with the key switch at the control desk, ends automatically after four hours and is indicated as "Remote maintenance active" on the operator panel; IPsec VPN with multi-factor authentication and personal accounts for remote technicians; logging of every session with user, time and actions performed, retention in accordance with Annex III No. 1.2.1 lit. f. Evidence reference Path B: IEC 62443-3-3 SR 1.1, SR 1.13, SR 2.1, SR 2.8, SR 3.8.

Step 3 · Information Operating instructions (chapter Cybersecurity, section Remote maintenance): procedure for enabling and ending remote maintenance sessions, obligation for a responsible person to be available on site, action in the event of suspected unauthorised access (end the session with the key switch, inform the manufacturer), contact for the manufacturer's security notifications.

Risk after: **4** Residual risk accepted: Yes

Maintenance (18 hazards)

No. 6		Mechanical	Risk before: S 5 · P 3 · RZ 15	
Hazard of crushing and impact due to unexpected restart of the turntable or the robot after an emergency stop or after fault clearance: if a coordinated restart prevention system (EN ISO 11161) is absent, individual sub-machines may start up automatically while persons are still present in the hazardous area.				
Sub-machine: Overall system (restart coordination) · also in: Troubleshooting, Setting up				
Step 1 · Inherent	Inherent possibilities exhausted: restart after an emergency stop or after fault clearance is a control-system event that cannot be constructively eliminated by the functional principle of the overall installation (coordinated automatic operation of robot and turntable) without cancelling the machine function. No geometric or energetic measure exists that would prevent the restart itself without abolishing the machine function. Protection must therefore be achieved entirely through Level 2 measures (control system and interlocking).			
Step 2 · Technical	1. Coordinated restart prevention in accordance with EN ISO 11161:2007+A1:2010 Section 5.6: the overall installation control system shall not release the restart of a sub-machine (turntable, robot) until a deliberate, manual restart command has been issued from a safe position outside all hazardous areas. The restart command shall NOT be triggered automatically following acknowledgement of the emergency stop or following fault clearance. 2. Safety function SF-01 (safe stop, stop category 1 on opening of the maintenance door, PLr d in accordance with EN ISO 13849-1:2023) and SF-03 (emergency stop of the overall installation, stop category 1, PLr d in accordance with EN ISO 13849-1:2023) ensure that all drives are safely brought to a standstill. The restart prevention is implemented as an integral part of safety functions SF-01, SF-03 and SF-04 and is executed at their respective PLr (SF-04: PLr e; SF-01 and SF-03: PLr d in accordance with EN ISO 13849-1:2023). 3. Safety function SF-04 (release of the 180-degree pivoting movement of the turntable only when the pivot area is clear, PLr e in accordance with EN ISO 13849-1:2023): the turntable may only execute its pivoting movement when the pivot area has been detected as clear by a suitable protective device (e.g. light curtain Type 4 in accordance with EN 61496-1, positioned in accordance with EN ISO 13855:2024). This function remains active after restart and prevents start-up in the presence of persons. 4. Safety function SF-05 (safely reduced speed of 250 mm/s with enabling device in set-up mode, PLr d in accordance with EN ISO 13849-1:2023): in set-up mode, restart shall be released exclusively via an enabling device (3-position in accordance with EN ISO 10218-2:2025 Section 5.7.7), so that an unexpected restart at full speed is excluded. 5. De-energisation and energy isolation in accordance with EN ISO 14118:2018: before entering the hazardous area for fault-finding or maintenance, the energy supply to all relevant drives (electrical, pneumatic in accordance with EN ISO 4414:2010) shall be disconnected by means of a lockable isolating device and secured against unintentional re-energisation (lockout/tagout). Residual energy (stored pneumatic energy, gravitational component of the turntable) shall be dissipated or mechanically secured before any intervention. 6. Guard locking of the maintenance door in accordance with EN ISO 14119:2025 with escape release: the guard locking keeps the maintenance door closed as long as hazardous movements have not been safely brought to a standstill (stop category 1 completed). Integration is carried out within the scope of SF-01 (PLr d).			
Step 3 · Information	1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the restart sequence after an emergency stop and after fault clearance; explicit statement that restart is permissible only after all hazardous areas have been fully vacated and a manual acknowledgement command has been issued from outside. Description of the lockout/tagout procedure in accordance with EN ISO 14118:2018 for all maintenance and fault-finding activities. 2. Warning labelling at all access doors and acknowledgement units: warning of unexpected restart (warning sign 'Warning: automatic start-up' in accordance with DIN EN ISO 7010), notice of the obligation to acknowledge from outside. 3. Qualification requirement: set-up and maintenance activities may only be carried out by instructed specialist personnel who have been trained in the restart procedure and the lockout/tagout method (EN ISO 10218-2:2025 Section 7.5.12). 4. PPE specification: safety footwear (S2/S3) shall be worn when entering the hazardous area for fault-finding or maintenance; additional PPE as determined by the operator's workplace risk assessment.			
Risk after: 5		Residual risk accepted: Yes		

No. 8 MechanicalRisk before: S 3 · P 4 · **RZ 12**

Cutting and puncture hazard from the welding wire (solid wire 1.0 to 1.2 mm) at the welding torch: The wire protruding from the torch acts like a needle; during setting, wire threading or torch cleaning, hands and fingers can be punctured or cut.

Sub-machine: Welding torch / wire feed · also in: Setting up, Cleaning

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| Step 1 · Inherent | Automatic wire retraction after the end of welding: The wire feed control automatically retracts the wire by a defined amount (e.g. 5 to 10 mm) into the torch after each welding cycle, so that the sharp wire tip is recessed within the contact tip and no longer protrudes freely. This constructively minimises the hazard point (free-standing wire tip) for the setting and cleaning life phases. In addition: selection of a wire feed system that, in inching mode (setting), advances the wire only when the button is continuously pressed (dead man's principle), so that the wire is not advanced in an uncontrolled manner. |
| Step 2 · Technical | 1. Mechanical wire length limitation: An adjustable wire length stop (torch protection cap with a defined opening) is provided at the torch neck, limiting the maximum protruding wire to the minimum dimension necessary for the process. 2. Interlocking of wire feed during cleaning and maintenance: The wire feed function is inhibited by the safety controller as soon as the maintenance door is opened (safety function SF-01, PLr d in accordance with EN ISO 13849-1:2023). 3. Set-up mode with safely reduced speed: In set-up mode, the wire feed is limited to the safely reduced speed in accordance with SF-05 (PLr d), thereby preventing unintentional rapid shooting of the wire. 4. Marking of the hazard point on the torch and wire feed in accordance with DIN EN ISO 7010 (warning of pointed injury hazard). |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Explicit note that the welding wire presents a sharp, pierceable tip even when stationary. Description of the safe procedure for threading wire (wire feed inhibited, cut the wire end cleanly with side cutters, never probe with the bare hand). 2. Warning marking on the torch holder and on the wire feed unit: warning sign 'Warning: hand injuries' in accordance with DIN EN ISO 7010. 3. Qualification requirement: activities on the torch and wire feed (threading wire, cleaning) may only be carried out by instructed specialist personnel; requirement to be documented in the operating instructions. 4. PPE specification: cut-resistant protective gloves (protection class in accordance with EN 388, minimum 2X42 or equivalent) must be worn when threading wire and when cleaning the torch; specification to be included in the operating instructions and on the notice posted at the workplace. 5. Note on safe cutting of the wire tip: before any manual activity on the torch, the wire tip must be cut cleanly and burr-free with a suitable pair of side cutters; the tool is to be made available at the workplace. |

Risk after: **6** Residual risk accepted: Yes

No. 10 MechanicalRisk before: S 3 · P 3 · **RZ 9**

Hazard of tripping, slipping and falling in the area of the loading station and the maintenance aisle due to weld spatter on the floor, cables, hoses (compressed air, shielding gas) and wet areas during cleaning work.

Sub-machine: Loading station / maintenance aisle · also in: Operation, Setting up, Cleaning, Troubleshooting

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| Step 1 · Inherent | Keep cables and hoses (compressed air, shielding gas) out of the floor area of the loading station and maintenance aisle by means of constructive routing in cable ducts, energy chain systems or ceiling-suspended cable management systems, so that no trip hazards arise. Design connections at the loading station as ceiling pendants or wall-mounted socket panels. Reduce weld-spatter exposure on the floor by means of constructive shielding plates (spatter-protection shields) at the welding station, so that discharge into the operator area is minimised. Provide the floor covering in the loading station and maintenance aisle with an anti-slip surface (assessment group R 11 or higher in accordance with BGR/GUV-R 181, suitability for wet conditions to be verified), so that the slip hazard is inherently reduced. |
| Step 2 · Technical | Limit the residual risk from remaining trip and slip hazards by means of the following technical measures: (1) Floor markings (yellow/black in accordance with ISO 7010) to identify traffic routes and hazardous areas in accordance with (EU) 2023/1230 Annex III No. 1.1.2 and No. 1.6.2. (2) Adequate fixed lighting of the loading station and maintenance aisle in accordance with (EU) 2023/1230 Annex III No. 1.1.4, so that obstacles and wet areas can be detected at an early stage; illuminance to be specified according to the visual task; machine-integrated lighting to be designed in accordance with EN 1837. (3) Drip trays or spatter-protection mats in the immediate welding area that are easy to remove and clean. |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): (1) Reference to the hazard of tripping and slipping due to weld spatter, hoses and wet conditions; prescribe cleaning intervals and cleaning procedures for the floor area. (2) Qualification requirement: all persons entering the loading station and maintenance aisle must have been instructed in the hazards and the traffic-route layout. (3) PPE specification: safety footwear with anti-slip soles (S2 or S3 in accordance with EN ISO 20345) shall be worn when entering the loading station and maintenance aisle. (4) Warning labelling at the access to the loading station and maintenance aisle: affix a warning sign for slip hazard (ISO 7010, warning sign 'Warning: slippery surface') and the mandatory sign 'Wear safety footwear' (ISO 7010, mandatory sign). |

Risk after: **6** Residual risk accepted: Yes

No. 11 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Hazard arising from simultaneous access by several persons to different zones of the cell (EN ISO 11161): a second person is present inside the cell without the setter being aware of this; when the robot or the turntable starts up, the second person is struck.

Sub-machine: Overall system (zone access) · also in: Setting up, Troubleshooting

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| Step 1 · Inherent | Inherent possibilities exhausted: the functional principle of the overall installation requires accessible zones for set-up, maintenance and fault-finding work. The hazard arises from the simultaneous presence of several persons in different zones, which cannot be resolved by geometry, distance or energy limitation alone without defeating the operational purpose. A reduction of the robot or turntable energy to a level that safely excludes injury is not technically realisable with this type of installation. |
| Step 2 · Technical | 1. Presence-detection concept in accordance with EN ISO 11161:2007+A1:2010 Section 5.6 (access control for assemblies of machinery): a key-transfer or key-interlocking system (key-transfer box) shall be used for each access point to the cell. Each person entering the cell removes a personal key; start-up of the installation is possible only when all keys have been returned. The number of keys corresponds to the maximum permissible number of persons inside the cell. This concept shall be integrated into the safety control system. 2. Zone-specific guard locking at all access doors in accordance with EN ISO 14119:2025 with escape release (escape facility) in accordance with EN ISO 14119:2025 Section 6.9.1, so that persons trapped inside the zone can leave it at any time. 3. The release of start-up (robot and turntable) shall be implemented as a safety function: start-up is possible only when all access doors are closed and locked AND all personal keys are inserted in the key-transfer box. This function shall be assigned to the existing SF-04 (turntable release, PLr e) and SF-01 (standstill on maintenance door, PLr d). Since SF-04 carries the highest requirement level with PLr e, the entire access-control function shall be designed to PLr e in accordance with EN ISO 13849-1:2023. 4. In set-up mode, SF-05 applies (safely reduced speed of 250 mm/s with enabling device, PLr d in accordance with EN ISO 13849-1:2023). The enabling device is person-specific; a second enabling device shall be provided if two persons must work simultaneously in set-up mode, whereby both enabling devices must be actuated simultaneously (AND logic) or start-up remains generally inhibited as long as more than one person is detected inside the cell. 5. Safety distances between the robot working space and areas where persons are present shall be maintained and documented in accordance with EN ISO 13857:2019 Table 1 and EN ISO 10218-2:2025 Sections 5.4.6 and 5.8.9. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the key-transfer concept, the maximum permissible number of persons per zone, the obligation to remove the key before entering and to return the key before start-up. Procedural instruction for multi-person operations (setting up, maintenance, fault-finding) with clear role assignment (responsible person, coordination). 2. Warning signs at all access points: Warning of automatic start-up (warning sign in accordance with DIN EN ISO 7010, warning of dangerous machine parts), notice of key obligation and personnel-tracking concept. 3. Qualification requirement: Setting-up and maintenance personnel must be instructed in the multi-person access concept and the operation of the key-transfer box. The instruction must be documented. 4. PPE specification in the operating instructions: Safety footwear, close-fitting protective clothing (no entanglement risk from loose clothing) when inside the cell. |

Risk after: **5** Residual risk accepted: Yes

No. 12 ElectricalRisk before: S 5 · P 2 · **RZ 10**

Hazard from direct or indirect contact with live parts of the welding power source, the robot control cabinet and the cell control system (400 V AC, 32 kVA): Contact with terminals, cables or the interior of the control cabinet when the cabinet is open without isolation can lead to electric shock with ventricular fibrillation or burns.

Sub-machine: Electrical installation (control cabinet / welding power source) · also in: Commissioning, Troubleshooting

Step 1 · Inherent	All live parts inside the control cabinet (terminals, busbars, power terminals of the welding power source) are designed with touch-proof covers (degree of protection at least IP 2X or IPXXB in accordance with EN 60204-1:2018 Section 6.2.2), so that contact with live parts is prevented by the enclosure form itself without the need for a guard. In addition, minimum clearances between live and accessible parts are designed such that the degree of protection IP 2X is maintained even with the cabinet door open (protective caps, insulating covers on terminal strips). This addresses (EU) 2023/1230 Annex III No. 1.5.1 (Electrical energy supply) by analogy, as well as EN 60204-1:2018 Section 6.2.
Step 2 · Technical	1. Isolation and de-energisation (LOTO): Main switch with lockable zero position in accordance with EN 60204-1:2018 Section 5.3 and EN ISO 14118:2018 (prevention of unexpected start-up / energy isolation). The main switch must disconnect the entire system from the supply on all poles as an isolating device; residual voltage at the capacitors of the welding power source is to be limited to below 60 V DC within 5 s by means of a discharge time or active discharge circuit (requirement from EN 60204-1:2018 Section 5.4). Cabinet door interlock: The doors of the main control cabinets are fitted with a door interlock (key switch or tool-operated fastener) that prevents unauthorised opening (EN 60204-1:2018 Section 6.2.2). 2. Protective equipotential bonding and protective conductor: All control cabinet enclosures, the welding power source and the robot control cabinet are connected via a continuous protective conductor (PE) of adequate cross-section (EN 60204-1:2018 Section 8.2), so that in the event of an insulation fault the fault current is safely dissipated and the protective device (circuit breaker / RCD) trips. 3. Residual current device (RCD): Use of an RCD (Type B, since DC fault currents from frequency inverters and the welding power source are possible) with a tripping current of 30 mA for circuits at which persons are working, in accordance with EN 60204-1:2018 Section 8.3 (insofar as this is feasible on the supply side and compatible with the welding process; otherwise insulation monitoring in accordance with EN 60204-1:2018 Section 8.3 as an alternative). Not a safety function with a PLr requirement; the measures act passively and by design (warning labelling: see Level 3).
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Document the isolation procedure (LOTO) with a step-by-step instruction, including the discharge time of the capacitors of the welding power source and verification of the absence of voltage using a suitable measuring instrument (voltage tester Category CAT III 600 V). Qualification requirement: Work on the electrical installation may only be carried out by electrically skilled persons (ESP) in accordance with DGUV Vorschrift 3 / BGV A3, or under the supervision of an ESP by electrically instructed persons. PPE specification: Insulating gloves (protection class in accordance with EN 60903 corresponding to the rated voltage of 1000 V), safety goggles (arc flash protection) and antistatic footwear are to be worn when working in an open cabinet. Warning labelling: Warning of dangerous electrical voltage (ISO 7010 W012) to be affixed permanently and clearly visible to all cabinet doors and to the welding power source. Residual risk note in the operating instructions: After operation of the main switch, capacitors in the welding power source and in the frequency inverter of the robot may carry dangerous voltages for a defined period (as specified by the component manufacturer); absence of voltage must always be verified by measurement.

Risk after: **5** Residual risk accepted: Yes

No. 17 ThermalRisk before: S 3 · P 3 · **RZ 9**

Risk of burns from the hot welding torch and torch neck: The torch neck and the contact tip are strongly heated after the welding process; when changing the torch, during cleaning or during set-up without a cooling period, hands and fingers may be burned.

Sub-machine: Welding torch · also in: Setting up, Cleaning

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| Step 1 · Inherent | Use of active torch cooling (water-cooled torch instead of an air-cooled torch), provided the welding process permits this: The continuous water cooling limits the thermal energy in the torch neck and at the contact tip by design to a significantly lower temperature level. Additionally: The torch holder and the change system are designed such that the operator, when changing the torch, touches only thermally decoupled grip areas (plastic or ceramic handle, no direct metal contact with the torch neck). Design in accordance with EN ISO 13732-1:2008 (contact temperature limits for metal: pain threshold approx. 48 °C, burn threshold depending on contact time and material). |
| Step 2 · Technical | 1. Technical cooling-time interlock (if a temperature sensor is fitted or can be retrofitted at the burner neck): release of manual access to the burner only after the temperature falls below a defined limit value; integration into the safety control system as a safety function (PLr to be determined by EN ISO 13849-1 risk graph). 2. Fixed/movable guard: the welding cell is fitted with a protective enclosure in accordance with EN ISO 14120:2015; access to the burner for maintenance and cleaning is provided exclusively via the secured maintenance door (SF-01, PLr d). Unintentional access to the hot burner during automatic operation is thereby constructively excluded. 3. Provision of a burner rest with a thermally insulated receptacle (ceramic or silicone pad) immediately at the welding station, so that the burner is placed down in a defined manner after the process and is not set down on conductive metal surfaces. |
| Step 3 · Information | 1. Operating instructions: state the cooling time after the end of welding explicitly before any torch change, cleaning or set-up work on the burner (adopt the reference value from the burner manufacturer's specifications); include a procedure for torch changes with the step 'wait for cooling time or check temperature'. 2. Warning labelling: permanently and clearly affix the warning sign 'Warning: hot surface' (ISO 7010) to the burner area and to the maintenance door. 3. Qualification: only instructed persons may carry out torch changes and cleaning; instruction covers the risk of burns, cooling times and correct use of PPE. 4. PPE specification: heat-protection gloves (suitable for contact heat, protection class in accordance with EN 407) are mandatory during torch changes, cleaning and set-up work on the burner; this requirement shall be stated in the operating instructions and indicated by the mandatory sign 'Wear protective gloves' (ISO 7010) at the maintenance door. |

Risk after: **3** Residual risk accepted: Yes

No. 19 RadiationRisk before: S 4 · P 2 · **RZ 8**

Hazard from electromagnetic fields (EMF) generated by the welding power source and the welding cables: High welding currents generate strong magnetic fields; persons with active implants (cardiac pacemakers, insulin pumps) may be endangered by the fields.

Sub-machine: Welding power source / welding cables · also in: Operation, Setting up

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| Step 1 · Inherent | Route and bundle the welding cables (current conductor and return conductor) so that the forward and return conductors are brought into close spatial proximity (twisted or parallel-routed cable pairs with minimum distance between them): The magnetic fields of both conductors partially cancel each other out, which significantly reduces the resultant field strength in the surrounding area. Keep cables as short as technically possible and avoid unnecessary coiling or routing in loops, as loops increase field strength. Install the welding power source in a separate switchgear area or ancillary room with a structural distance from regular areas of presence, to the extent permitted by the machine concept. |
| Step 2 · Technical | Secure access to the welding area (welding cell) during operation by means of the existing fixed guard (safety fence in accordance with EN ISO 14120:2015), so that persons cannot enter the immediate vicinity of the active welding cables during automatic operation. Design access doors with guard locking in accordance with EN ISO 14119:2025 (SF-01, PLr d), which permits entry only after the welding current has been switched off. During setting-up mode and during maintenance work in the vicinity of cables: switch off the welding current before entering the hazard zone and secure it against being switched on again (energy isolation and standstill in accordance with EN ISO 14118:2018). Ensure a minimum distance from the welding area for persons with implants by means of structural measures (e.g. cordoning off the immediate vicinity outside the safety fence openings), to the extent that presence outside the cell is possible. Note: The suitability of additional EMF shielding measures (e.g. magnetically shielding cable ducts) is to be assessed on a project-specific basis. |
| Step 3 · Information | Operating instructions: Explicit statement that operation of the welding machine generates strong electromagnetic fields. Persons with active or passive metallic implants (cardiac pacemakers, insulin pumps, cochlear implants, metal implants) must not enter the immediate vicinity of the welding cables and the welding power source. Before commencing setting-up or maintenance activities in the vicinity of cables, the welding current must be switched off. Qualification requirement: Setting-up and maintenance personnel must be instructed regarding the EMF hazard; persons with known implants must be excluded from activities in the immediate vicinity of active welding cables. Warning labelling: Attach the warning sign for magnetic fields (warning sign in accordance with DIN EN ISO 7010, sign W006 "Warning: magnetic field") at the accesses to the welding cell and on the welding power source. Additionally, attach prohibition signs for persons with cardiac pacemakers (P007 in accordance with DIN EN ISO 7010) at all accesses. EMF emissions are to be described qualitatively in the operating instructions; the basis for assessment is the manufacturer's data for the welding power source in accordance with EN IEC 62822-2 (assessment of arc welding equipment with regard to EMF exposure of persons). |

Risk after: **4** Residual risk accepted: Yes

No. 20 Substances/materialsRisk before: S 4 · P 4 · **RZ 16**

Hazard from inhaling welding fumes and vapours (metal oxides, manganese, iron oxides): MAG welding of structural steel generates harmful particles and gases; when extraction is inadequate (saturated filter cartridge, system switched off), concentrations in the operator's breathing zone exceed the workplace exposure limits.

Sub-machine: Overall system (extraction / welding area) · also in: Operation, Setting up, Cleaning

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| Step 1 · Inherent | Substitution of the welding consumable: Use of solid-wire electrodes with a demonstrably reduced manganese content (low-Mn alloy, e.g. Mn content < 1.0 % in accordance with the safety data sheet) instead of flux-cored wire electrodes or high-manganese wires, to the extent that the welding task (structural steel, weld quality) permits this. In addition: optimisation of welding parameters (arc voltage, wire feed speed, shielding gas composition) to a low-fume setting in accordance with the welding power source manufacturer's recommendation, in order to minimise fume generation at source. Both measures genuinely reduce the emitted pollutant mass and thereby reduce the severity of exposure. |
| Step 2 · Technical | Technical ventilation and extraction in accordance with EN ISO 21904-1:2020 (welding fume extraction): Source extraction directly at the welding point (extraction nozzle or integrated torch extraction) with a volumetric flow rate that ensures the capture velocity at the point of generation. The extraction system must be equipped with filter monitoring (differential-pressure switch) that triggers an alarm when the filter cartridge is saturated and inhibits welding operation via the machine control system (safety function: operating enable only when extraction is running, PLr to be determined in accordance with EN ISO 13849-1 risk graph). Enclosure of the welding area (welding booth/housing) in accordance with EN ISO 14120:2015, to the extent compatible with the turntable concept, in order to minimise fume escape into the operator area. Ambient air monitoring for welding fume concentration at the loading station is recommended as an additional operator measure. |
| Step 3 · Information | Operating instructions (in accordance with (EU) 2023/1230 Annex III No. 1.7.4): Specification of the welding fume types emitted and reference to the workplace exposure limits to be observed in accordance with TRGS 900 and TRGS 528; instruction for regular inspection and replacement of filter cartridges (maintenance interval in accordance with manufacturer's specification EN ISO 21904-1:2020); prohibition of welding operation when the extraction system has failed or is switched off. Warning signs at the welding area: warning of harmful vapours and fumes (ISO 7010, warning sign), obligation to wear respiratory protection (ISO 7010, mandatory sign 'Wear respiratory protection') as residual risk marking. PPE requirement: respiratory protection of at least FFP2 (preferably FFP3 or powered air-purifying respirator) for setting-up, maintenance and cleaning work in the welding area when the enclosure is open or the extraction system is switched off. Qualification requirement: operators and setting-up personnel must be instructed in the hazards of welding fumes and the correct operation of the extraction system (TRGS 528 Section 5). |

Risk after: **6** Residual risk accepted: Yes

No. 21

Substances/materials

Risk before: S 4 · P 2 · **RZ 8**

Hazard from shielding gas (argon-CO₂ mixture M21) in the event of leakage: Shielding gas is heavier than air (CO₂ content) and may accumulate near floor level; in the event of larger leakages in poorly ventilated areas, there is a risk of asphyxiation due to oxygen displacement.

Sub-machine: Shielding gas supply / piping system · also in: Operation, Troubleshooting

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| Step 1 · Inherent | Pressure limitation in the piping system: Limit the operating pressure of the shielding gas supply to the minimum level required for the welding process (pressure regulator directly at the withdrawal point of the cylinder battery or at the supply connection). A lower system pressure reduces the quantity of gas escaping in the event of a fault and thus the potential for accumulation. Additionally: design the pipe routing and connection points so that leakages are constructively minimised: use of cutting ring fittings or press fittings instead of hose clamps on fixed pipe sections; reduce hose lengths to the minimum operationally necessary; no routing of pipes near floor level in pits or enclosed chambers (route near the ceiling where possible). These measures address the energy source (stored pressurised gas) and the hazard location (accumulation zone) directly. |
| Step 2 · Technical | 1. Automatic shut-off of the gas supply: Solenoid valve (de-energised closed) in the shielding gas supply line, which automatically shuts off the gas supply upon machine stop, emergency stop (SF-03) and during operating pauses; additionally, a manual shut-off valve outside the cell. 2. Leak monitoring: Plausibility check of gas consumption via the machine control system (indication when gas flow occurs without an active welding process, as a leakage indicator); daily visual inspection of hose connections as a maintenance requirement. 3. Installation of the shielding gas supply (cylinder battery or withdrawal station) in a ventilated area of the hall, not in pits, basements or confined recesses. If installed in poorly ventilated areas, the operator is required to provide an oxygen warning device (note in the operating instructions). A safety function with a PLr requirement is not necessary for this hazard; the risk is controlled by means of shut-off, installation location and ventilation. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Note on the risk of asphyxiation due to oxygen displacement in the event of larger leaks in poorly ventilated areas; requirement for adequate hall ventilation at the installation site; work on the gas supply only with the line shut off and depressurised (EN ISO 14118:2018). 2. Qualification: Work on compressed gas lines and fittings only by instructed specialist personnel; instruction in accordance with DGUV Regel 100-500 Chapter 2.26 and TRGS 528 (operator's obligation). 3. Warning labelling: Note on the risk of asphyxiation in poorly ventilated areas at the gas supply installation site; prohibition sign 'No entry for unauthorised persons' on locked supply areas (DIN EN ISO 7010). 4. When working in confined or poorly ventilated areas (e.g. cylinder changes in recesses): use a portable oxygen warning device; no lone working. |

Risk after: **4**

Residual risk accepted: Yes

No. 22 Substances/materialsRisk before: S 3 · P 2 · **RZ 6**

Hazard from filter dust when changing the filter cartridge of the welding fume extraction unit: The filter cartridge contains separated welding fumes with metal oxides and fine particles; when changed without appropriate respiratory protective measures, dusts are released and inhaled.

Sub-machine: Welding fume extraction (filter unit) · also in: Cleaning

- Step 1 · Inherent** Constructive dust retention during filter change: The filter unit is equipped with an integrated bag-in/bag-out system or a dust-tight change cassette, so that the contaminated filter cartridge can be removed and sealed in a closed plastic bag without direct contact with dust. This constructively minimises dust release at the source (substitution of open removal by a closed change procedure in accordance with EN ISO 12100 Section 6.2.4). Additionally: the cleaning pulse (pressure burst) prior to the change is to be permitted ONLY with the housing closed and the extraction system deactivated, in order to compact dust deposits in the cartridge and reduce release when opening.
- Step 2 · Technical** Technical protective measures for the remaining residual risk (residual dust when opening the housing and handling the cartridge): 1. Extraction housing with negative-pressure interlock: The filter housing may by design only be opened when the fan is switched off and the system is depressurised (mechanical interlock, no safety function with PLr requirement, as no motion drive is involved). 2. Local extraction at the change location: A connection stub for a mobile extraction unit (industrial vacuum cleaner dust class H in accordance with EN 60335-2-69, suitability for welding fume dusts) is to be provided on the filter housing; this is activated during the change and captures released residual particles. 3. Labelling of the filter unit: Warning sign "Warning: harmful or irritating substances" in accordance with DIN EN ISO 7010 to be permanently affixed to the filter housing.
- Step 3 · Information** User information for the remaining residual risk: 1. Operating instructions (chapter: Maintenance/Cleaning): Detailed step-by-step instruction for the filter change with description of the bag-in/bag-out procedure; information on the composition of the separated dusts (metal oxides, fine particles, possibly CMR substances depending on the weld material); disposal note (contaminated filter cartridges to be disposed of as hazardous waste in accordance with applicable waste regulations). 2. Qualification requirement: Filter change to be carried out only by trained specialist personnel who have been informed of the hazard from welding fume dusts. 3. PPE specification: During the filter change, the following must be worn as a minimum: respiratory protection FFP3 (half-mask) in accordance with EN 149 for fine particles and metal oxides; protective gloves (chemical-resistant); safety spectacles (particle protection). PPE requirements are to be specified permanently in the operating instructions and by means of a mandatory sign "Wear respiratory protection" (DIN EN ISO 7010) on the filter housing. 4. Reference to occupational health and safety legislation: The operator is to be advised of their obligations under TRGS 528 (welding operations) and the Gefahrstoffverordnung (GefStoffV), in particular regarding the risk assessment for CMR dusts and the provision of suitable PPE.

Risk after: **3** Residual risk accepted: Yes

No. 23 Substances/materialsRisk before: S 4 · P 3 · **RZ 12**

Hazard from residual pneumatic energy during maintenance and fault-clearing work: After the compressed air supply is switched off, residual pressure remains in the lines and cylinders of the clamping device; uncontrolled pressure release can cause clamping elements to move suddenly and injure persons or eject workpieces.

Sub-machine: Pneumatic clamping device / compressed air system · also in: Troubleshooting

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| Step 1 · Inherent | Minimise residual pneumatic energy by means of a pressureless spring-accumulator design: Design clamping cylinders as spring-actuated clamps (spring-close principle) so that the clamping force is maintained in the de-energised and depressurised state by the spring, leaving no residual pneumatic energy potential for the clamping movement. Additionally: minimise the line volume and accumulator volume between the maintenance shut-off valve and the cylinder by design (short valves mounted directly on the cylinder) in order to reduce the stored energy. Design in accordance with EN ISO 4414:2010 Section 5.4 (pressure limitation, energy minimisation). Note: The severity of a remaining residual energy event is genuinely reduced by this measure, as the kinetic energy of the clamping elements is considerably lower with a reduced residual volume and a spring-accumulator principle. |
| Step 2 · Technical | 1. Maintenance shut-off valve with venting function (lockout/tagout-capable) in accordance with EN ISO 4414:2010 Section 5.4.2 and EN ISO 14118:2018: Install a shut-off valve with integrated, controlled venting (soft-exhaust function) at the inlet of the pneumatic clamping device; in the shut-off position, the valve must vent the downstream line section in a controlled and throttled manner before any intervention is possible. The valve shall be secured with a lock (lockout device). 2. Pressure gauge or pressure indicator on the line section between the shut-off valve and the cylinder, so that the operator can visually verify pressure reduction to 0 bar (EN ISO 4414:2010 Section 5.4.3). 3. If control-side monitoring of pressure reduction is implemented as a release condition for maintenance access (e.g. pressure sensor evaluated in the safety controller as a prerequisite for unlocking maintenance door SF-01); integration into safety function SF-01 (PLr d, EN ISO 13849-1:2023). 4. Fixed/movable guard (maintenance door/protective enclosure) in accordance with EN ISO 14120:2015 with guard locking in accordance with EN ISO 14119:2025, which is unlocked only after complete pressure reduction (pressure sensor signal = 0 bar); observe safety distances in accordance with EN ISO 13857:2019. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Work instruction for maintenance and fault clearing on the pneumatic clamping device with an explicit step-by-step procedure: (a) shut off the compressed air supply at the maintenance shut-off valve, (b) wait for venting and check pressure indicator for 0 bar, (c) apply lockout lock, (d) only then intervene in the system. Include a note on the hazard from residual pressure and ejected workpieces. 2. Warning labelling on the clamping device and on the shut-off valve: warning sign 'Warning of dangerous overpressure' and 'Warning of flying parts' in accordance with DIN EN ISO 7010 (sign semantics: yellow warning triangle with the corresponding pictogram); information sign 'Before intervention: vent to 0 bar and lock shut-off valve'. 3. Qualification requirement: maintenance and fault-clearing work on the pneumatics only by instructed specialists with knowledge of pneumatic safety rules (EN ISO 4414:2010). 4. PPE specification: prescribe safety goggles (eye protection against flying parts) and protective gloves when opening pneumatic connections. |

Risk after: **3** Residual risk accepted: Yes

No. 27 ErgonomicRisk before: S 2 · P 3 · **RZ 6**

Insufficient lighting at the loading station and in the maintenance walkway: inadequate illuminance makes it difficult to load and unload workpieces safely and to carry out maintenance work, and increases the risk of errors and accidents.

Sub-machine: Loading station / maintenance aisle · also in: Operation, Setting up, Cleaning

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| Step 1 · Inherent | Machine-integrated workplace lighting at the loading station and in the maintenance walkway to be provided as part of the design: luminaires are permanently integrated into the machine structure (e.g. built into the enclosure frame or protective housing) so that the illuminance at the loading station and in the maintenance walkway is permanently ensured independently of the hall lighting. The design is carried out in accordance with EN ISO 12100:2010 section 6.2.6 (ergonomic design) in conjunction with EN 1837 (machine-integrated lighting); reference values: 500 lx at the loading station, 200 lx in the maintenance walkway, with the respective visual task being the determining factor. The constructive integration eliminates dependence on external lighting sources that may be inadequate. |
| Step 2 · Technical | Residual risk from failure or shadowing of the integrated luminaires: monitoring of the operational readiness of the workplace lighting by the machine control system (notification in the event of lamp failure). In addition, maintenance walkway areas to be marked with retroreflective floor markings (trip hazards, aisle boundaries) in accordance with DIN EN ISO 7010 (sign W007, warning of trip hazard, at relevant locations). A safety function within the meaning of EN ISO 13849-1 is not required for lighting monitoring; in the event of a lighting failure, work is to be discontinued (level 3). |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): specification of the required minimum illuminance at the loading station and in the maintenance walkway; notice that work is to be discontinued in the event of failure of the integrated lighting until the lighting has been restored. Warning marking in accordance with DIN EN ISO 7010 on the maintenance walkway door: notice of restricted visibility in the event of lamp failure. Qualification requirement: maintenance personnel must be instructed in checking the lighting function before commencing work. Use suitable portable luminaires for brief inspections in the event of a lighting failure; resume regular work only after the lighting has been restored. |

Risk after: **2** Residual risk accepted: Yes

No. 30 CombinationRisk before: S 5 · P 2 · **RZ 10**

Hazard arising from incorrect parameterisation of the robot control system or the safety control system (e.g. incorrect safety distances, incorrect speed limits in set-up mode, incorrect zone releases): Erroneous parameters may result in safety functions not operating as intended, thereby endangering persons through robot movements or rotary table movements.

Sub-machine: Overall system (control / safety control) · also in: Commissioning, Setting up

- Step 1 · Inherent** Safety-relevant parameters (speed limits, protection zones, zone releases) are stored exclusively in the safety control system (safety PLC) and are protected against unauthorised or inadvertent modification by a hardware key-switch concept or a password-protected, role-based access concept. Parameter sets for safety functions SF-01 to SF-05 are stored in the safety control system as immutable, checksum-protected data records (e.g. CRC-32 or equivalent), so that any unintended modification is automatically detected at system start-up and a safe state is enforced. This principle corresponds to the inherently safe control principle in accordance with EN ISO 12100 Section 6.2.11 (control principles that limit the occurrence of hazards) and reduces the possibility of erroneous parameters becoming effective at all.
- Step 2 · Technical** 1. Validation requirement before release: Every change to safety-relevant parameters requires a documented acceptance test (functional test of all affected safety functions SF-01 to SF-05) carried out by two authorised persons (four-eyes principle) before recommissioning. The safety control system may not release automatic operation until a positive acknowledgement has been given. Basis: EN ISO 13849-2:2012 (validation of safety functions) and EN ISO 11161:2007+A1:2010 Section 5.4 (verification and validation for integrated manufacturing systems). 2. Parameter verification by the safety control system: The safety control system (PLr e for SF-04, PLr d for SF-01, SF-03, SF-05 in accordance with EN ISO 13849-1:2023) checks the consistency of the safety-relevant parameters against stored reference values (checksum comparison) at start-up and cyclically. In the event of a discrepancy, stop category 1 in accordance with EN 60204-1:2018 is triggered and a restart is inhibited (no automatic restart in accordance with EN ISO 14118:2018). 3. Set-up mode SF-05: The safely reduced speed of 250 mm/s (SF-05, PLr d) is limited at hardware level in the safety control system and cannot be overridden by parameters of the robot control system. Monitoring is performed by an SRP/CS in accordance with EN ISO 13849-1:2023, category and PL in accordance with SF-05 (PLr d). 4. Zone release rotary table SF-04: The release of the 180-degree swivel movement (SF-04, PLr e) is performed exclusively via the safety control system on the basis of verified sensor signals; a release caused by erroneous zone parameters in the robot control system alone is excluded by design. 5. Change management: All parameter changes are stored with a time stamp, user identification and predecessor/successor value in a tamper-proof change log (audit trail) of the safety control system. Basis: EN ISO 11161:2007+A1:2010.
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the parameter change procedure with a step-by-step guide, listing of all safety-relevant parameters for each safety function (SF-01 to SF-05), obligation to carry out a validation test after each change, and documentation obligation in the change log. 2. Qualification requirement: Parameter changes to the safety control system may only be carried out by specialist personnel with demonstrated qualification in functional safety (e.g. TÜV certification as Functional Safety Engineer or equivalent) and knowledge of the system. This is to be set out in the operating instructions and in an operating procedure. 3. Warning labelling: A warning sign 'Warning of dangerous electrical voltage or unexpected machine movements' (ISO 7010) and a prohibition sign 'No unauthorised access' (ISO 7010) are to be affixed to the safety control system and the control cabinet. Additionally, an information sign stating: 'Parameter changes by authorised specialist personnel only; subsequent validation test required'. 4. Commissioning checklist: Before every initial commissioning and after every parameter change, a system-specific commissioning checklist is to be completed and signed (basis: EN ISO 11161:2007+A1:2010 Section 5.4).

Risk after: **5** Residual risk accepted: Yes

No. 34 ThermalRisk before: S 3 · P 3 · **RZ 9**

Fire hazard in the welding fume extraction system (filter fire): Sparks and glowing particles drawn in by the process can accumulate in the filter cartridge and ignite a smouldering fire or filter fire, including in a time-delayed manner after the end of a shift. Fire smoke can spread via the pipework system and the air recirculation into the hall.

also in: Operation

- Step 1 · Inherent** Spark reduction at the point of origin through constructive design of the welding parameters and the extraction geometry: Position the extraction nozzle as close as technically possible to the welding point (maximise the capture rate) so that sparks have already cooled before they reach the filter cartridge. In addition, provide a pre-spark separator (baffle plate/cyclone separator) as an integrated component directly upstream of the filter cartridge, which separates coarse particles and sparks by inertia before they come into contact with the filter medium. This component is a constructive part of the extraction system, not a downstream protective device. Design in accordance with EN ISO 21904-1:2020 (requirements for welding fume extraction systems), which specifies spark separation as a constructive requirement for the system.
- Step 2 · Technical** The remaining residual risk of a filter fire is limited by the following technical protective measures: 1. Thermal monitoring of the filter cartridge: temperature sensor (thermostat or thermocouple) in the filter housing with a trigger threshold; upon exceedance, automatic shutdown of the extraction fan and closing of a motorised shut-off damper in the pipework system to prevent the supply of oxygen. Integration into the machine control system; PLr to be determined in accordance with EN ISO 13849-1 (risk graph). 2. Extinguishing device at the filter housing: at least one closable extinguishing agent inlet opening (extinguishing lance) on the housing; optionally an automatic extinguishing device (CO₂ or water spray), selection to be agreed with the operator's fire protection concept. 3. Motorised shut-off damper in the air recirculation duct to the hall: automatic closure upon fire alarm to prevent the spread of smoke into the hall. Integration into the building management system or machine control system. 4. Smoke and CO detectors in the filter housing and in the exhaust air duct as a redundant detection level, with alarm forwarding to a permanently staffed location or to a fire alarm control panel (operator's responsibility, to be agreed with the building fire protection concept). 5. Run-on time of the extraction fan after the end of welding: programme a minimum run-on time of 10 minutes at the control system level so that glowing particles still present in the pipework are fully transported into the separator and cooled before the system is shut down. Design of the run-on time based on the pipework length and the volumetric flow rate.
- Step 3 · Information** Operating instructions (in accordance with (EU) 2023/1230 Annex III No. 1.7.4): - Reference to the fire hazard from sparks and glowing particles in the filter system; description of the damage mechanism including time-delayed ignition. - The prescribed run-on time of the extraction fan after the end of welding (minimum value from the design) as a binding operating instruction. - Maintenance intervals for filter cartridges, pre-spark separators and temperature sensors; specification of the loading level at which the filter cartridge is to be replaced (manufacturer's specification EN ISO 21904-1:2020). - Prohibition on operating the extraction system with a defective temperature sensor or deactivated extinguishing system. - Procedure in the event of a fire alarm: vacate the installation immediately, alert the fire brigade, do not attempt to deal with the filter housing independently (opening it can fan a smouldering fire). - Note that after the end of a shift, a visual inspection of the filter housing (temperature, odour) is to be carried out before the building is vacated. Warning labelling on the extraction system (DIN EN ISO 7010): - Warning of fire hazard (warning of flammable substances/sparks) on the filter housing and maintenance opening. - Prohibition sign 'Do not open in the event of a fire alarm' on the maintenance door of the filter housing. Qualification and instruction: - Operating personnel and maintenance personnel are to be instructed before commencing work and thereafter at least annually on the fire hazard, the function of the protective devices and the correct behaviour in the event of a fire (operator's obligation). - Maintenance work on the filter system only by instructed personnel wearing appropriate PPE (protective gloves, and where applicable respiratory protection during filter replacement due to welding fume exposure).

Risk after: **3** Residual risk accepted: Yes

No. 40 Corruption/securityRisk before: S 3 · P 3 · **RZ 9**

Safety-relevant software not identifiable or labelled: The version status and checksum of the safety software cannot be retrieved at the machine, and safety-relevant software and data are not designated as such. After an intervention, update or device replacement, it cannot be determined whether the machine is still in the inspected state; operation with non-approved software remains undetected. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.1.9 para. 4, 1.7.4.2]

Sub-machine: Software / Documentation · also in: Commissioning, Operation

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| Step 1 · Inherent | Design safety-relevant software as a distinct unit with its own version number and checksum (separate from standard and visualisation software) so that unambiguous identification is technically possible. |
| Step 2 · Technical | Information page on the HMI showing the version and checksum of all safety-relevant software components (always easily accessible without login, Annex III No. 1.1.9 para. 4), labelling of safety-relevant data in file names, menus and exports, comparison with the acceptance report at start-up. Evidence reference Route B: IEC 62443-3-3 SR 3.4. |
| Step 3 · Information | Operating instructions: list of safety-relevant software and data with versions (Annex III No. 1.7.4.2), instructions for retrieving version information, note on the significance for conformity and on the obligation to report deviations. |

Risk after: **3** Residual risk accepted: Yes

No. 41 Corruption/securityRisk before: S 3 · P 3 · **RZ 9**

Missing or incomplete records of interventions (logging): Interventions in safety-relevant hardware, software or configuration are not recorded, or are recorded without a timestamp and originator; logs overwrite themselves after a short period or are open to manipulation. Unauthorised interventions remain undetected and the audit trail is not available upon request by the authorities. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 2, 1.1.9 para. 5, 1.2.1 lit. f]

Sub-machine: Control / logging · also in: Operation, Troubleshooting

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| Step 1 · Inherent | Provide event logging as a fixed function of the control system (not deactivatable by the operator), with a non-volatile memory of sufficient capacity. |
| Step 2 · Technical | Logging of safety-relevant events with timestamp, user identity and content of the change (log-on, parameter and configuration change, software upload with version and checksum, opening of safety-relevant assemblies, remote-access sessions), protection against deletion and modification, export in readable form, retention of uploads and associated data for up to five years after uploading (Annex III No. 1.2.1 lit. f). Evidence reference Route B: IEC 62443-3-3 SR 2.8, SR 2.9, SR 2.11, SR 3.9, SR 6.1. |
| Step 3 · Information | Operating instructions: Access to and export of logs, operator's retention obligations when the machine is transferred, procedure in the event of a regulatory request, note on storage capacity and time synchronisation. |

Risk after: **3** Residual risk accepted: Yes

No. 43 Corruption/securityRisk before: S 5 · P 2 · **RZ 10**

Unsecured engineering access to the safety controller: The programming access of the safety controller or safety PLC is reachable without a password or with the manufacturer's default credentials; the safety program can be overwritten or placed in a stopped state during operation, and forcing of inputs and outputs is possible. Protective functions are rendered ineffective or actuators are controlled directly. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 2, 1.1.9 para. 3, 1.2.1 lit. a]

Sub-machine: Safety control / engineering · also in: Commissioning, Troubleshooting

Step 1 · Inherent	Programming access to the safety controller physically separated from the process network (dedicated port, inside a locked control cabinet), no forcing of safety-relevant signals in the series state, programme changes only in the secured stop state of the machine.
Step 2 · Technical	Individual password for the safety programme access with mandatory password change at commissioning, write protection and access protection levels of the controller activated, logging of all accesses and programme changes with version and checksum, display of the programme status on the HMI. Evidence reference Route B: IEC 62443-3-3 SR 1.1, SR 1.5, SR 2.1, SR 2.8, SR 3.4, SR 7.7.
Step 3 · Information	Operating instructions: Access protection and password management as an operator obligation, prohibition of programme changes without re-verification and documentation, reference to the requirements for substantial modification.

Risk after: **5** Residual risk accepted: Yes

No. 44 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Unauthorised or faulty remote access via the remote maintenance gateway: Via the IPsec VPN connection of the remote maintenance gateway, an unauthorised person with stolen credentials or an authorised technician at the wrong moment intervenes in the cell controller: program or parameter change, acknowledgement of faults or starting of movements while persons are at the loading station or in the maintenance walkway. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.1.9 para. 3, 1.2.1 lit. a, 1.2.1 lit. d]

Sub-machine: Remote maintenance gateway / cell controller · also in: Operation, Troubleshooting

Step 1 · Inherent	Remote access designed so that it cannot trigger hazardous movements or bypass safety functions: the remote maintenance gateway only reaches the standard controller and the operator panel; the safety PLC has no remote access path. Movement commands and acknowledgement of faults are only possible from control positions with a view of the danger zone (Annex III No. 1.2.2).
Step 2 · Technical	Remote maintenance disabled on delivery; a session can only be enabled on site with the key switch at the control desk, ends automatically after four hours and is indicated as "Remote maintenance active" on the operator panel; IPsec VPN with multi-factor authentication and personal accounts for remote technicians; logging of every session with user, time and actions performed, retention in accordance with Annex III No. 1.2.1 lit. f. Evidence reference Path B: IEC 62443-3-3 SR 1.1, SR 1.13, SR 2.1, SR 2.8, SR 3.8.
Step 3 · Information	Operating instructions (chapter Cybersecurity, section Remote maintenance): procedure for enabling and ending remote maintenance sessions, obligation for a responsible person to be available on site, action in the event of suspected unauthorised access (end the session with the key switch, inform the manufacturer), contact for the manufacturer's security notifications.

Risk after: **4** Residual risk accepted: Yes

Cleaning (6 hazards)

No. 8		Mechanical	Risk before: S 3 · P 4 · RZ 12	
Cutting and puncture hazard from the welding wire (solid wire 1.0 to 1.2 mm) at the welding torch: The wire protruding from the torch acts like a needle; during setting, wire threading or torch cleaning, hands and fingers can be punctured or cut.				
Sub-machine: Welding torch / wire feed · also in: Setting up, Maintenance				
Step 1 · Inherent	Automatic wire retraction after the end of welding: The wire feed control automatically retracts the wire by a defined amount (e.g. 5 to 10 mm) into the torch after each welding cycle, so that the sharp wire tip is recessed within the contact tip and no longer protrudes freely. This constructively minimises the hazard point (free-standing wire tip) for the setting and cleaning life phases. In addition: selection of a wire feed system that, in inching mode (setting), advances the wire only when the button is continuously pressed (dead man's principle), so that the wire is not advanced in an uncontrolled manner.			
Step 2 · Technical	1. Mechanical wire length limitation: An adjustable wire length stop (torch protection cap with a defined opening) is provided at the torch neck, limiting the maximum protruding wire to the minimum dimension necessary for the process. 2. Interlocking of wire feed during cleaning and maintenance: The wire feed function is inhibited by the safety controller as soon as the maintenance door is opened (safety function SF-01, PLr d in accordance with EN ISO 13849-1:2023). 3. Set-up mode with safely reduced speed: In set-up mode, the wire feed is limited to the safely reduced speed in accordance with SF-05 (PLr d), thereby preventing unintentional rapid shooting of the wire. 4. Marking of the hazard point on the torch and wire feed in accordance with DIN EN ISO 7010 (warning of pointed injury hazard).			
Step 3 · Information	1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Explicit note that the welding wire presents a sharp, pierceable tip even when stationary. Description of the safe procedure for threading wire (wire feed inhibited, cut the wire end cleanly with side cutters, never probe with the bare hand). 2. Warning marking on the torch holder and on the wire feed unit: warning sign 'Warning: hand injuries' in accordance with DIN EN ISO 7010. 3. Qualification requirement: activities on the torch and wire feed (threading wire, cleaning) may only be carried out by instructed specialist personnel; requirement to be documented in the operating instructions. 4. PPE specification: cut-resistant protective gloves (protection class in accordance with EN 388, minimum 2X42 or equivalent) must be worn when threading wire and when cleaning the torch; specification to be included in the operating instructions and on the notice posted at the workplace. 5. Note on safe cutting of the wire tip: before any manual activity on the torch, the wire tip must be cut cleanly and burr-free with a suitable pair of side cutters; the tool is to be made available at the workplace.			
Risk after:	6	Residual risk accepted: Yes		

No. 10 MechanicalRisk before: S 3 · P 3 · **RZ 9**

Hazard of tripping, slipping and falling in the area of the loading station and the maintenance aisle due to weld spatter on the floor, cables, hoses (compressed air, shielding gas) and wet areas during cleaning work.

Sub-machine: Loading station / maintenance aisle · also in: Operation, Setting up, Maintenance, Troubleshooting

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| Step 1 · Inherent | Keep cables and hoses (compressed air, shielding gas) out of the floor area of the loading station and maintenance aisle by means of constructive routing in cable ducts, energy chain systems or ceiling-suspended cable management systems, so that no trip hazards arise. Design connections at the loading station as ceiling pendants or wall-mounted socket panels. Reduce weld-spatter exposure on the floor by means of constructive shielding plates (spatter-protection shields) at the welding station, so that discharge into the operator area is minimised. Provide the floor covering in the loading station and maintenance aisle with an anti-slip surface (assessment group R 11 or higher in accordance with BGR/GUV-R 181, suitability for wet conditions to be verified), so that the slip hazard is inherently reduced. |
| Step 2 · Technical | Limit the residual risk from remaining trip and slip hazards by means of the following technical measures: (1) Floor markings (yellow/black in accordance with ISO 7010) to identify traffic routes and hazardous areas in accordance with (EU) 2023/1230 Annex III No. 1.1.2 and No. 1.6.2. (2) Adequate fixed lighting of the loading station and maintenance aisle in accordance with (EU) 2023/1230 Annex III No. 1.1.4, so that obstacles and wet areas can be detected at an early stage; illuminance to be specified according to the visual task; machine-integrated lighting to be designed in accordance with EN 1837. (3) Drip trays or spatter-protection mats in the immediate welding area that are easy to remove and clean. |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): (1) Reference to the hazard of tripping and slipping due to weld spatter, hoses and wet conditions; prescribe cleaning intervals and cleaning procedures for the floor area. (2) Qualification requirement: all persons entering the loading station and maintenance aisle must have been instructed in the hazards and the traffic-route layout. (3) PPE specification: safety footwear with anti-slip soles (S2 or S3 in accordance with EN ISO 20345) shall be worn when entering the loading station and maintenance aisle. (4) Warning labelling at the access to the loading station and maintenance aisle: affix a warning sign for slip hazard (ISO 7010, warning sign 'Warning: slippery surface') and the mandatory sign 'Wear safety footwear' (ISO 7010, mandatory sign). |

Risk after: **6** Residual risk accepted: Yes

No. 17 ThermalRisk before: S 3 · P 3 · **RZ 9**

Risk of burns from the hot welding torch and torch neck: The torch neck and the contact tip are strongly heated after the welding process; when changing the torch, during cleaning or during set-up without a cooling period, hands and fingers may be burned.

Sub-machine: Welding torch · also in: Maintenance, Setting up

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| Step 1 · Inherent | Use of active torch cooling (water-cooled torch instead of an air-cooled torch), provided the welding process permits this: The continuous water cooling limits the thermal energy in the torch neck and at the contact tip by design to a significantly lower temperature level. Additionally: The torch holder and the change system are designed such that the operator, when changing the torch, touches only thermally decoupled grip areas (plastic or ceramic handle, no direct metal contact with the torch neck). Design in accordance with EN ISO 13732-1:2008 (contact temperature limits for metal: pain threshold approx. 48 °C, burn threshold depending on contact time and material). |
| Step 2 · Technical | 1. Technical cooling-time interlock (if a temperature sensor is fitted or can be retrofitted at the burner neck): release of manual access to the burner only after the temperature falls below a defined limit value; integration into the safety control system as a safety function (PLr to be determined by EN ISO 13849-1 risk graph). 2. Fixed/movable guard: the welding cell is fitted with a protective enclosure in accordance with EN ISO 14120:2015; access to the burner for maintenance and cleaning is provided exclusively via the secured maintenance door (SF-01, PLr d). Unintentional access to the hot burner during automatic operation is thereby constructively excluded. 3. Provision of a burner rest with a thermally insulated receptacle (ceramic or silicone pad) immediately at the welding station, so that the burner is placed down in a defined manner after the process and is not set down on conductive metal surfaces. |
| Step 3 · Information | 1. Operating instructions: state the cooling time after the end of welding explicitly before any torch change, cleaning or set-up work on the burner (adopt the reference value from the burner manufacturer's specifications); include a procedure for torch changes with the step 'wait for cooling time or check temperature'. 2. Warning labelling: permanently and clearly affix the warning sign 'Warning: hot surface' (ISO 7010) to the burner area and to the maintenance door. 3. Qualification: only instructed persons may carry out torch changes and cleaning; instruction covers the risk of burns, cooling times and correct use of PPE. 4. PPE specification: heat-protection gloves (suitable for contact heat, protection class in accordance with EN 407) are mandatory during torch changes, cleaning and set-up work on the burner; this requirement shall be stated in the operating instructions and indicated by the mandatory sign 'Wear protective gloves' (ISO 7010) at the maintenance door. |

Risk after: **3** Residual risk accepted: Yes

No. 20 Substances/materialsRisk before: S 4 · P 4 · **RZ 16**

Hazard from inhaling welding fumes and vapours (metal oxides, manganese, iron oxides): MAG welding of structural steel generates harmful particles and gases; when extraction is inadequate (saturated filter cartridge, system switched off), concentrations in the operator's breathing zone exceed the workplace exposure limits.

Sub-machine: Overall system (extraction / welding area) · also in: Operation, Setting up, Maintenance

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| Step 1 · Inherent | Substitution of the welding consumable: Use of solid-wire electrodes with a demonstrably reduced manganese content (low-Mn alloy, e.g. Mn content < 1.0 % in accordance with the safety data sheet) instead of flux-cored wire electrodes or high-manganese wires, to the extent that the welding task (structural steel, weld quality) permits this. In addition: optimisation of welding parameters (arc voltage, wire feed speed, shielding gas composition) to a low-fume setting in accordance with the welding power source manufacturer's recommendation, in order to minimise fume generation at source. Both measures genuinely reduce the emitted pollutant mass and thereby reduce the severity of exposure. |
| Step 2 · Technical | Technical ventilation and extraction in accordance with EN ISO 21904-1:2020 (welding fume extraction): Source extraction directly at the welding point (extraction nozzle or integrated torch extraction) with a volumetric flow rate that ensures the capture velocity at the point of generation. The extraction system must be equipped with filter monitoring (differential-pressure switch) that triggers an alarm when the filter cartridge is saturated and inhibits welding operation via the machine control system (safety function: operating enable only when extraction is running, PLr to be determined in accordance with EN ISO 13849-1 risk graph). Enclosure of the welding area (welding booth/housing) in accordance with EN ISO 14120:2015, to the extent compatible with the turntable concept, in order to minimise fume escape into the operator area. Ambient air monitoring for welding fume concentration at the loading station is recommended as an additional operator measure. |
| Step 3 · Information | Operating instructions (in accordance with (EU) 2023/1230 Annex III No. 1.7.4): Specification of the welding fume types emitted and reference to the workplace exposure limits to be observed in accordance with TRGS 900 and TRGS 528; instruction for regular inspection and replacement of filter cartridges (maintenance interval in accordance with manufacturer's specification EN ISO 21904-1:2020); prohibition of welding operation when the extraction system has failed or is switched off. Warning signs at the welding area: warning of harmful vapours and fumes (ISO 7010, warning sign), obligation to wear respiratory protection (ISO 7010, mandatory sign 'Wear respiratory protection') as residual risk marking. PPE requirement: respiratory protection of at least FFP2 (preferably FFP3 or powered air-purifying respirator) for setting-up, maintenance and cleaning work in the welding area when the enclosure is open or the extraction system is switched off. Qualification requirement: operators and setting-up personnel must be instructed in the hazards of welding fumes and the correct operation of the extraction system (TRGS 528 Section 5). |

Risk after: **6** Residual risk accepted: Yes

No. 22 Substances/materialsRisk before: S 3 · P 2 · **RZ 6**

Hazard from filter dust when changing the filter cartridge of the welding fume extraction unit: The filter cartridge contains separated welding fumes with metal oxides and fine particles; when changed without appropriate respiratory protective measures, dusts are released and inhaled.

Sub-machine: Welding fume extraction (filter unit) · also in: Maintenance

- Step 1 · Inherent** Constructive dust retention during filter change: The filter unit is equipped with an integrated bag-in/bag-out system or a dust-tight change cassette, so that the contaminated filter cartridge can be removed and sealed in a closed plastic bag without direct contact with dust. This constructively minimises dust release at the source (substitution of open removal by a closed change procedure in accordance with EN ISO 12100 Section 6.2.4). Additionally: the cleaning pulse (pressure burst) prior to the change is to be permitted ONLY with the housing closed and the extraction system deactivated, in order to compact dust deposits in the cartridge and reduce release when opening.
- Step 2 · Technical** Technical protective measures for the remaining residual risk (residual dust when opening the housing and handling the cartridge): 1. Extraction housing with negative-pressure interlock: The filter housing may by design only be opened when the fan is switched off and the system is depressurised (mechanical interlock, no safety function with PLr requirement, as no motion drive is involved). 2. Local extraction at the change location: A connection stub for a mobile extraction unit (industrial vacuum cleaner dust class H in accordance with EN 60335-2-69, suitability for welding fume dusts) is to be provided on the filter housing; this is activated during the change and captures released residual particles. 3. Labelling of the filter unit: Warning sign "Warning: harmful or irritating substances" in accordance with DIN EN ISO 7010 to be permanently affixed to the filter housing.
- Step 3 · Information** User information for the remaining residual risk: 1. Operating instructions (chapter: Maintenance/Cleaning): Detailed step-by-step instruction for the filter change with description of the bag-in/bag-out procedure; information on the composition of the separated dusts (metal oxides, fine particles, possibly CMR substances depending on the weld material); disposal note (contaminated filter cartridges to be disposed of as hazardous waste in accordance with applicable waste regulations). 2. Qualification requirement: Filter change to be carried out only by trained specialist personnel who have been informed of the hazard from welding fume dusts. 3. PPE specification: During the filter change, the following must be worn as a minimum: respiratory protection FFP3 (half-mask) in accordance with EN 149 for fine particles and metal oxides; protective gloves (chemical-resistant); safety spectacles (particle protection). PPE requirements are to be specified permanently in the operating instructions and by means of a mandatory sign "Wear respiratory protection" (DIN EN ISO 7010) on the filter housing. 4. Reference to occupational health and safety legislation: The operator is to be advised of their obligations under TRGS 528 (welding operations) and the Gefahrstoffverordnung (GefStoffV), in particular regarding the risk assessment for CMR dusts and the provision of suitable PPE.

Risk after: **3** Residual risk accepted: Yes

No. 27 ErgonomicRisk before: S 2 · P 3 · **RZ 6**

Insufficient lighting at the loading station and in the maintenance walkway: inadequate illuminance makes it difficult to load and unload workpieces safely and to carry out maintenance work, and increases the risk of errors and accidents.

Sub-machine: Loading station / maintenance aisle · also in: Operation, Setting up, Maintenance

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| Step 1 · Inherent | Machine-integrated workplace lighting at the loading station and in the maintenance walkway to be provided as part of the design: luminaires are permanently integrated into the machine structure (e.g. built into the enclosure frame or protective housing) so that the illuminance at the loading station and in the maintenance walkway is permanently ensured independently of the hall lighting. The design is carried out in accordance with EN ISO 12100:2010 section 6.2.6 (ergonomic design) in conjunction with EN 1837 (machine-integrated lighting); reference values: 500 lx at the loading station, 200 lx in the maintenance walkway, with the respective visual task being the determining factor. The constructive integration eliminates dependence on external lighting sources that may be inadequate. |
| Step 2 · Technical | Residual risk from failure or shadowing of the integrated luminaires: monitoring of the operational readiness of the workplace lighting by the machine control system (notification in the event of lamp failure). In addition, maintenance walkway areas to be marked with retroreflective floor markings (trip hazards, aisle boundaries) in accordance with DIN EN ISO 7010 (sign W007, warning of trip hazard, at relevant locations). A safety function within the meaning of EN ISO 13849-1 is not required for lighting monitoring; in the event of a lighting failure, work is to be discontinued (level 3). |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): specification of the required minimum illuminance at the loading station and in the maintenance walkway; notice that work is to be discontinued in the event of failure of the integrated lighting until the lighting has been restored. Warning marking in accordance with DIN EN ISO 7010 on the maintenance walkway door: notice of restricted visibility in the event of lamp failure. Qualification requirement: maintenance personnel must be instructed in checking the lighting function before commencing work. Use suitable portable luminaires for brief inspections in the event of a lighting failure; resume regular work only after the lighting has been restored. |

Risk after: **2** Residual risk accepted: Yes

Troubleshooting (15 hazards)

No. 1 Mechanical	Risk before: S 5 · P 3 · RZ 15
Crushing and shearing hazard from the turntable during the automatic turning operation: Body parts of the operator (hands, arms) may be drawn in and crushed between the rotating table and the fixed centre wall or the protective fence, in particular when reaching into the turntable during turning to reposition a displaced workpiece (reasonably foreseeable misuse).	
<i>Sub-machine: Turning table (rotary table unit) · also in: Operation, Setting up</i>	
Step 1 · Inherent	Design the gap dimensions between the rotating table edge and the fixed centre wall as well as the protective fence such that no crushing points arise: comply with the minimum distances in accordance with EN ISO 13854:2019 Table 1 (25 mm for fingers, 100 mm for the hand, 120 mm for the arm, 500 mm for the body). If neither the small nor the large gap can be achieved by design, the geometry of the table frame must be configured so that no converging wedge shape is created (parallel or diverging flanks instead of a converging gap). In addition: reduce the mass and pivoting speed of the turntable to the functionally necessary minimum (drive design) in order to limit the kinetic energy acting in the crushing gap.
Step 2 · Technical	Residual risk after level 1: The swivel area remains a hazard zone that must not be entered while the drive is running. Technical protective measures: 1. Release of the swivel movement only when the swivel area is clear (SF-04, PLr e, EN ISO 13849-1:2023): BWS (light curtain type 4 in accordance with EN 61496-1) monitors the swivel area completely; arrangement and safety distance in accordance with EN ISO 13855:2024. 2. Guard locking of the access door to the turntable area in accordance with EN ISO 14119:2025 with escape release (SF-01, PLr d; stop category 1 in accordance with EN 60204-1:2018). 3. Set-up mode: swivel movement only at safely reduced speed of 250 mm/s and with the enabling device actuated (SF-05, PLr d, stop category 1 in accordance with EN 60204-1:2018). 4. Emergency stop in the operator area in accordance with EN ISO 13850:2015, integrated into SF-03 (PLr d, stop category 1 in accordance with EN 60204-1:2018). 5. Energy isolation prior to interventions: isolating valve with mechanical latching (lockout) in accordance with EN ISO 4414:2010; secure gravitational lowering by means of mechanical support (EN ISO 14118:2018).
Step 3 · Information	1. Operating instructions: entering the swivel area while the turntable is running or unsecured is prohibited. Before any intervention (e.g. repositioning a workpiece), the system must be completely switched off and secured (lockout/tagout). A separate procedure with an enabling device applies to set-up mode and is described in the operating instructions. 2. Warning signs on the machine: warning signs are affixed to the turntable: "Warning: hand injury hazard", "Warning: rotating parts" and "Entry prohibited during operation" (in accordance with DIN EN ISO 7010). 3. Who may intervene: set-up and fault rectification may only be carried out by trained personnel. Training must be repeated at least once a year and recorded in writing. 4. Personal protective equipment: protective gloves are prohibited at the turntable, as they increase the risk of the hand being drawn in. Safety footwear (protection class S2 or S3) is mandatory throughout the entire system area.
Risk after: 5 Residual risk accepted: Yes	
	
Warning: crushing	

No. 4 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Crushing hazard at the interface between the turning table and the welding robot (transfer area): During the turning operation the loaded fixture moves into the working area of the robot; uncoordinated entry of the robot into the turning area or missing interlock between the turning table movement and the robot enable can lead to collisions and crushing injuries.

Sub-machine: Interface: turning table / welding robot · also in: Operation, Setting up

Step 1 · Inherent	The pivoting radius of the turning table and the working space boundary of the robot (TCP envelope) are coordinated with each other during the design phase such that the maximum pivoting range of the fixture and the minimum robot working space maintain a geometric minimum distance of ≥ 500 mm (safety distance against reaching with the arm in accordance with EN ISO 13857:2019 Table 1, body opening arm) from each other when both movements would be active simultaneously. This minimises the overlap zone by design; complete elimination of the overlap is not possible with this system topology due to functional constraints, so that the remaining residual overlap is safeguarded by Level 2.
Step 2 · Technical	SF-04 'Enable of the 180-degree pivoting movement of the turning table only when the pivoting area is clear' with PLr e in accordance with EN ISO 13849-1:2023 (risk graph: S2/F2/P2). Implementation as an interlocked safety function in the safety PLC: (a) Robot standstill monitoring: the robot must be in a defined rest position (safe position) outside the pivoting zone and must confirm this via a safe feedback signal (e.g. safe output of the robot controller in accordance with EN ISO 10218-2:2025 Sections 5.4.7 and 5.5.8) before the turning table enable is granted. (b) Turning table enable to the robot: as long as the turning table is not in its end position and locked, the robot controller receives no enable signal for the entry area; guard locking of the pivoting movement via a safety drive or mechanical interlock. (c) Guard locking of the maintenance door to the pivoting area in accordance with EN ISO 14119:2025 with escape release, incorporated in SF-01 (PLr d). (d) Emergency stop of the complete system in accordance with EN ISO 13850:2015, incorporated in SF-03 (PLr d), stop category 1 in accordance with EN 60204-1:2018. (e) In set-up mode SF-05 applies: safely reduced speed ≤ 250 mm/s with enabling device (PLr d); the setter may enter the pivoting area only with the enabling device activated and at reduced speed. Safety distance of the fixed guard (safety fence) to the pivoting area to be calculated and documented in accordance with EN ISO 13855:2024 and EN ISO 13857:2019; safety fence to be designed in accordance with EN ISO 14120:2015.
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the interlock logic SF-04 and the permissible operating modes; explicit notice that entering the pivoting area while the system is running is prohibited. Set-up mode: qualification requirement to be documented (only trained specialist personnel with knowledge of the enabling device). Warning labelling at the pivoting area: warning of crushing hazard (ISO 7010, warning sign 'Warning: hand injury' or 'Warning: dangerous area') and prohibition sign 'No entry' (ISO 7010) at all access points. PPE specification in the operating instructions: safety footwear; in set-up mode additionally close-fitting protective clothing (no entanglement risk from loose clothing). Note on residual risk in set-up mode and fault-finding: always keep the enabling device activated, never enter the pivoting area without the enabling device.

Risk after: **5** Residual risk accepted: Yes

No. 5 MechanicalRisk before: S 4 · P 3 · **RZ 12**

Falling of workpieces or fixture parts due to failure of the pneumatic clamping device: In the event of compressed air failure or leakage, the clamping elements open in an uncontrolled manner; workpieces of up to 40 kg may fall from the rotary table and strike persons at the loading station.

Sub-machine: Pneumatic clamping device (rotary table) · also in: Operation, Setting up

Step 1 · Inherent	Use of clamping elements with a spring-force closing principle ("Normally Closed", NC): The clamping force is generated by pre-tensioned springs; compressed air is only required for opening (releasing) the clamping elements. In the event of compressed air failure or leakage, the workpiece remains securely clamped. The spring force is designed for the maximum workpiece weight of 40 kg plus a safety factor in accordance with EN ISO 4414:2010 Section 5.4 (fail-safe principle). Additionally: limitation of the operating pressure to the minimum level required for the opening function, in order to minimise the pneumatic energy stored in the event of a fault (EN ISO 4414:2010 Section 5.3).
Step 2 · Technical	1. Pressure monitoring with safety function: Pressure switch in the supply circuit of the clamping device; if the minimum pressure required for the opening function is not reached, the release of the rotary motion of the rotary table is inhibited (interlocked with SF-04, PLr e in accordance with EN ISO 13849-1:2023). As long as sufficient pressure is not present, the rotary table must not rotate and the loading release is not granted. 2. Mechanical interlock of the rotary motion: Positive locking of the rotary table in the loading position, so that unintended rotation with a clamped or loose workpiece is prevented; the interlock is released only after confirmed clamping force (interlocked with SF-04, PLr e). 3. Enclosure/catch device: Mechanical catch device (e.g. catch rail or deflector plate) below the rotary table, designed for the maximum workpiece weight of 40 kg and the maximum drop height, to keep falling parts away from the loading station; design in accordance with EN ISO 14120:2015. 4. Safety distance at the loading station: Arrangement of the loading station such that the hazard zone below the rotary table is outside the regular area of presence; safety distance to be verified and documented in accordance with EN ISO 13857:2019 Table 1 (upper limbs).
Step 3 · Information	1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the NC clamping principle and the pressure monitoring; prohibition of remaining beneath the rotary table during operation and during fault-finding without secured standstill; procedure in the event of compressed air failure (shut down the machine, restore the compressed air supply, remove the workpiece only after a pressure check). 2. Energy isolation prior to interventions: Instruction for complete pressure relief of the pneumatic system prior to maintenance and servicing work in accordance with EN ISO 4414:2010 Section 5.2 and EN ISO 14118:2018 (prevention of unexpected restart and unexpected energy release); provide a shut-off and exhaust valve with lockout facility. 3. Warning labelling: Attach the warning sign "Warning: overhead load" and the warning sign "Warning: hand injuries" in accordance with DIN EN ISO 7010 to the rotary table and at the loading station. 4. Qualification: Fault-finding and setting-up work to be carried out by trained specialist personnel only; requirements to be specified in the operating instructions. 5. PPE: Prescribe the wearing of safety footwear (EN ISO 20345, protection class S2 or S3) at the loading station as residual risk protection.

Risk after: **4** Residual risk accepted: Yes

No. 6 MechanicalRisk before: S 5 · P 3 · **RZ 15**

Hazard of crushing and impact due to unexpected restart of the turntable or the robot after an emergency stop or after fault clearance: if a coordinated restart prevention system (EN ISO 11161) is absent, individual sub-machines may start up automatically while persons are still present in the hazardous area.

Sub-machine: Overall system (restart coordination) · also in: Maintenance, Setting up

- Step 1 · Inherent** Inherent possibilities exhausted: restart after an emergency stop or after fault clearance is a control-system event that cannot be constructively eliminated by the functional principle of the overall installation (coordinated automatic operation of robot and turntable) without cancelling the machine function. No geometric or energetic measure exists that would prevent the restart itself without abolishing the machine function. Protection must therefore be achieved entirely through Level 2 measures (control system and interlocking).
- Step 2 · Technical** 1. Coordinated restart prevention in accordance with EN ISO 11161:2007+A1:2010 Section 5.6: the overall installation control system shall not release the restart of a sub-machine (turntable, robot) until a deliberate, manual restart command has been issued from a safe position outside all hazardous areas. The restart command shall NOT be triggered automatically following acknowledgement of the emergency stop or following fault clearance. 2. Safety function SF-01 (safe stop, stop category 1 on opening of the maintenance door, PLr d in accordance with EN ISO 13849-1:2023) and SF-03 (emergency stop of the overall installation, stop category 1, PLr d in accordance with EN ISO 13849-1:2023) ensure that all drives are safely brought to a standstill. The restart prevention is implemented as an integral part of safety functions SF-01, SF-03 and SF-04 and is executed at their respective PLr (SF-04: PLr e; SF-01 and SF-03: PLr d in accordance with EN ISO 13849-1:2023). 3. Safety function SF-04 (release of the 180-degree pivoting movement of the turntable only when the pivot area is clear, PLr e in accordance with EN ISO 13849-1:2023): the turntable may only execute its pivoting movement when the pivot area has been detected as clear by a suitable protective device (e.g. light curtain Type 4 in accordance with EN 61496-1, positioned in accordance with EN ISO 13855:2024). This function remains active after restart and prevents start-up in the presence of persons. 4. Safety function SF-05 (safely reduced speed of 250 mm/s with enabling device in set-up mode, PLr d in accordance with EN ISO 13849-1:2023): in set-up mode, restart shall be released exclusively via an enabling device (3-position in accordance with EN ISO 10218-2:2025 Section 5.7.7), so that an unexpected restart at full speed is excluded. 5. De-energisation and energy isolation in accordance with EN ISO 14118:2018: before entering the hazardous area for fault-finding or maintenance, the energy supply to all relevant drives (electrical, pneumatic in accordance with EN ISO 4414:2010) shall be disconnected by means of a lockable isolating device and secured against unintentional re-energisation (lockout/tagout). Residual energy (stored pneumatic energy, gravitational component of the turntable) shall be dissipated or mechanically secured before any intervention. 6. Guard locking of the maintenance door in accordance with EN ISO 14119:2025 with escape release: the guard locking keeps the maintenance door closed as long as hazardous movements have not been safely brought to a standstill (stop category 1 completed). Integration is carried out within the scope of SF-01 (PLr d).
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the restart sequence after an emergency stop and after fault clearance; explicit statement that restart is permissible only after all hazardous areas have been fully vacated and a manual acknowledgement command has been issued from outside. Description of the lockout/tagout procedure in accordance with EN ISO 14118:2018 for all maintenance and fault-finding activities. 2. Warning labelling at all access doors and acknowledgement units: warning of unexpected restart (warning sign 'Warning: automatic start-up' in accordance with DIN EN ISO 7010), notice of the obligation to acknowledge from outside. 3. Qualification requirement: set-up and maintenance activities may only be carried out by instructed specialist personnel who have been trained in the restart procedure and the lockout/tagout method (EN ISO 10218-2:2025 Section 7.5.12). 4. PPE specification: safety footwear (S2/S3) shall be worn when entering the hazardous area for fault-finding or maintenance; additional PPE as determined by the operator's workplace risk assessment.

Risk after: **5** Residual risk accepted: Yes

No. 7 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Missing or uncoordinated emergency stop function between sub-machines (robot, turning table, welding power source, extraction system): an emergency stop at one sub-machine does not necessarily stop all other sub-machines; persons may be endangered by components that continue to run.

Sub-machine: Overall system (emergency stop coordination) · also in: Operation, Setting up

Step 1 · Inherent	Inherent possibilities exhausted: the coordination of several independent controllers necessarily requires a higher-level control logic. A purely constructive measure (geometry, energy limitation, substitution) cannot replace the missing interconnection of the emergency stop circuits. The functional principle of the linked plant necessitates active control coordination.
Step 2 · Technical	Higher-level emergency stop circuit (SF-03) in accordance with EN ISO 13850:2015 and EN ISO 11161:2007+A1:2010: all emergency stop actuating devices of the complete plant are integrated into a common, higher-level safety circuit which, on actuation at any point, brings all sub-machines (robot, turning table, welding power source, extraction system) to a coordinated standstill. Stop category 1 in accordance with EN 60204-1:2018 (controlled stopping, followed by energy disconnection): the robot performs a controlled stop along its path, the turning table brakes actively, the welding power source is de-energised, and the extraction system runs on (not a safety function, but operationally required). Safety function SF-03 is to be designed to PLr d in accordance with EN ISO 13849-1:2023 (Category 3 or 4, depending on architecture). Integration of the robot is carried out via the robot controller in accordance with EN ISO 10218-2:2025 Section 5.3.3 (span of control of the emergency stop, safety interface to the higher-level controller). Emergency stop actuating devices are to be designed in accordance with EN ISO 13850:2015 (mushroom-head pushbutton, yellow background, self-latching, release only by deliberate action). Emergency stop actuating devices are to be positioned such that at least one actuating device is reachable from every operating position without exposure to a hazard (EN ISO 13850:2015 Section 4.4). Restart interlock: after an emergency stop, a manual reset is required before the plant can restart (EN ISO 13850:2015 Section 4.1.4), in order to prevent unexpected restart in accordance with EN ISO 14118:2018.
Step 3 · Information	Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): description of the emergency stop topology of the complete plant with a layout plan of all emergency stop actuating devices and the area of effect of each actuating device. Clear instruction that after an emergency stop, the hazard zone of all sub-machines must be inspected before the reset is carried out. Set-up mode and fault-finding: instruction that intervention in the hazard zone is only permissible after all sub-machines have come to a complete standstill and reset protection has been secured (key switch or lock). Qualification requirement: set-up and fault-finding only by instructed specialist personnel who are familiar with the emergency stop topology. Warning marking at all operator panels: information sign indicating the area of effect of the respective emergency stop actuating device (warning of unexpected start-up of adjacent sub-machines, signs in accordance with DIN EN ISO 7010, warning of automatic start-up).

Risk after: **5** Residual risk accepted: Yes

No. 10 MechanicalRisk before: S 3 · P 3 · **RZ 9**

Hazard of tripping, slipping and falling in the area of the loading station and the maintenance aisle due to weld spatter on the floor, cables, hoses (compressed air, shielding gas) and wet areas during cleaning work.

Sub-machine: Loading station / maintenance aisle · also in: Operation, Setting up, Maintenance, Cleaning

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| Step 1 · Inherent | Keep cables and hoses (compressed air, shielding gas) out of the floor area of the loading station and maintenance aisle by means of constructive routing in cable ducts, energy chain systems or ceiling-suspended cable management systems, so that no trip hazards arise. Design connections at the loading station as ceiling pendants or wall-mounted socket panels. Reduce weld-spatter exposure on the floor by means of constructive shielding plates (spatter-protection shields) at the welding station, so that discharge into the operator area is minimised. Provide the floor covering in the loading station and maintenance aisle with an anti-slip surface (assessment group R 11 or higher in accordance with BGR/GUV-R 181, suitability for wet conditions to be verified), so that the slip hazard is inherently reduced. |
| Step 2 · Technical | Limit the residual risk from remaining trip and slip hazards by means of the following technical measures: (1) Floor markings (yellow/black in accordance with ISO 7010) to identify traffic routes and hazardous areas in accordance with (EU) 2023/1230 Annex III No. 1.1.2 and No. 1.6.2. (2) Adequate fixed lighting of the loading station and maintenance aisle in accordance with (EU) 2023/1230 Annex III No. 1.1.4, so that obstacles and wet areas can be detected at an early stage; illuminance to be specified according to the visual task; machine-integrated lighting to be designed in accordance with EN 1837. (3) Drip trays or spatter-protection mats in the immediate welding area that are easy to remove and clean. |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): (1) Reference to the hazard of tripping and slipping due to weld spatter, hoses and wet conditions; prescribe cleaning intervals and cleaning procedures for the floor area. (2) Qualification requirement: all persons entering the loading station and maintenance aisle must have been instructed in the hazards and the traffic-route layout. (3) PPE specification: safety footwear with anti-slip soles (S2 or S3 in accordance with EN ISO 20345) shall be worn when entering the loading station and maintenance aisle. (4) Warning labelling at the access to the loading station and maintenance aisle: affix a warning sign for slip hazard (ISO 7010, warning sign 'Warning: slippery surface') and the mandatory sign 'Wear safety footwear' (ISO 7010, mandatory sign). |

Risk after: **6** Residual risk accepted: Yes

No. 11 MechanicalRisk before: S 5 · P 2 · **RZ 10**

Hazard arising from simultaneous access by several persons to different zones of the cell (EN ISO 11161): a second person is present inside the cell without the setter being aware of this; when the robot or the turntable starts up, the second person is struck.

Sub-machine: Overall system (zone access) · also in: Setting up, Maintenance

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| Step 1 · Inherent | Inherent possibilities exhausted: the functional principle of the overall installation requires accessible zones for set-up, maintenance and fault-finding work. The hazard arises from the simultaneous presence of several persons in different zones, which cannot be resolved by geometry, distance or energy limitation alone without defeating the operational purpose. A reduction of the robot or turntable energy to a level that safely excludes injury is not technically realisable with this type of installation. |
| Step 2 · Technical | 1. Presence-detection concept in accordance with EN ISO 11161:2007+A1:2010 Section 5.6 (access control for assemblies of machinery): a key-transfer or key-interlocking system (key-transfer box) shall be used for each access point to the cell. Each person entering the cell removes a personal key; start-up of the installation is possible only when all keys have been returned. The number of keys corresponds to the maximum permissible number of persons inside the cell. This concept shall be integrated into the safety control system. 2. Zone-specific guard locking at all access doors in accordance with EN ISO 14119:2025 with escape release (escape facility) in accordance with EN ISO 14119:2025 Section 6.9.1, so that persons trapped inside the zone can leave it at any time. 3. The release of start-up (robot and turntable) shall be implemented as a safety function: start-up is possible only when all access doors are closed and locked AND all personal keys are inserted in the key-transfer box. This function shall be assigned to the existing SF-04 (turntable release, PLr e) and SF-01 (standstill on maintenance door, PLr d). Since SF-04 carries the highest requirement level with PLr e, the entire access-control function shall be designed to PLr e in accordance with EN ISO 13849-1:2023. 4. In set-up mode, SF-05 applies (safely reduced speed of 250 mm/s with enabling device, PLr d in accordance with EN ISO 13849-1:2023). The enabling device is person-specific; a second enabling device shall be provided if two persons must work simultaneously in set-up mode, whereby both enabling devices must be actuated simultaneously (AND logic) or start-up remains generally inhibited as long as more than one person is detected inside the cell. 5. Safety distances between the robot working space and areas where persons are present shall be maintained and documented in accordance with EN ISO 13857:2019 Table 1 and EN ISO 10218-2:2025 Sections 5.4.6 and 5.8.9. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the key-transfer concept, the maximum permissible number of persons per zone, the obligation to remove the key before entering and to return the key before start-up. Procedural instruction for multi-person operations (setting up, maintenance, fault-finding) with clear role assignment (responsible person, coordination). 2. Warning signs at all access points: Warning of automatic start-up (warning sign in accordance with DIN EN ISO 7010, warning of dangerous machine parts), notice of key obligation and personnel-tracking concept. 3. Qualification requirement: Setting-up and maintenance personnel must be instructed in the multi-person access concept and the operation of the key-transfer box. The instruction must be documented. 4. PPE specification in the operating instructions: Safety footwear, close-fitting protective clothing (no entanglement risk from loose clothing) when inside the cell. |

Risk after: **5** Residual risk accepted: Yes

No. 12 ElectricalRisk before: S 5 · P 2 · **RZ 10**

Hazard from direct or indirect contact with live parts of the welding power source, the robot control cabinet and the cell control system (400 V AC, 32 kVA): Contact with terminals, cables or the interior of the control cabinet when the cabinet is open without isolation can lead to electric shock with ventricular fibrillation or burns.

Sub-machine: Electrical installation (control cabinet / welding power source) · also in: Maintenance, Commissioning

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| Step 1 · Inherent | All live parts inside the control cabinet (terminals, busbars, power terminals of the welding power source) are designed with touch-proof covers (degree of protection at least IP 2X or IPXXB in accordance with EN 60204-1:2018 Section 6.2.2), so that contact with live parts is prevented by the enclosure form itself without the need for a guard. In addition, minimum clearances between live and accessible parts are designed such that the degree of protection IP 2X is maintained even with the cabinet door open (protective caps, insulating covers on terminal strips). This addresses (EU) 2023/1230 Annex III No. 1.5.1 (Electrical energy supply) by analogy, as well as EN 60204-1:2018 Section 6.2. |
| Step 2 · Technical | 1. Isolation and de-energisation (LOTO): Main switch with lockable zero position in accordance with EN 60204-1:2018 Section 5.3 and EN ISO 14118:2018 (prevention of unexpected start-up / energy isolation). The main switch must disconnect the entire system from the supply on all poles as an isolating device; residual voltage at the capacitors of the welding power source is to be limited to below 60 V DC within 5 s by means of a discharge time or active discharge circuit (requirement from EN 60204-1:2018 Section 5.4). Cabinet door interlock: The doors of the main control cabinets are fitted with a door interlock (key switch or tool-operated fastener) that prevents unauthorised opening (EN 60204-1:2018 Section 6.2.2). 2. Protective equipotential bonding and protective conductor: All control cabinet enclosures, the welding power source and the robot control cabinet are connected via a continuous protective conductor (PE) of adequate cross-section (EN 60204-1:2018 Section 8.2), so that in the event of an insulation fault the fault current is safely dissipated and the protective device (circuit breaker / RCD) trips. 3. Residual current device (RCD): Use of an RCD (Type B, since DC fault currents from frequency inverters and the welding power source are possible) with a tripping current of 30 mA for circuits at which persons are working, in accordance with EN 60204-1:2018 Section 8.3 (insofar as this is feasible on the supply side and compatible with the welding process; otherwise insulation monitoring in accordance with EN 60204-1:2018 Section 8.3 as an alternative). Not a safety function with a PLr requirement; the measures act passively and by design (warning labelling: see Level 3). |
| Step 3 · Information | Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Document the isolation procedure (LOTO) with a step-by-step instruction, including the discharge time of the capacitors of the welding power source and verification of the absence of voltage using a suitable measuring instrument (voltage tester Category CAT III 600 V). Qualification requirement: Work on the electrical installation may only be carried out by electrically skilled persons (ESP) in accordance with DGUV Vorschrift 3 / BGV A3, or under the supervision of an ESP by electrically instructed persons. PPE specification: Insulating gloves (protection class in accordance with EN 60903 corresponding to the rated voltage of 1000 V), safety goggles (arc flash protection) and antistatic footwear are to be worn when working in an open cabinet. Warning labelling: Warning of dangerous electrical voltage (ISO 7010 W012) to be affixed permanently and clearly visible to all cabinet doors and to the welding power source. Residual risk note in the operating instructions: After operation of the main switch, capacitors in the welding power source and in the frequency inverter of the robot may carry dangerous voltages for a defined period (as specified by the component manufacturer); absence of voltage must always be verified by measurement. |

Risk after: **5** Residual risk accepted: Yes

No. 13 ElectricalRisk before: S 4 · P 2 · **RZ 8**

Hazard from welding current at the workpiece and at the fixture: the welding circuit carries high currents (typically 100 to 350 A); in the event of a faulty earth connection or damaged insulation, persons who touch the workpiece or the fixture may receive an electric shock.

Sub-machine: Welding power source / fixture · also in: Setting up, Operation

- Step 1 · Inherent** Design the fixture frame and workpiece holders such that touchable conductive surfaces that lie within the welding current circuit are galvanically isolated from the machine frame by constructive insulation (e.g. insulating plates made of Pertinax/glass-fibre epoxy between the fixture base plate and the machine table, as well as insulating clamping jaw inserts). This constructively interrupts the unintentional current path via the frame and touchable external surfaces. In addition: define the earth cable connection point directly on the workpiece or at a designated location on the fixture that is not touchable by the operator, and integrate it by means of shaping (recess, cable routing channel) in such a way that incorrect positioning of the earth clamp is constructively impeded.
- Step 2 · Technical** 1. Welding power source: Procurement of a welding power source with protection class I and degree of protection of at least IP23S in accordance with EN IEC 60974-1 (procurement requirement); integration into the protective conductor chain of the overall installation shall be carried out in accordance with EN 60204-1:2018 Section 8 (protective conductor cross-sections, connection points). 2. Monitoring of the earth connection: If the welding power source or the system control supports an earth current monitoring function, this shall be activated; in the event of interruption or an impermissibly high contact resistance, the welding process is inhibited (safety function in accordance with EN ISO 13849-1:2023, PLr to be determined according to risk graph, as no project-specific SF has been defined for this function). 3. Equipotential bonding: All conductive parts of the fixture that are not deliberately insulated are included in the protective equipotential bonding of the installation (EN 60204-1:2018 Section 8.2). 4. Access restriction during the welding process: The loading station is safeguarded by the light curtain (SF-02, PLr e in accordance with EN ISO 13849-1:2023); during active welding, access to the welding area is prevented by the interlocked maintenance door (SF-01, PLr d) and the enable logic of the turn-over table (SF-04, PLr e), so that contact with live parts in automatic mode is prevented by both constructive and control-engineering means. 5. Cable management: Welding cables and earth cables are routed in enclosed cable ducts or protective conduits (protection against mechanical damage); minimum bending radii as specified by the manufacturer shall be observed; cables shall be secured with strain relief.
- Step 3 · Information** 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Description of the correct connection of the earth clamp (position, cleaning of the contact surface, permissible clamping areas); notice that touching the workpiece and the fixture during the welding process is prohibited; inspection interval for insulation and cable condition (recommended: daily visual inspection, semi-annual insulation measurement by a qualified electrician). 2. Qualification requirement: Setting up, fault-finding and maintenance on the welding power source and its connections may only be carried out by a qualified electrician or an electrotechnically instructed person under the supervision of a qualified electrician (EN 60204-1:2018 Section 4.2). 3. Warning labelling on the fixture and in the welding area: Attach warning signs 'Warning of electric voltage' and 'Warning of hand injuries from welding spatter' in accordance with DIN EN ISO 7010 at a clearly visible location; attach an information sign 'Check earth clamp before commencing welding'. 4. PPE specification in the operating instructions: When setting up and fault-finding in the welding area, insulating gloves (protection class suitable for low voltage) and welding protective clothing shall be worn.

Risk after: **4** Residual risk accepted: Yes

No. 21

Substances/materials

Risk before: S 4 · P 2 · **RZ 8**

Hazard from shielding gas (argon-CO₂ mixture M21) in the event of leakage: Shielding gas is heavier than air (CO₂ content) and may accumulate near floor level; in the event of larger leakages in poorly ventilated areas, there is a risk of asphyxiation due to oxygen displacement.

Sub-machine: Shielding gas supply / piping system · also in: Operation, Maintenance

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| Step 1 · Inherent | Pressure limitation in the piping system: Limit the operating pressure of the shielding gas supply to the minimum level required for the welding process (pressure regulator directly at the withdrawal point of the cylinder battery or at the supply connection). A lower system pressure reduces the quantity of gas escaping in the event of a fault and thus the potential for accumulation. Additionally: design the pipe routing and connection points so that leakages are constructively minimised: use of cutting ring fittings or press fittings instead of hose clamps on fixed pipe sections; reduce hose lengths to the minimum operationally necessary; no routing of pipes near floor level in pits or enclosed chambers (route near the ceiling where possible). These measures address the energy source (stored pressurised gas) and the hazard location (accumulation zone) directly. |
| Step 2 · Technical | 1. Automatic shut-off of the gas supply: Solenoid valve (de-energised closed) in the shielding gas supply line, which automatically shuts off the gas supply upon machine stop, emergency stop (SF-03) and during operating pauses; additionally, a manual shut-off valve outside the cell. 2. Leak monitoring: Plausibility check of gas consumption via the machine control system (indication when gas flow occurs without an active welding process, as a leakage indicator); daily visual inspection of hose connections as a maintenance requirement. 3. Installation of the shielding gas supply (cylinder battery or withdrawal station) in a ventilated area of the hall, not in pits, basements or confined recesses. If installed in poorly ventilated areas, the operator is required to provide an oxygen warning device (note in the operating instructions). A safety function with a PLr requirement is not necessary for this hazard; the risk is controlled by means of shut-off, installation location and ventilation. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Note on the risk of asphyxiation due to oxygen displacement in the event of larger leaks in poorly ventilated areas; requirement for adequate hall ventilation at the installation site; work on the gas supply only with the line shut off and depressurised (EN ISO 14118:2018). 2. Qualification: Work on compressed gas lines and fittings only by instructed specialist personnel; instruction in accordance with DGUV Regel 100-500 Chapter 2.26 and TRGS 528 (operator's obligation). 3. Warning labelling: Note on the risk of asphyxiation in poorly ventilated areas at the gas supply installation site; prohibition sign 'No entry for unauthorised persons' on locked supply areas (DIN EN ISO 7010). 4. When working in confined or poorly ventilated areas (e.g. cylinder changes in recesses): use a portable oxygen warning device; no lone working. |

Risk after: **4**

Residual risk accepted: Yes

No. 23 Substances/materialsRisk before: S 4 · P 3 · **RZ 12**

Hazard from residual pneumatic energy during maintenance and fault-clearing work: After the compressed air supply is switched off, residual pressure remains in the lines and cylinders of the clamping device; uncontrolled pressure release can cause clamping elements to move suddenly and injure persons or eject workpieces.

Sub-machine: Pneumatic clamping device / compressed air system · also in: Maintenance

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| Step 1 · Inherent | Minimise residual pneumatic energy by means of a pressureless spring-accumulator design: Design clamping cylinders as spring-actuated clamps (spring-close principle) so that the clamping force is maintained in the de-energised and depressurised state by the spring, leaving no residual pneumatic energy potential for the clamping movement. Additionally: minimise the line volume and accumulator volume between the maintenance shut-off valve and the cylinder by design (short valves mounted directly on the cylinder) in order to reduce the stored energy. Design in accordance with EN ISO 4414:2010 Section 5.4 (pressure limitation, energy minimisation). Note: The severity of a remaining residual energy event is genuinely reduced by this measure, as the kinetic energy of the clamping elements is considerably lower with a reduced residual volume and a spring-accumulator principle. |
| Step 2 · Technical | 1. Maintenance shut-off valve with venting function (lockout/tagout-capable) in accordance with EN ISO 4414:2010 Section 5.4.2 and EN ISO 14118:2018: Install a shut-off valve with integrated, controlled venting (soft-exhaust function) at the inlet of the pneumatic clamping device; in the shut-off position, the valve must vent the downstream line section in a controlled and throttled manner before any intervention is possible. The valve shall be secured with a lock (lockout device). 2. Pressure gauge or pressure indicator on the line section between the shut-off valve and the cylinder, so that the operator can visually verify pressure reduction to 0 bar (EN ISO 4414:2010 Section 5.4.3). 3. If control-side monitoring of pressure reduction is implemented as a release condition for maintenance access (e.g. pressure sensor evaluated in the safety controller as a prerequisite for unlocking maintenance door SF-01); integration into safety function SF-01 (PLr d, EN ISO 13849-1:2023). 4. Fixed/movable guard (maintenance door/protective enclosure) in accordance with EN ISO 14120:2015 with guard locking in accordance with EN ISO 14119:2025, which is unlocked only after complete pressure reduction (pressure sensor signal = 0 bar); observe safety distances in accordance with EN ISO 13857:2019. |
| Step 3 · Information | 1. Operating instructions ((EU) 2023/1230 Annex III No. 1.7.4): Work instruction for maintenance and fault clearing on the pneumatic clamping device with an explicit step-by-step procedure: (a) shut off the compressed air supply at the maintenance shut-off valve, (b) wait for venting and check pressure indicator for 0 bar, (c) apply lockout lock, (d) only then intervene in the system. Include a note on the hazard from residual pressure and ejected workpieces. 2. Warning labelling on the clamping device and on the shut-off valve: warning sign 'Warning of dangerous overpressure' and 'Warning of flying parts' in accordance with DIN EN ISO 7010 (sign semantics: yellow warning triangle with the corresponding pictogram); information sign 'Before intervention: vent to 0 bar and lock shut-off valve'. 3. Qualification requirement: maintenance and fault-clearing work on the pneumatics only by instructed specialists with knowledge of pneumatic safety rules (EN ISO 4414:2010). 4. PPE specification: prescribe safety goggles (eye protection against flying parts) and protective gloves when opening pneumatic connections. |

Risk after: **3** Residual risk accepted: Yes

No. 31 CombinationRisk before: S 5 · P 2 · **RZ 10**

Hazard from differing safety levels of the partial machines from different manufacturers (robot, welding power source, turntable, extraction system): missing or incomplete interface interlocking between the partial machines may result in one partial machine starting up even though another is in an unsafe condition (EN ISO 11161).

Sub-machine: Overall system (system integration) · also in: Commissioning, Operation

- Step 1 · Inherent** System architecture with a single, superordinate safety controller (Safety Master) as an inherently safe control principle in accordance with EN ISO 12100 Section 6.2.11: All safety-relevant status signals of the sub-machines (robot operating mode, turning table end position, extraction system operation, welding power source ready) are routed exclusively via the Safety Master. No sub-machine drive receives an enable signal unless the Safety Master has assessed the overall state as safe. Through this centralisation, the possibility of an incomplete interface interlock is constructively reduced to a minimum: there are no parallel, mutually independent enable paths between the sub-machines. The interface definition is carried out in accordance with EN ISO 11161:2007+A1:2010 Section 5 (system integration, responsibilities, interface description) and is documented in the safety concept of the overall installation.
- Step 2 · Technical** Level 2a: Interlock matrix in accordance with EN ISO 11161:2007+A1:2010 Section 6: For each sub-machine combination, a complete state matrix (operating mode x state of the other sub-machines) is created and implemented in the safety controller. Each enable signal is implemented as an AND-combination of all relevant safety states. Level 2b: Safety function SF-04 (enable of the 180-degree pivoting movement of the turning table only when the pivoting area is clear, PLr e in accordance with project specification) ensures that the turning table only pivots when the robot is demonstrably outside the pivoting area. The safety function is designed to PLr e in accordance with EN ISO 13849-1:2023 and validated in accordance with EN ISO 13849-2:2012. Level 2c: Safety function SF-01 (safe stopping upon opening of the maintenance door, stop category 1, PLr d) and SF-02 (safe stopping upon interruption of the light curtain, PLr e) are coordinated across the entire installation: a stop signal from one sub-machine triggers the coordinated stop of all sub-machines via the Safety Master. Stop categories in accordance with EN 60204-1:2018 Section 9.2.2 are to be defined per drive (robot: stop category 1 in accordance with SF-01/SF-03; turning table: stop category 1 in accordance with SF-03). Level 2d: Emergency stop of the overall installation (SF-03, stop category 1, PLr d in accordance with project specification) in accordance with EN ISO 13850:2015 acts on all sub-machines simultaneously via the Safety Master. Emergency stop command devices are arranged at all operator stations and access points. Level 2e: Prevention of unexpected start-up in accordance with EN ISO 14118:2018: After every stop (emergency stop, activation of a protective device, interruption of energy supply), a deliberate restart command is required; automatic restart is excluded. Level 2f: Setting mode with safely reduced speed (SF-05, 250 mm/s, PLr d in accordance with project specification) and enabling device for the robot in accordance with EN ISO 10218-2:2025 Section 5.7.7; in this mode, all other sub-machines (turning table, welding power source) are interlocked and at standstill.
- Step 3 · Information** Operating instructions for the overall installation in accordance with (EU) 2023/1230 Annex III No. 1.7.4: The interface interlock logic (state matrix, enable conditions per sub-machine) is to be documented in full. For each sub-machine, the handover point of safety responsibility (sub-machine manufacturer up to the interface, integrator from the interface onwards) is to be defined in writing in accordance with EN ISO 11161:2007+A1:2010 Section 4.3 and stated in the operating instructions. Qualification requirement: commissioning, parameterisation and modifications to the safety controller may only be carried out by qualified specialist personnel with knowledge of EN ISO 13849-1:2023 and EN ISO 11161. Warning labelling at all operator panels: warning against unexpected start-up of sub-machines (warning sign in accordance with DIN EN ISO 7010, warning against automatic start-up). The operating instructions must describe procedures for fault-finding and commissioning, including the sequence in which sub-machines may be commissioned and the verification steps for checking the interface interlock prior to the first automatic operation.

Risk after: **5** Residual risk accepted: Yes

No. 41 Corruption/securityRisk before: S 3 · P 3 · **RZ 9**

Missing or incomplete records of interventions (logging): Interventions in safety-relevant hardware, software or configuration are not recorded, or are recorded without a timestamp and originator; logs overwrite themselves after a short period or are open to manipulation. Unauthorised interventions remain undetected and the audit trail is not available upon request by the authorities. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 2, 1.1.9 para. 5, 1.2.1 lit. f]

Sub-machine: Control / logging · also in: Operation, Maintenance

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| Step 1 · Inherent | Provide event logging as a fixed function of the control system (not deactivatable by the operator), with a non-volatile memory of sufficient capacity. |
| Step 2 · Technical | Logging of safety-relevant events with timestamp, user identity and content of the change (log-on, parameter and configuration change, software upload with version and checksum, opening of safety-relevant assemblies, remote-access sessions), protection against deletion and modification, export in readable form, retention of uploads and associated data for up to five years after uploading (Annex III No. 1.2.1 lit. f). Evidence reference Route B: IEC 62443-3-3 SR 2.8, SR 2.9, SR 2.11, SR 3.9, SR 6.1. |
| Step 3 · Information | Operating instructions: Access to and export of logs, operator's retention obligations when the machine is transferred, procedure in the event of a regulatory request, note on storage capacity and time synchronisation. |

Risk after: **3** Residual risk accepted: Yes

No. 43 Corruption/securityRisk before: S 5 · P 2 · **RZ 10**

Unsecured engineering access to the safety controller: The programming access of the safety controller or safety PLC is reachable without a password or with the manufacturer's default credentials; the safety program can be overwritten or placed in a stopped state during operation, and forcing of inputs and outputs is possible. Protective functions are rendered ineffective or actuators are controlled directly. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 2, 1.1.9 para. 3, 1.2.1 lit. a]

Sub-machine: Safety control / engineering · also in: Commissioning, Maintenance

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| Step 1 · Inherent | Programming access to the safety controller physically separated from the process network (dedicated port, inside a locked control cabinet), no forcing of safety-relevant signals in the series state, programme changes only in the secured stop state of the machine. |
| Step 2 · Technical | Individual password for the safety programme access with mandatory password change at commissioning, write protection and access protection levels of the controller activated, logging of all accesses and programme changes with version and checksum, display of the programme status on the HMI. Evidence reference Route B: IEC 62443-3-3 SR 1.1, SR 1.5, SR 2.1, SR 2.8, SR 3.4, SR 7.7. |
| Step 3 · Information | Operating instructions: Access protection and password management as an operator obligation, prohibition of programme changes without re-verification and documentation, reference to the requirements for substantial modification. |

Risk after: **5** Residual risk accepted: Yes

No. 44 Corruption/securityRisk before: S 4 · P 3 · **RZ 12**

Unauthorised or faulty remote access via the remote maintenance gateway: Via the IPsec VPN connection of the remote maintenance gateway, an unauthorised person with stolen credentials or an authorised technician at the wrong moment intervenes in the cell controller: program or parameter change, acknowledgement of faults or starting of movements while persons are at the loading station or in the maintenance walkway. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 1, 1.1.9 para. 3, 1.2.1 lit. a, 1.2.1 lit. d]

Sub-machine: Remote maintenance gateway / cell controller · also in: Operation, Maintenance

Step 1 · Inherent	Remote access designed so that it cannot trigger hazardous movements or bypass safety functions: the remote maintenance gateway only reaches the standard controller and the operator panel; the safety PLC has no remote access path. Movement commands and acknowledgement of faults are only possible from control positions with a view of the danger zone (Annex III No. 1.2.2).
Step 2 · Technical	Remote maintenance disabled on delivery; a session can only be enabled on site with the key switch at the control desk, ends automatically after four hours and is indicated as "Remote maintenance active" on the operator panel; IPsec VPN with multi-factor authentication and personal accounts for remote technicians; logging of every session with user, time and actions performed, retention in accordance with Annex III No. 1.2.1 lit. f. Evidence reference Path B: IEC 62443-3-3 SR 1.1, SR 1.13, SR 2.1, SR 2.8, SR 3.8.
Step 3 · Information	Operating instructions (chapter Cybersecurity, section Remote maintenance): procedure for enabling and ending remote maintenance sessions, obligation for a responsible person to be available on site, action in the event of suspected unauthorised access (end the session with the key switch, inform the manufacturer), contact for the manufacturer's security notifications.

Risk after: **4** Residual risk accepted: Yes

Assessments under further legal acts (own methodology, not part of the risk assessment according to EN ISO 12100)

Each assessment follows the methodology of the legal act concerned. Hazards to persons arising from it are listed with their risk estimation in the hazard list.

Electromagnetic compatibility (EMC 2014/30/EU)

Apparatus (finished appliance, or a combination made available as a single functional unit), Industrial environment: evidence still outstanding (Measurement on the complete system (laboratory test report)). Immunity according to EN IEC 61000-6-2, emission according to EN IEC 61000-6-4. 1 point outstanding.

MR (EU) 2023/1230 Annex III No. 1.2.1 (safety and reliability of control systems), No. 1.5.10 and No. 1.5.11 (radiation from the machine and external radiation): the control system has to remain safe even under electromagnetic disturbance. In addition, the EMC Directive 2014/30/EU applies with the essential requirements of Annex I: the emission must not make the intended operation of other equipment impossible, and the machine must be sufficiently immune to the disturbances to be expected. Procedure under Art. 14 (Annex II internal production control or Annex III EU type-examination). For fixed installations, Annex I No. 2 applies instead of conformity assessment, with the good engineering practices and the documentation obligation of Art. 19(1).

Classification	Apparatus (finished appliance, or a combination made available as a single functional unit)
Electromagnetic environment	Industrial environment
Immunity	EN IEC 61000-6-2
Emission	EN IEC 61000-6-4
Route of evidence	Measurement on the complete system (laboratory test report)
Test evidence	RSZ-2600-EMV-001
Safety functions depending on electronic systems	yes, evidence of increased immunity outstanding
Conformity assessment procedure (Article 14)	Internal production control (Annex II, Module A)
Result	Evidence outstanding

Cybersecurity (CRA, Regulation (EU) 2024/2847)

Covered under Article 2(1) CRA, classification: Default product (not listed in Annex III or IV). The reporting obligations under Article 14 CRA apply to this product; the remaining obligations apply where it is placed on the market on or after 11 December 2027 or substantially modified on or after that date (Article 71(2), Article 69(2) CRA).

The Machinery Regulation (EU) 2023/1230 requires protection against corruption in Annex III No. 1.1.9 and safe control systems in No. 1.2.1. Alongside it stands the Cyber Resilience Act (Regulation (EU) 2024/2847) with obligations of its own: it applies to products with digital elements whose use includes a direct or indirect data connection to a device or network (Article 2(1) CRA). The reporting obligations under Article 14 CRA have applied since 11 September 2026, including to products already placed on the market (Article 69(3) CRA); the remaining obligations apply to products placed on the market on or after 11 December 2027 or substantially modified on or after that date (Article 71(2), Article 69(2) CRA). Both legal acts apply side by side. CRA compliance may facilitate

the demonstration of compliance with Annex III No. 1.1.9 and 1.2.1 (recital 53 CRA), but it creates no presumption of conformity (Article 20(9) of the Machinery Regulation, a contrario).

Scope (Article 2(1) CRA)	Covered: the product falls under the Cyber Resilience Act (Article 2(1) CRA). Which obligations apply today depends on the date of placing on the market.
Core functionality (Article 7(1) CRA)	Robot-assisted MAG welding of steel assemblies in series production. The software controls the robot, rotary table, welding process and fume extraction. Networking, VPN and access functions come from purchased components and are not the core functionality of the cell; they are recorded as components with their own classification.
Classification (Annexes III and IV CRA)	Default product (not listed in Annex III or IV)
Classification confirmed	Yes
Obligations in force	The product is placed on the market before 11 December 2027. Of the Cyber Resilience Act, only the reporting obligations under Article 14 then apply (Article 69(3) CRA); the essential cybersecurity requirements, the CRA conformity assessment and the CRA CE marking only apply once the product is substantially modified on or after 11 December 2027 (Article 69(2) CRA). Cybersecurity requirements under other legal acts are unaffected, such as those of the Radio Equipment Directive via Delegated Regulation (EU) 2022/30 until 10 December 2027 and Annex III No. 1.1.9 of the Machinery Regulation from 20 January 2027.
Reporting obligations (Article 14 CRA)	The reporting obligations under Article 14 CRA have applied since 11 September 2026, including for products placed on the market earlier (Article 69(3) CRA).
EU declaration of conformity (Article 28 CRA)	No declaration under the Regulation: for placing on the market before 11 December 2027 only the reporting obligations under Article 14 apply (Article 69(3) CRA), as long as the product is not substantially modified afterwards (Article 69(2) CRA).
Cybersecurity risk assessment and evidence	The cybersecurity risk assessment under Article 13(2) and (3) CRA, the requirements of Annex I, the third-party components, the support period and the reporting process are kept separately and documented in the CRA report. They are not a risk assessment to EN ISO 12100.

2. Applied standards

harmonised standards from the checklist

Type-A standards (basic safety standards) ⁽¹⁾

Standard	Title	Directives
EN ISO 12100:2010	Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100:2010)	2006/42/EG

Type-B standards (generic safety standards) ⁽²⁰⁾

Standard	Title	Directives
DIN EN ISO 7010	Graphical symbols. Safety colours and safety signs. Registered safety signs	
EN 1005-2:2003+A1:2008	Safety of machinery - Human physical performance - Part 2: Manual handling of machinery and component parts of machinery	2006/42/EG
EN 60204-1:2018	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	2006/42/EG, 2014/35/EU
EN 61000-6-4:2019	—	
EN IEC 61000-6-2:2019	Electromagnetic compatibility (EMC). Part 6-2: Generic standards. Immunity for industrial environments	2014/30/EU
EN ISO 11161:2007+A1:2010	Safety of machinery. Integrated manufacturing systems. Basic requirements	2006/42/EG
EN ISO 11202:2010	Acoustics - Noise emitted by machinery and equipment - Determination of emission sound pressure levels at a work station and at other specified positions applying approximate environmental corrections (ISO 11202:2010) EN ISO 11202:2010/A1:2021	2006/42/EG
EN ISO 13732-1:2008	Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 1: Hot surfaces (ISO 13732-1:2006)	2006/42/EG
EN ISO 13849-1:2023	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design (ISO 13849-1:2023)	2006/42/EG
EN ISO 13849-2:2012	Safety of machinery - Safety-related parts of control systems - Part 2: Validation (ISO 13849-2:2012)	2006/42/EG
EN ISO 13850:2015	Safety of machinery - Emergency stop function - Principles for design (ISO 13850:2015)	2006/42/EG

Standard	Title	Directives
EN ISO 13854:2019	Safety of machinery - Minimum gaps to avoid crushing of parts of the human body (ISO 13854:2017)	2006/42/EG
EN ISO 13855:2024	Safety of machinery - Positioning of safeguards with respect to the approach of the human body (ISO 13855:2024)	2006/42/EG
EN ISO 13857:2019	Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs (ISO 13857:2019)	2006/42/EG
EN ISO 14118:2018	Safety of machinery - Prevention of unexpected start-up (ISO 14118:2017)	2006/42/EG
EN ISO 14119:2025	Safety of machinery - Interlocking devices associated with guards - Principles for design and selection (ISO 14119:2024) EN ISO 14119:2025/A11:2026	2006/42/EG
EN ISO 14120:2015	Safety of machinery - Guards - General requirements for the design and construction of fixed and movable guards (ISO 14120:2015)	2006/42/EG
EN ISO 3746:2010	Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Survey method using an enveloping measurement surface over a reflecting plane (ISO 3746:2010)	2000/14/EG, 2006/42/EG
EN ISO 4414:2010	Pneumatic fluid power - General rules and safety requirements for systems and their components (ISO 4414:2010)	2006/42/EG
EN ISO 4871:2009	Acoustics - Declaration and verification of noise emission values of machinery and equipment (ISO 4871:1996)	2000/14/EG, 2006/42/EG

Type-C standards (product standards) ⁽³⁾

Standard	Title	Directives
EN ISO 10218-1:2025	Robotics - Safety requirements - Part 1: Industrial robots (ISO 10218-1:2025)	2006/42/EG
EN ISO 10218-2:2025	Robotics - Safety requirements - Part 2: Industrial robot applications and robot cells (ISO 10218-2:2025)	2006/42/EG
EN ISO 21904-1:2020	Health and safety in welding and allied processes - Equipment for capture and separation of welding fume - Part 1: General requirements (ISO 21904-1:2020)	2006/42/EG

3. Declaration of Conformity

Annex II MD / Annex V MR



EU Declaration of Conformity

in accordance with Annex V Part A of the Machinery Regulation (EU) 2023/1230

1. Manufacturer

Muster Maschinenbau GmbH
Beispielstraße 1
12345 Musterstadt, Germany

Person authorised to compile the technical file:

Muster Maschinenbau GmbH
Beispielstraße 1, 12345 Musterstadt, Germany

2. Product

Designation: Robotic welding cell RSZ-2600 (assembly of machinery)

Type/model: RSZ-2600

Serial number(s): RSZ2600-2026-0001

Year of construction: 2026

3. Applicable Union harmonisation legislation

Machinery Regulation (EU) 2023/1230 (OJ L 165, 29.6.2023, p. 1)

Further applicable Union harmonisation legislation

Conformity with the following Union legislation is also declared:

- EMC Directive 2014/30/EU (OJ L 96, 29.3.2014, p. 79)

4. Harmonised standards applied

Machinery Regulation (EU) 2023/1230

- EN ISO 12100:2010
- EN ISO 13849-1:2023
- EN 60204-1:2018
- EN ISO 13857:2019
- EN ISO 13855:2024
- EN ISO 14120:2015
- EN ISO 11161:2007+A1:2010 (parts applied: in part)
- EN ISO 10218-2:2025
- EN ISO 4414:2010
- EN ISO 13850:2015
- EN ISO 13854:2019
- EN ISO 11202:2010

- EN ISO 4871:2009
- EN ISO 14119:2025
- EN ISO 14118:2018
- EN ISO 13849-2:2012
- EN ISO 10218-1:2025
- EN ISO 13732-1:2008
- EN ISO 21904-1:2020
- EN ISO 3746:2010
- EN 1005-2:2003+A1:2008

EMC Directive 2014/30/EU

- EN 61000-6-2:2019

Other Applied Technical Standards and Specifications

- EN 61000-6-4:2019

5. Conformity assessment procedure (EU-Maschinenverordnung (EU) 2023/1230)

Internal production control (Module A, Annex VI)

We hereby declare under our sole responsibility that the machinery described above is in conformity with all relevant provisions of the Machinery Regulation (EU) 2023/1230. The machinery fulfils the essential health and safety requirements of Annex III of the Machinery Regulation (EU) 2023/1230. Conformity with the following Union legislation is also declared: EMC Directive 2014/30/EU (OJ L 96, 29.3.2014, p. 79).

Musterstadt, 18/08/2026



M. Beispiel

CE representative

4. Technical documentation

Annex VII MD / Annex IV MR (machinery law)

Technical file according to Annex IV Part A of MR (EU) 2023/1230

52 of 54 items completed (96%) · Mandatory items open: 0 of 35

1. General information (5/5)

Basic information on the product and manufacturer — Annex IV Part A MR, marking according to Annex III No. 1.7.3 MR

Name and address of the manufacturer

MANDATORY

Done

Full company name with commercial register number

Note: Taken from project data: manufacturer data from the settings. Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, master sheet Technical Documentation.

Name and address of the authorised representative (if any)

Not applicable

Only if an authorised representative has been appointed in the EU

Note: Not applicable: the manufacturer is established in the European Union; an authorised representative in accordance with Art. 3 No. 19 MR (appointment in accordance with Art. 12 MR) has therefore not been appointed.

Justification (n/a): The manufacturer Muster Maschinenbau GmbH is established in the EU (Germany) and fulfils all manufacturer obligations under MR (EU) 2023/1230 itself. An authorised representative within the meaning of Art. 3 No. 19 MR (appointment in accordance with Art. 12 MR) has therefore not been appointed.

Designation of the machinery / product designation

MANDATORY

Done

Unique designation including type, series, model

Note: Taken from project data: machine designation from the project. Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, master sheet Technical Documentation.

Serial number / model range

MANDATORY

Done

Unique identification of each individual machine

Note: Serial number RSZ2600-2026-0001. Single unit manufactured as special-purpose machinery, not a series. Stated on the nameplate and in the declaration of conformity.

Year of construction

MANDATORY

Done

Year in which the manufacturing process was completed

Note: 2026. Stated on the nameplate in accordance with Annex III No. 1.7.3 MR and in the declaration of conformity.

2. General description of the machinery (4/4)

Technical description and intended use — Annex IV Part A (a) MR

General description of the machinery

MANDATORY

Done

Operating principle, design, main components

Note: Document RSZ-2600-TD-01 System description, Rev. A. Robotic welding cell comprising an articulated-arm robot (partly completed machinery with declaration of incorporation), two-station rotary table, MAG welding power source, welding fume extraction unit, protective fence with interlocked maintenance door and light curtain at the loading station. Placed on the market as an assembly of machinery in accordance with Art. 3 No. 1 lit. d MR (EU) 2023/1230.

Intended use **MANDATORY** **Done**

What the machine is intended for — including reasonably foreseeable misuse

Note: Taken from project data: intended use from the risk assessment (step 1). Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, risk assessment, section Intended Use.

Limits of the machine **MANDATORY** **Done**

Limits of use, space limits, time limits (service life, maintenance intervals)

Note: Taken from project data: limits of the machine from the risk assessment (step 1). Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, risk assessment, section Limits of the Machine.

Drawings, photos and diagrams **MANDATORY** **Done**

Overall view, detailed views of safety-relevant areas

Note: Drawing set RSZ-2600-ZG-001 to -042, Rev. B, with overall view, sections through the turn-over table, detail of the protective fence and light curtain mounting. Filing in PDM under project MUSTER-2026-001.

3. Risk assessment (5/5)

Documentation of the risk assessment according to EN ISO 12100 — Annex IV Part A (b) MR

Description of the procedure applied **MANDATORY** **Done**

Methodology according to EN ISO 12100 (risk estimation, evaluation, reduction)

Note: Taken from project data: risk assessment in the project (methodology in accordance with EN ISO 12100, documented in the RA export). Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, risk assessment, methodology section.

List of all identified hazards **MANDATORY** **Done**

Systematic hazard identification for all life phases

Note: Taken from project data: 42 hazards in the risk assessment. Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, risk assessment (Module 1 of the dossier).

Protection objectives / requirements applied **MANDATORY** **Done**

Which essential health and safety requirements (Annex I) are applicable

Note: Comparison of the essential health and safety requirements of Annex III MR (EU) 2023/1230: checklist RSZ-2600-TD-03, Rev. A. Key items: 1.2.1, 1.2.4.3, 1.2.4.4, 1.2.5, 1.2.6, 1.3.7, 1.4.1, 1.4.2.2, 1.5.1, 1.5.8, 1.5.10, 1.5.13, 1.6.3, 1.7.1, 1.7.3, 1.7.4.

Description of the protective measures **MANDATORY** **Done**

Three-step method: inherently safe design → technical protective measures → information for use

Note: Taken from project data: measures per hazard in the risk assessment. Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, risk assessment (Module 1 of the dossier).

Residual risks and their evaluation **MANDATORY** **Done**

Documentation of accepted residual risks with justification

Note: Taken from project data: residual risk acceptance documented in the risk assessment. Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, risk assessment, residual risk documentation.

4. Standards and directives (3/3)

Applied standards and complied directives — Annex IV Part A (e) and (f) MR

List of all EU directives applied

MANDATORY

Done

MD 2006/42/EC, MR 2023/1230, EMC Directive, LVD, etc.

Note: Taken from project data: directives from the standards analysis and declaration of conformity. Verified on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, standards analysis and declaration of conformity.

List of all harmonised standards applied

MANDATORY

Done

Type A, B and C standards with full title and edition date

Note: Taken from project data: 24 standards in the standards checklist. Reviewed on 2026-08-18; filing location: PDM system Muster Maschinenbau, project MUSTER-2026-001, standards checklist (Module 2 of the dossier).

Other technical specifications

Done

Non-harmonised standards, industry standards, internal specifications

Note: Component-related product standards: Proof of conformity rests with the respective supplier; the integrator does not declare them as applied standards. EN 61496-1:2020 and EN 61496-2:2020 (Type 4 light curtain, proof provided by the BWS manufacturer), EN IEC 60974-1:2022 (welding power source, supplier conformity via the Low Voltage and EMC Directives), EN ISO 21904-1:2020 (welding fume extraction, proof provided by the equipment manufacturer), EN ISO 10218-1:2025 (robot, proof via the declaration of incorporation in accordance with Annex V Part B together with the assembly instructions). Used by the integrator as a basis for selection and design, without presumption of conformity: EN ISO 25980:2023 (welding protection curtains and screens).

5. Drawings and calculations (7/7)

Technical documents and evidence — Annex IV Part A (c), (d) and (g) MR

General arrangement / overview drawing

MANDATORY

Done

Scale overall drawing with main dimensions

Note: Layout drawing RSZ-2600-LAY-001, Rev. C: installation plan with protective fence, maintenance door, light curtain, operator station, escape route and minimum distances to adjacent installations.

Circuit diagrams (electrical, pneumatic, hydraulic)

MANDATORY

Done

Complete circuit diagrams of all control circuits according to EN 60204-1

Note: Electrical circuit diagram RSZ-2600-EPL-001 in accordance with EN 60204-1 Section 17, with terminal plan and equipment list. Pneumatic diagram RSZ-2600-PPL-001 in accordance with EN ISO 4414, with service unit, safety exhaust valve and workpiece clamps. Hydraulics not present on this machine.

Safety circuit diagrams / safety functions

MANDATORY

Done

Representation of all safety-related parts of the control system (SRP/CS)

Note: Safety circuit diagram RSZ-2600-SPL-001 with safety functions SF-01 to SF-05, assignment of sensors, safety PLC and shutdown paths, feedback circuits of the positively guided contactors.

Strength calculations / structural analysis

MANDATORY

Done

Calculation evidence for load-bearing parts, welds, etc.

Performance level evidence (PLd/PLe)

MANDATORY

Done

Calculation according to EN ISO 13849-1 or SIL according to EN IEC 62061

Note: SISTEMA projects RSZ-2600_SF01 to _SF05 with reports as PDF. Verification PL greater than or equal to PLr fulfilled for all five safety functions (SF-01 PL d, SF-02 PL e, SF-03 PL d, SF-04 PL e, SF-05 PL d). Validation in accordance with EN ISO 13849-2 documented in RSZ-2600-VAL-001.

EMC test report Done

Evidence of electromagnetic compatibility according to the EMC Directive

Note: EMC test report RSZ-2600-EMV-001: immunity in accordance with EN 61000-6-2:2019 and emission in accordance with EN 61000-6-4:2019 for industrial areas, including consideration of the reactions of the welding power source on the safety PLC.

Noise measurement report Done

Measurement according to EN ISO 3744 / EN ISO 11204 — must be stated in the operating instructions

Note: Noise measurement report RSZ-2600-LRM-001: determination in accordance with EN ISO 11202:2010, declaration and verification in accordance with EN ISO 4871:2009. Emission sound pressure level at the operator station LpA 84 dB(A), uncertainty K equals 2.5 dB, A-weighted sound power level LWA 96 dB(A). Operating condition and measurement method described in the report.

6. Tests and checks (4/4)

Test reports and acceptance documentation — Annex IV Part A (g) and (o) MR

Test reports / test results MANDATORY Done

Results of all tests and measurements carried out

Functional test of safety devices MANDATORY Done

Evidence of the function of all protective devices (emergency stop, safety doors, light curtains)

Protective conductor test / insulation measurement MANDATORY Done

Electrical safety test according to EN 60204-1

Note: Electrical test in accordance with EN 60204-1 Section 18, test report RSZ-2600-ELP-001: continuity of the protective conductor system, insulation resistance, voltage test, protection against residual voltages and functional test.

Acceptance report Done

Documentation of the final acceptance with signature

Note: Factory acceptance test RSZ-2600-FAT-001 and site acceptance test at the operator's premises RSZ-2600-SAT-001, each countersigned by manufacturer and operator, with defect list and release note.

7. Operating instructions (9/9)

Complete operating instructions with all mandatory information — Annex IV Part A (i) MR, content according to Annex III No. 1.7.4 MR

Original language + translations into the national language MANDATORY Done

Mark the original language, translation for each target country

Note: Operating instructions in the original version in German, identified as original operating instructions in accordance with Annex III No. 1.7.4.1 letter a MR. English version identified as a translation of the original operating instructions. Delivery in the language of the country of use.

Safety notices and warnings MANDATORY Done

Residual risks, intended use, prohibited use

Note: Operating instructions Chapter 2. Warnings and safety notices corresponding to the ISO 7010 signs from the risk assessment (W012, W017, W027, P006, P007, M003, M004, M008), coordinated with the labelling on the machine in accordance with Annex III No. 1.7.1 and 1.7.3 MR.

Assembly and commissioning instructions

MANDATORY

Done

Transport, installation, connection, initial commissioning

Note: Operating instructions Chapter 8 (Assembly/Installation/Commissioning), including the incorporated assembly instructions of the robot manufacturer in accordance with Annex XI MR and the installation conditions from its declaration of incorporation.

Instructions for use

MANDATORY

Done

Description of all operating modes, controls, displays

Note: Operating instructions Chapter 9: Operation in automatic and setup modes, loading procedure with lifting aid specification from 10 kg, response to activation of the light curtain, acknowledgement after emergency stop.

Maintenance and servicing instructions

MANDATORY

Done

Maintenance intervals, lubrication schedules, wear parts, spare parts list

Note: Operating instructions Chapter 10 with maintenance schedule, semi-annual testing of safety functions SF-01 to SF-05, testing of the guard locking in accordance with EN ISO 14119, replacement interval for the filter cartridge of the welding fume extraction system and isolation requirements (LOTO) before each intervention.

Fault clearance

MANDATORY

Done

Typical faults, fault diagnosis, remedial measures

Note: Operating instructions Chapter 10, section on fault clearance with fault table (Annex III No. 1.7.4.2 MR). Before any intervention in the robot working area, the system must be isolated and secured against re-energisation; access exclusively via the interlocked maintenance door.

Decommissioning and disposal

MANDATORY

Done

Instructions for safe dismantling and disposal notices

Note: Operating instructions Chapter 11: venting the pneumatics via the safety exhaust valve, waiting for the discharge time of the intermediate-circuit capacitors (measured 1.9 s to ≤ 60 V; waiting time at least 1 minute), disposal of the filter cartridges of the welding fume extraction system as hazardous waste, disassembly in reverse order of assembly.

Noise emission values

MANDATORY

Done

Workplace-related emission sound pressure level and sound power level

Note: Operating instructions Chapter 3 in accordance with Annex III No. 1.7.4.2 lit. u MR: emission sound pressure level L_{pA} 84 dB(A) at the operator station, uncertainty K equal to 2.5 dB, A-weighted sound power level L_{WA} 96 dB(A), as L_{pA} exceeds 80 dB(A). L_{pA} determined in accordance with EN ISO 11202, L_{WA} in accordance with EN ISO 3746, declared in accordance with EN ISO 4871.

Vibration data (if applicable)

Not applicable

State hand-arm (> 2.5 m/s²) and whole-body vibration (> 0.5 m/s²) if the declaration threshold under MR Annex III 2.2.1.1 (hand-arm) or 3.6.3.1 (whole-body) is exceeded

Note: Not applicable: the machine is stationary, has no hand-held or hand-guided operating element and no seated workstation. The hand-arm vibration measurable at the control panel is below the action value; evidence in RSZ-2600-VIB-001.

8. Conformity assessment (4/4)

Completion of the conformity assessment procedure — Annex V Part A MR (declaration of conformity), Art. 23 and 24 MR (CE marking), Art. 10(3) MR (retention)

EU declaration of conformity issued**MANDATORY****Done**

According to Annex II MD / Annex V MR — with all mandatory information

Note: EU declaration of conformity (internal document no. RSZ-2600-KE-01, filed in PDM) in accordance with Annex V Part A MR (EU) 2023/1230, drawn up in Step 7 of this project. Conformity assessment procedure: internal production control (Module A) in accordance with Art. 25 para. 4 in conjunction with Annex VI MR; the machine does not fall under any category of Annex I MR, neither Part A nor Part B. MR transition: the first placing on the market is planned for March 2027 and therefore falls after the date of application of the Machinery Regulation (EU) 2023/1230 on 20.01.2027; the machine is to be assessed throughout in accordance with the MR. Only bringing forward the placing on the market to before 20.01.2027 would make the Machinery Directive 2006/42/EC applicable.

CE marking affixed**MANDATORY****Done**

Clearly visible, legible and durable on the machine

Note: CE marking in accordance with Art. 23 and 24 MR on the nameplate at the operator panel, character height 10 mm, permanent, visible and legible. Affixing only after signing of the declaration of conformity.

Rating plate affixed**MANDATORY****Done**

Minimum information: manufacturer, designation, year of construction, serial number

Note: Nameplate in accordance with Annex III No. 1.7.3 MR: Muster Maschinenbau GmbH with full address, designation Robotic Welding Cell RSZ-2600, series or type designation, serial number, year of manufacture 2026, CE marking.

Technical file retained for ten years**MANDATORY****Done**

From the last date of manufacture — retention obligation of the manufacturer

Note: Retention in accordance with Art. 10 para. 3 MR for at least ten years after placing the machine on the market. Filing in the PDM system of the manufacturer (Muster Maschinenbau GmbH); responsibility lies with the documentation representative named in the declaration of conformity.

9. Cybersecurity (CRA) (11/13)

Technical documentation under Annex VII of the Cyber Resilience Act, insofar as the points are relevant to the product. For a unit placed on the market before 11 December 2027 it is voluntary preparation and only becomes mandatory after a substantial modification on or after that date (Article 69(2) CRA); for units placed on the market on or after 11 December 2027 it is mandatory (Article 71(2) CRA). Without a confirmed date the classification remains open. — Annex VII of Regulation (EU) 2024/2847 (CRA), Article 13(12) and Article 31 CRA

Intended purpose**Done**

Annex VII No. 1(a) CRA

Note: Intended purpose in the CRA report (scope of the assessment) and in the operating instructions, Safety chapter.

Software versions affecting compliance**Done**

Annex VII No. 1(b) CRA

Note: Released software versions with checksums in the software bill of materials RSZ-2600-SBOM and in the acceptance report.

Photographs or illustrations (hardware)**Done**

Annex VII No. 1(c) CRA

Note: Overall view and layout drawing of the cell in the technical documentation under Annex IV of the Machinery Regulation.

User information per Annex II Done

Annex VII No. 1(d) CRA

Note: Operating instructions, chapter 13 Cybersecurity.

Design information, system architecture Done

Annex VII No. 2(a) CRA

Note: Network plan with cell network, gateway and MES segment (NET-01), data flow diagram DFP-01, interfaces and assets in the CRA report.

Vulnerability handling processes, SBOM, CVD, contact, update distribution Done

Annex VII No. 2(b) CRA

Note: Procedure VA-SEC-04, software bill of materials RSZ-2600-SBOM, coordinated vulnerability disclosure policy, contact address, update concept UPD-01.

Production and monitoring processes Open

Annex VII No. 2(c) CRA

Note: Software release and vulnerability check will be added to the production test by the end of 2026.

Cybersecurity risk assessment Done

Annex VII No. 3 CRA

Note: CRA report: scope of the assessment, interfaces and assets, risk assessment, requirements matrix.

Support period rationale Done

Annex VII No. 4 CRA

Note: CRA report, support period section (12 years, until 03/2039, with justification).

Standards, specifications, schemes applied Done

Annex VII No. 5 CRA

Note: No harmonised standard for the Cyber Resilience Act has been published in the Official Journal (status 17 September 2026); IEC 62443-4-1 and IEC 62443-4-2 used as guidance, without presumption of conformity.

Test reports Open

Annex VII No. 6 CRA

Note: Reports NET-T-02 and RST-01 are available; the penetration test on the reference cell follows before placing on the market.

Copy of EU declaration of conformity Not applicable

Annex VII No. 7 CRA

Justification (n/a): Placing on the market on 15 March 2027, i.e. before 11 December 2027: the main obligations of the Cyber Resilience Act do not apply to this unit (Article 69(2) and Article 71(2) CRA), so there is no EU declaration of conformity under this Regulation.

SBOM on reasoned request Done

Annex VII No. 8 CRA

Note: The software bill of materials RSZ-2600-SBOM exists for every software version and is provided to the market surveillance authority upon a reasoned request.

5. Test reports

Safety and functional tests

1. Electrical testing according to EN 60204-1

Electrical safety test of the machine control system — EN 60204-1:2018

Protective conductor test (continuity measurement) MANDATORY Passed

Test 1 under EN 60204-1 clause 18.2: continuity of the protective bonding circuit, resistance between the PE terminal and all accessible conductive parts

Measured value (Ω): 0.08 Ω (PE to most remote accessible point, protective fence earthing point)

Date: 18/08/2026

Fault loop impedance and disconnection conditions MANDATORY Passed

Test 2 under EN 60204-1 clause 18.2: measure the fault loop impedance and verify that the associated overcurrent protective device is suitable for automatic disconnection in the TN system

Measured value Z_s (Ω): $Z_s = 0.28 \Omega$, disconnection condition met with 63 A gG

Date: 17/08/2026

Insulation resistance measurement MANDATORY Passed

Test under EN 60204-1 clause 18.3: measurement between live conductors and the protective bonding circuit at 500 V DC; insulation resistance at least 1 M Ω (on individual sections with slip rings or similar, at least 50 k Ω)

Measured value (M Ω): > 100 M Ω at 500 V DC (all main circuits against PE)

Date: 18/08/2026

Voltage test / dielectric strength test Not applicable

Voltage test under EN 60204-1 clause 18.4: test voltage = 2 × rated supply voltage or 1000 V, whichever is GREATER, for approximately 1 second. FIRST disconnect equipment not rated for this test voltage (frequency inverters, power supplies, electronics)

Date: 18/08/2026

Justification: Voltage test in accordance with 18.4 not performed (optional test; frequency converters and electronics would have to be disconnected). Proof provided via 18.2 (protective conductor, loop impedance), 18.3 (insulation resistance) and 18.5 (residual voltage).

Residual voltage test MANDATORY Passed

Test under EN 60204-1 clause 18.5: after disconnecting the supply, the residual voltage at accessible live parts must drop to 60 V or less within 5 s (at plugs and sockets without touch protection: within 1 s)

Discharge time to ≤ 60 V (s): 1.9 s to ≤ 60 V (intermediate circuit of welding power source)

Date: 17/08/2026

Emergency stop function tested (electrical) MANDATORY Passed

All emergency stop devices tested for function and type of release

Date: 08/08/2026

Circuit diagram conformity MANDATORY Passed

Wiring matches the circuit diagram, ferrules fitted, labelling present

Date: 08/08/2026

EMC measures documented Passed

Shielded cables, filter circuitry, earthing concept

Date: 08/08/2026

2. Functional test of safety devices

Test of all safety-related functions — EN ISO 13849-1 / EN IEC 62061

Emergency stop: all stations and operating modes MANDATORY Passed

Emergency stop halts all hazardous movements in every operating mode

Date: 08/08/2026

Guard doors / guard gates with interlocking MANDATORY Passed

Opening stops the machine; closing alone does not restart it (restart interlock)

Date: 08/08/2026

Photoelectric barrier / AOPD / light curtain MANDATORY Passed

Interruption stops the hazardous movement; if muting is fitted: muting is correctly configured and monitored

Date: 08/08/2026

Justification: Type 4 light curtain at the loading station verified (SF-02); muting is not provided on this system (this verification point is therefore not applicable).

Two-hand control (if fitted) Not applicable

Simultaneity condition, reset condition, spatial arrangement

Date: 18/08/2026

Justification: No two-hand control device present; set-up mode is safeguarded by the three-position enabling device (SF-05).

Restart interlock after power failure MANDATORY Passed

No unexpected restart after power is restored

Date: 08/08/2026

Mode selector switch MANDATORY Passed

Switching between operating modes correct, reduced speed in setting mode

Date: 08/08/2026

3. Mechanical tests

Mechanical safety and strength — EN ISO 12100 / machine-specific C standards

Guard grille: distances to EN ISO 13857 MANDATORY Passed

Safety distances to hazard points are correct

Date: 08/08/2026

Fastening of the guards MANDATORY Passed

Removable only with a tool, no loose connections

Date: 08/08/2026

Overrun distance measurement**MANDATORY****Passed**

Overrun after the guard is triggered is within tolerance

Overrun distance (mm): 45 mm (turning table after triggering the guard locking request; tolerance ≤ 60 mm)

Date: 18/08/2026

Stability / anchoring**MANDATORY****Passed**

Machine installed and anchored so it cannot tip over

Date: 08/08/2026

Trip/slip hazards eliminated**Passed**

Cables and hoses routed away, oil spills removed

Date: 08/08/2026

4. Hydraulics / pneumatics

Test of the fluid power system — EN ISO 4413 / EN ISO 4414

Pressure test**MANDATORY****Passed**

System pressure within specification, pressure relief valve functional

System pressure (bar): 6.0 bar (system pressure; pressure relief valve response pressure 7.5 bar verified)

Date: 18/08/2026

Leakage test**MANDATORY****Passed**

No visible leaks at fittings, hoses or cylinders

Date: 08/08/2026

Hose/line condition**MANDATORY****Passed**

No kinks, chafing points or ageing; burst protection fitted

Date: 08/08/2026

Residual pressure release documented**MANDATORY****Passed**

Procedure for depressurising for maintenance is in place

Date: 08/08/2026

5. Noise emission

Noise measurement at the workstation — EN ISO 3744 / EN ISO 11204 / 2003/10/EC

Emission sound pressure level determined**MANDATORY****Passed**

Sound pressure level at the operator's position and other relevant positions — the fact that L_{pA} does not exceed 70 dB(A) also requires this evidence

L_{pA} (dB(A)): $L_{pA} = 84$ dB(A), $K = 2.5$ dB (EN ISO 11202, operator station)

Date: 18/08/2026

Sound power level determined**MANDATORY****Passed**

LWA under EN ISO 3744 or EN ISO 3746 (to be stated if LpA exceeds 80 dB(A))

LWA (dB(A)): LWA = 96 dB(A) (EN ISO 3746)

Date: 18/08/2026

Noise statement entered in the operating instructions**MANDATORY****Passed**

Noise emission values stated under Annex III 1.7.4.2 MR; at LpA ≤ 70 dB(A) the fact that the value is not exceeded is stated explicitly

Date: 08/08/2026

6. Hazardous substances

Capture and control of released hazardous substances — EN ISO 12100 / EN 626-1 / GefStoffV

Released hazardous substances identified**MANDATORY****Passed**

The type and quantity of substances released during intended use (e.g. welding fume, ozone, dust, coolant mist, solvents) are recorded

Date: 08/08/2026

Capture at the point of origin**MANDATORY****Passed**

Extraction captures the substances at the source (takes priority over general ventilation measures, EN ISO 12100 No. 6.2.4)

Date: 08/08/2026

Effectiveness test of the extraction**MANDATORY****Passed**

Capture efficiency or air volume flow and capture velocity measured and documented

Volume flow (m³/h): 1,800 m³/h (extraction capacity at the capture hood, fault alarm threshold 1,400 m³/h)

Date: 18/08/2026

Filter/separation class and monitoring**MANDATORY****Passed**

Filter class matched to the substance (e.g. welding fume class W3), filter monitoring and maintenance interval defined

Filter/welding fume class: Welding fume separator class W3

Date: 18/08/2026

Tightness of substance-carrying parts**MANDATORY****Passed**

Lines, housings and connections of the substance-carrying components are tight; no uncontrolled release

Date: 08/08/2026

Statements in the operating instructions**MANDATORY****Passed**

The type of hazardous substances, required extraction rate, filter changes and personal protective equipment are described in the operating instructions

Date: 08/08/2026

7. Acceptance / release

Final acceptance and documentation — EN ISO 12100 / Betriebssicherheitsverordnung

Visual inspection of all guards**MANDATORY****Passed**

Completeness, damage, signs of tampering

Date: 08/08/2026**Rating plate complete and correct****MANDATORY****Passed**

Manufacturer, CE marking, type, year of manufacture, serial number

Date: 08/08/2026**Technical documentation complete****MANDATORY****Passed**

Operating instructions, circuit diagrams, declaration of conformity, risk assessment

Date: 08/08/2026**Operating personnel instructed/trained****MANDATORY****Passed**

Instruction documented with the signature of the trained persons

Date: 08/08/2026**Release by the responsible person****MANDATORY****Passed**

Signature of the CE officer / tester with date

Date: 18/08/2026

8. Protection against corruption (software, security)

Evidence according to MR Annex III No. 1.1.9, 1.2.1 (a)/(b)/(d)/(f) and 1.2.6; threat analysis according to prEN 50742 (draft) route A in the risk assessment, IEC 62443-3-3 as the reference for route B. No presumption of conformity without an OJ reference. — MR (EU) 2023/1230 Annex III No. 1.1.9 / prEN 50742 (draft) / IEC 62443-3-3

Connecting other equipment and remote access do not lead to a dangerous situation**MANDATORY****Passed**

Annex III No. 1.1.9(1). For every interface (wired, wireless, remote access) it is demonstrated that no function of the connected equipment and no remote access can trigger a dangerous situation (threat analysis with measures per interface). Evidence: interface inventory, threat scenarios in the risk assessment, interface description for integrators. Route B reference: SR 5.1, SR 5.2, SR 1.13.

Date: 15/09/2026**Safety-relevant hardware is protected against unintentional and deliberate corruption****MANDATORY****Passed**

Annex III No. 1.1.9(2), first sentence. Hardware components that transmit signals or data for access to conformity-relevant software are physically and logically protected (locked enclosures, seals, coded switches, disabled ports). Evidence: design description, control cabinet layout, list of protected assemblies. Route B reference: SR 7.6, SR 7.7.

Date: 15/09/2026**Records of interventions in safety-relevant hardware are collected****MANDATORY****Passed**

Annex III No. 1.1.9(2), second sentence. The machine records lawful and unlawful interventions in protected hardware components (opening, removal, connection events) with a timestamp. Evidence: control system event list, description of the logging, sample log from acceptance testing. Route B reference: SR 2.8, SR 2.11.

Date: 15/09/2026

Safety-relevant software and data are identified and protected**MANDATORY****Passed**

Annex III No. 1.1.9(3). Software and data that are critical for conformity are identified as such (register, labelling in the system and documentation) and protected against unintentional or deliberate corruption (integrity check, access protection). Evidence: register of safety-relevant software and data with versions and checksums, description of the protective mechanisms. Route B reference: SR 3.4, SR 2.1.

Date: 15/09/2026**Installed safety-relevant software can be identified on the machine at any time****MANDATORY****Passed**

Annex III No. 1.1.9(4). The machine identifies the software installed for safe operation (version, checksum) and makes this information available at any time in an easily accessible form (e.g. an info page on the HMI without login). Evidence: screenshot of the version display, comparison with the acceptance record, description in the operating instructions. Route B reference: SR 3.4.

Date: 15/09/2026**Records of interventions in software and configuration are collected****MANDATORY****Passed**

Annex III No. 1.1.9(5). Lawful and unlawful interventions in the software, as well as changes to the installed software or its configuration, are logged (user, time, content, version). Evidence: change and event log of the control system, export capability, sample log. Route B reference: SR 2.8, SR 2.9, SR 6.1.

Date: 15/09/2026**The control system withstands reasonably foreseeable malicious attempts by third parties****MANDATORY****Open**

Annex III No. 1.2.1(a). Authentication, authorisation, hardening and segmentation are designed to fend off malicious attempts by third parties that could lead to a dangerous situation; no default passwords, minimal services. Evidence: security concept (zones, roles, password policy), hardening evidence, test log. Route B reference: SR 1.1, SR 1.5, SR 2.1, SR 7.7.

Traceability record available for up to five years after uploading**MANDATORY****Passed**

Annex III No. 1.2.1(f). Data on interventions and the versions of uploaded safety software remain accessible for up to five years after uploading, for the conformity evidence, on a reasoned request by an authority (storage concept, export, retention). Evidence: storage and retention concept, export procedure, manufacturer/operator responsibility stated in the operating instructions. Route B reference: SR 2.9, SR 6.1.

Date: 15/09/2026**Failure, restoration or change of the communication network connection is not dangerous****MANDATORY****Passed**

Annex III No. 1.2.6. Loss of communication, reconnection or a change of network do not lead to unintended start-up, uncontrolled parameter changes or prevented stopping. Evidence: test log of communication failure in all operating modes, description of the behaviour in the operating instructions. Route B reference: SR 7.1, SR 7.2.

Date: 15/09/2026**Wireless control: communication failure or a faulty connection is not dangerous****MANDATORY****Not applicable**

Annex III No. 1.2.1, last paragraph. For wireless control, a loss of communication, a dropped connection or a faulty connection do not lead to a dangerous situation (safe stopping, unambiguous pairing). Evidence: test log of connection loss with stopping time, pairing procedure. Route B reference: SR 3.1, SR 3.8.

Date: 15/09/2026**Justification:** No wireless control: the interface inventory of the cell contains no radio interface.

Operating instructions include software identification, update procedure and network/remote access requirements

MANDATORY

Passed

Annex III No. 1.7.4.2 in conjunction with No. 1.1.9(4) and No. 1.1.2(e). The operating instructions describe how the installed safety-relevant software is identified, the update procedure with a subsequent functional test, the requirements for the operator's network and the approval of remote access, and the retention of the logs. Evidence: software/security chapter of the operating instructions.

Date: 18/09/2026

A process for security updates and vulnerability reports is defined

MANDATORY

Passed

Annex III No. 1.1.9(3) and No. 1.2.1(b) (protection over the lifetime, General principles No. 1). The manufacturer has defined how vulnerabilities in safety-relevant software are reported, assessed and remedied, and how updates are distributed to operators (contact point, deadlines, responsibilities). Note: compliance with the Cyber Resilience Act (EU) 2024/2847 can make it easier to demonstrate Annex III No. 1.1.9 and 1.2.1 (CRA recital 53), but it does not establish a presumption of conformity with the MR (a contrario from Article 20(9) MR); the manufacturer demonstrates the coverage. Evidence: process description (e.g. following IEC 62443-4-1 practices DM and SUM), contact point stated in the operating instructions. Route B reference: IEC 62443-4-1 DM, IEC 62443-4-1 SUM.

Date: 15/09/2026

9. Electromagnetic compatibility (EMC)

Evidence under the EMC Directive 2014/30/EU (Art. 2, 3, 14, 15 to 19; Annexes I to III) and MD Annex I No. 1.2.1, 1.5.10 and 1.5.11 or MR Annex III; classification, environment class, route of evidence and procedure in the risk assessment module. This check does not replace the electrical safety verification to EN 60204-1 (Section 1). — 2014/30/EU Annex I / EN IEC 61000-6-1 to -6-4 / EN 61800-3 / EN 61326-3-1

Classification as apparatus or fixed installation documented

MANDATORY

Passed

Art. 2, Art. 3 No. 1 to 3, Art. 19. It is recorded whether the machine is made available on the market as apparatus, is operated as a fixed installation on a permanent basis at a predetermined location, or is intended solely for incorporation into a given fixed installation. Conformity assessment, declaration and CE marking depend on this. Any exclusion under Art. 2 must be substantiated with reasons. Evidence: classification in the risk assessment, technical documentation.

Classification: Apparatus: assembly made available on the market as a functional unit, not a fixed installation

Date: 18/08/2026

Environment class defined and justified

MANDATORY

Passed

Annex I No. 1; EN IEC 61000-6-1 to -6-4. The electromagnetic environment is defined (industrial environment, or residential, commercial and light-industrial environment) and matches the intended installation site. It determines which generic standards for immunity and emission apply. Where the machine is used in both environments, the stricter requirement applies in each case. Evidence: definition in the risk assessment, statement in the operating instructions.

Environment class: Industrial environment (installation in the production hall), generic standards EN IEC 61000-6-2 and -6-4

Date: 18/08/2026

Electromagnetic compatibility assessment available

MANDATORY

Passed

Annex I No. 1; Annex II No. 2. The assessment covers all relevant emission and immunity phenomena, all conditions that are normal in intended operation and all configurations that the manufacturer designates as representative. Where the case is argued through components and installation rules instead of being measured, the reasoning is traceable for each phenomenon. Evidence: test report from a laboratory, or a documented assessment supported by component evidence.

Evidence: Test report RSZ-2600-EMV-001, measurement on the complete system

Date: 18/08/2026

Manufacturers' declarations for the interference-relevant components complete **MANDATORY**

Passed

Annex II No. 2 and 3. For frequency inverters, servo amplifiers, power supplies, control systems, sensors and other interference-relevant equipment, the manufacturers' EMC declarations or test reports together with the standards applied are available. For drives, the category to EN 61800-3 is recorded. Evidence: component list with declarations and standards applied.

Date: 18/08/2026

Component manufacturers' installation requirements met and documented **MANDATORY** **Passed**

Annex II No. 2; Annex I No. 2 for fixed installations. Screening and screen termination, mains and motor filters, earthing and equipotential bonding, segregated cable routing, maximum motor cable lengths and control cabinet construction comply with the component manufacturers' requirements. The implementation is documented, not merely asserted. Evidence: installation description, circuit diagram, photographs of the screen termination.

Date: 18/08/2026

Immunity of safety-related functions demonstrated **Open**

MD Annex I No. 1.2.1 or MR Annex III No. 1.2.1; EN 61000-6-7, EN 61326-3-1. Where safety functions depend on electronic systems, the generic standard is not sufficient: the increased immunity has to be demonstrated to EN 61000-6-7 or EN 61326-3-1. Where this does not apply, mark it as not applicable. Evidence: test report with increased test levels, evidence of the safe state in the event of a disturbance.

Conformity assessment procedure carried out **MANDATORY** **Passed**

Art. 14; Annex II, Annex III. Internal production control to Annex II, or EU type-examination with conformity to type to Annex III. Where Annex III is used, the name and identification number of the notified body and the certificate are available. The technical documentation is complete. Evidence: technical documentation and, where applicable, the certificate of the notified body.

Procedure: Internal production control (Annex II, Module A)

Date: 18/08/2026

Information in the operating instructions complete **MANDATORY** **Passed**

Art. 18; EN 61800-3. The operating instructions state the intended electromagnetic environment, the installation requirements and the limits of the intended use. For drives of categories C2 to C4, this includes the note that installation and commissioning are to be carried out by qualified personnel and that the machine is not intended for the first environment. Evidence: the installation and electrical connection chapter of the operating instructions.

Date: 18/09/2026

EU declaration of conformity names the EMC Directive and the standards applied **MANDATORY**

Passed

Art. 15, Art. 16, Art. 17; Art. 19(1). The declaration lists Directive 2014/30/EU and the harmonised or other standards applied; the CE marking thereby also covers EMC. For fixed installations no declaration is required; instead, the documentation under Art. 19(1) has to be kept available. Evidence: declaration of conformity module, documentation of the fixed installation.

Date: 18/08/2026

10. Cybersecurity (CRA)

Evidence under the Cyber Resilience Act (Regulation (EU) 2024/2847) (Articles 13, 14, 28, 30, 31 and 32; Annexes I, II, V, VII and VIII). The reporting obligations under Article 14 have applied since 11 September 2026, including to products already placed on the market; the remaining obligations apply to products placed on the market on or after 11 December 2027 or substantially modified on or after that date (Article 71(2), Article 69(2) CRA). Only the classification and the reporting process are therefore marked as mandatory; the other eight items must be met as soon as the remaining obligations apply to the product. Classification and procedure are kept in the risk assessment; the cybersecurity risk assessment, the requirements matrix of Annex I and the reporting process in the CRA report. This check does not replace the evidence on protection against corruption under Annex III No. 1.1.9 of

Scope and classification determined

MANDATORY

Passed

Articles 2 and 7, Annexes III and IV CRA. It is recorded whether the product has a data connection within the meaning of Article 2(1), whether an exclusion under Article 2(2) to (7) applies and which category of Annex III or IV the core functionality falls into.

Evidence: Classification in the risk assessment module or in the CRA report, with date and responsible person.

Date: 15/09/2026

Cybersecurity risk assessment is available

Passed

Article 13(2) to (4), Annex VII No. 3 CRA. The risks have been identified and assessed, the essential requirements of Annex I Part I have been examined against them, and the assessment forms part of the technical documentation. It is updated during the support period. Evidence: CRA report with risk table and requirements matrix.

Date: 15/09/2026

Essential cybersecurity requirements implemented

Passed

Article 13(1) and (3), Annex I Part I CRA. For every requirement of Annex I Part I No. 1 and No. 2(a) to (m) it is recorded whether it applies on the basis of the risk assessment, how it has been implemented and what evidence supports that. Evidence:

Requirements matrix with justification, implementation and evidence for each requirement.

Date: 15/09/2026

Vulnerability handling in place

Passed

Article 13(7) and 13(8) first subparagraph, Annex I Part II Nos 1 to 8 CRA. The requirements of Annex I, Part II are met: software bill of materials (SBOM), remediation of vulnerabilities without delay, regular testing, publication of information about fixed vulnerabilities, coordinated vulnerability disclosure policy, information sharing with a contact address for reports, secure distribution of updates and their dissemination without delay and, as a rule, free of charge, with advisory messages for users.

Evidence: Procedure description, SBOM in a machine-readable format, contact point for reports.

Date: 15/09/2026

Support period determined and stated, updates available

Passed

Article 13(8), (9) and (19), Annex II No. 7 CRA. The support period reflects the expected product lifetime and is at least five years, or the expected lifetime where that is shorter; five years is the floor, not a default. The end date is indicated clearly at the time of purchase, at least by month and year, and every security update provided remains available after it has been issued for at least ten years or for the remainder of the support period, whichever is longer. Evidence: Statement on the product, on its packaging or in the instructions for use; archive of the security updates delivered.

Support period: 12 years from placing on the market, until 03/2039

Date: 15/09/2026

Due diligence for bought-in components carried out

Open

Article 13(5) and (6) CRA. When integrating third-party components, including open-source ones, it has been verified that they do not compromise the cybersecurity of the product; vulnerabilities in such components are reported and remedied. Evidence: Component list with origin, version, verification and the source of security information.

Date: 15/09/2026

Reporting process under Article 14 in place

MANDATORY

Passed

Articles 14 and 16 CRA. Responsibility, availability and reporting channel for actively exploited vulnerabilities and severe incidents are defined: early warning within 24 hours, notification within 72 hours, final report, information to the users concerned.

Evidence: Written procedure naming the CSIRT, access to the reporting platform, availability.

Date: 15/09/2026

Information and instructions for the user complete Passed

Article 13(18), Annex II CRA. The information set out in Annex II accompanies the product, including the name and contact details of the manufacturer, the contact point for vulnerabilities, the product identification, the intended purpose with the security environment and security properties, circumstances leading to significant cybersecurity risks, where applicable, the internet address of the EU declaration of conformity, technical security support, the end of the support period and instructions on commissioning, updates and secure decommissioning. Evidence: Cybersecurity chapter of the instructions for use or the accompanying information.

Date: 15/09/2026

Conformity assessment carried out and declaration drawn up Not applicable

Article 13(12) and (20), Articles 28, 30 and 32, Annexes V and VIII CRA. The procedure under Article 32 has been carried out in line with the classification, the EU declaration of conformity is available, the CE marking has been affixed and a copy or a simplified declaration accompanies the product. Evidence: Declaration of conformity and, where applicable, the certificate of the notified body.

Date: 15/09/2026

Justification: Placing on the market on 15 March 2027, i.e. before 11 December 2027: the main obligations of the Cyber Resilience Act do not apply to this unit (Article 69(2) and Article 71(2) CRA), so there is neither a conformity assessment nor a declaration under this Regulation. The reporting obligations under Article 14 apply (Article 69(3) CRA).

Technical documentation drawn up and kept Open

Article 13(13), Article 31, Annex VII CRA. The technical documentation contains the information required by Annex VII and is kept for ten years from the placing on the market or for the support period, whichever is longer. Evidence: Technical documentation with description, risk assessment, requirements, standards and test reports.

Date: 15/09/2026

6. Functional safety

Performance level according to EN ISO 13849-1

This module does not replace SISTEMA. It determines the required performance level (PLr) and documents functional safety in the CE dossier. The safety-critical calculation of the achieved PL (category, MTTFd, DCavg, CCF, PFHd) and the manufacturers' component data (libraries according to VDMA 66413) must be carried out in or obtained from SISTEMA (IFA/DGUV, free of charge). The SISTEMA result is then entered here for the verification $PL \geq PLr$; the SISTEMA report belongs in the technical documentation as evidence.

Safety function	Hazards	Required	Achieved (SISTEMA)	Verification
SF-04 Enable of the 180-degree pivoting movement of the turn-over table only when the pivoting area is clear Dual-channel monitoring of the light curtain, clamp position and table position in the safety PLC; the pivot command is enabled only when the safety field is clear and the clamps are locked, pivot speed safely limited	No. 1, No. 4, No. 5, No. 6, No. 11, No. 30, No. 31, No. 32	PLr e S2/F2/P2	PL e · Cat. 4 · PFHd 2.7e-8 1/h	fulfilled (PL ≥ PLr)
SF-01 Safe stop (stop category 1) upon opening of the maintenance door Interlocking with guard locking in accordance with EN ISO 14119 (de-energisation principle), dual-channel evaluation in the safety PLC, STO on robot and turn-over table drive, guard locking released only after standstill monitoring	No. 1, No. 2, No. 3, No. 4, No. 6, No. 8, No. 11, No. 18, No. 23	PLr d S2/F1/P2	PL d · Cat. 3 · PFHd 4.7e-7 1/h	fulfilled (PL ≥ PLr)
SF-02 Safe stop upon interruption of the light curtain at the loading station Light curtain type 4 in accordance with EN IEC 61496-1/-2, resolution 30 mm, safety distance in accordance with EN ISO 13855, evaluation in the safety PLC, STO on robot and turn-over table drive	No. 1, No. 13, No. 32	PLr e S2/F2/P2	PL e · Cat. 4 · PFHd 2.5e-8 1/h	fulfilled (PL ≥ PLr)
SF-03 Emergency stop of the overall installation, stop category 1 Emergency stop command devices at the control panel and at the maintenance door, dual-channel to the safety PLC; acts on robot, turn-over table, welding power source and pneumatics of the entire cell	No. 1, No. 4, No. 6, No. 7, No. 21, No. 31	PLr d S2/F1/P2	PL d · Cat. 3 · PFHd 4.2e-7 1/h	fulfilled (PL ≥ PLr)

Safety function	Hazards	Required	Achieved (SISTEMA)	Verification
SF-05 Safely reduced speed of 250 mm/s with enabling device in setup mode Lockable operating mode selector switch, safe speed monitoring (SLS) of robot and turn-over table to 250 mm/s, three-position enabling device on the hand-held control unit; emergency stop remains effective	No. 1, No. 2, No. 4, No. 6, No. 8, No. 11, No. 30	PLr d S2/F2/P1	PL d · Cat. 3 · PFHd 4.5e-7 1/h	fulfilled (PL ≥ PLr)

7. Cybersecurity

Cyber Resilience Act (Regulation (EU) 2024/2847), contribution to the technical documentation under Annex VII CRA

For this product only the reporting obligations under Article 14 CRA apply under the Regulation (Article 69(3) CRA); the other obligations only apply after a substantial modification on or after 11 December 2027 (Article 69(2) CRA). The sections on scope, inventory, risks, requirements, components, vulnerabilities, support period and user information document voluntary preparation; items marked “Open” there are not obligations in force.

Confidential: this document contains security-relevant information on the attack surface of the product. Share it only with persons and bodies that need the information for the conformity assessment or market surveillance.

Classification, status of obligations and conformity assessment

Articles 2, 7, 8, 32, 69 and 71, Annexes III and IV CRA

Last changed: 17/09/2026, 01:18

Scope (Article 2(1) CRA)	Covered: the product falls under the Cyber Resilience Act (Article 2(1) CRA). Which obligations apply today depends on the date of placing on the market.
Core functionality (Article 7(1) CRA)	Robot-assisted MAG welding of steel assemblies in series production. The software controls the robot, rotary table, welding process and fume extraction. Networking, VPN and access functions come from purchased components and are not the core functionality of the cell; they are recorded as components with their own classification.
Classification (Annexes III and IV CRA)	Default product (not listed in Annex III or IV)
Classification confirmed	Yes
Obligations in force	The product is placed on the market before 11 December 2027. Of the Cyber Resilience Act, only the reporting obligations under Article 14 then apply (Article 69(3) CRA); the essential cybersecurity requirements, the CRA conformity assessment and the CRA CE marking only apply once the product is substantially modified on or after 11 December 2027 (Article 69(2) CRA). Cybersecurity requirements under other legal acts are unaffected, such as those of the Radio Equipment Directive via Delegated Regulation (EU) 2022/30 until 10 December 2027 and Annex III No. 1.1.9 of the Machinery Regulation from 20 January 2027.
Reporting obligations (Article 14 CRA)	The reporting obligations under Article 14 CRA have applied since 11 September 2026, including for products placed on the market earlier (Article 69(3) CRA).
EU declaration of conformity (Article 28 CRA)	No declaration under the Regulation: for placing on the market before 11 December 2027 only the reporting obligations under Article 14 apply (Article 69(3) CRA), as long as the product is not substantially modified afterwards (Article 69(2) CRA).
Date of placing on the market	15 March 2027 (planned)

- The date of placing on the market applies per unit. If further units of the same design are placed on the market on or after 11 December 2027, the remaining obligations of the Regulation apply to them. According to Commission guidance C(2026) 5252, paragraphs 33 to 39 (content of the draft approved on 27 July 2026), a series designed earlier then needs no redesign if the risk assessment demonstrates appropriate measures; conformity assessment, EU declaration of conformity and CE marking remain mandatory.

Basis of the assessment 5 of 5 documented

Article 13(3), second sentence, CRA

Intended purpose	Robot-assisted MAG welding of steel assemblies up to 40 kg in series production, installed stationary in a production hall. The cell is integrated into the operator's production network (orders from the MES) and is maintained remotely by the manufacturer over a VPN connection that the operator enables for each session.
Reasonably foreseeable use	Connecting the cell network directly to the office or internet network without the gateway; leaving remote maintenance permanently enabled; shared user accounts across shifts; importing programs from private USB drives; connecting further devices to the cell network; continued operation after the end of the support period without security updates.
Operating environment	Production hall with restricted access. Cell network (PROFINET) inside the locked control cabinet, separated from the operator's production network by the gateway with firewall; connection to the MES via OPC UA in a dedicated network segment. Internet access only through the VPN gateway and only for enabled maintenance sessions. Operation by trained staff with personal accounts; service by the manufacturer and qualified electricians appointed by the operator.
Assets to be protected	Safety functions and safety program of the safety PLC; control software and welding programs; user accounts and VPN certificates; event log; personal data of the operators; the operator's production network into which the cell is integrated.
Conditions of use	Operation only with the supplied gateway and in line with the network requirements of the operating instructions; remote maintenance only after enabling it at the control desk; the manufacturer's security updates are installed promptly in maintenance mode.
Expected product lifetime	12 years
Justification of the lifetime	Mechanics and drives are designed for 12 years in two-shift operation, which matches the service life of the predecessor cells at the operator. The suppliers of the robot controller and the safety PLC guarantee spare parts until at least 2039.

Interface and asset inventory

Basis of the assessment under Article 13(2) CRA; asset types modelled on EN 18031, supplemented by safety function and operational data

Last changed: 17/09/2026, 01:18

The inventory describes the attack surface of the product: every data connection with a device or network and the assets reachable through it. It is also the basis of the assessments on protection against corruption and on radio equipment.

Interfaces

Designation	Type	Protocol	Reachability	Safety function
Cell network to robot, rotary table and welding power source	Network / fieldbus / line integration	PROFINET IO with PROFIsafe	On site only (physical access)	Yes
Connection to the operator's MES	Network / fieldbus / line integration	OPC UA (Sign & Encrypt) over Ethernet	Local network of the installation	No
Remote maintenance via VPN gateway	Remote access / remote maintenance	IPsec VPN over the operator's internet connection	Reachable via the internet	No
Operator panel at the control desk	Operator panel (HMI) with user and parameter management	Touch operation with roles and user accounts	On site only (physical access)	No
USB port on the operator panel	USB / removable media	USB 2.0 for backups and program import	On site only (physical access)	No

Designation	Type	Protocol	Reachability	Safety function
Programming access to the safety PLC and the robot controller	Engineering / programming access	Engineering port (Ethernet) in the control cabinet	On site only (physical access)	Yes

Assets

Designation	Type	Protection goals	Interfaces
Safety functions SF-01 to SF-05 and the safety program of the safety PLC	Safety function of the machine	Integrity, Availability	Cell network to robot, rotary table and welding power source, Programming access to the safety PLC and the robot controller
Control, HMI and gateway software including version and checksums	Security asset (keys, passwords, security functions of the control system)	Integrity, Availability	Programming access to the safety PLC and the robot controller, Remote maintenance via VPN gateway, USB port on the operator panel, Operator panel at the control desk
User accounts, roles and VPN certificates	Security asset (keys, passwords, security functions of the control system)	Confidentiality, Integrity	Operator panel at the control desk, Remote maintenance via VPN gateway, Connection to the operator's MES
Welding programs and process parameters (current, voltage, wire feed, paths)	Operational and process data (recipes, parameters, production data)	Confidentiality, Integrity	Connection to the operator's MES, Operator panel at the control desk, USB port on the operator panel
Event log of logins, parameter changes and remote maintenance sessions	Operational and process data (recipes, parameters, production data)	Integrity, Availability	Operator panel at the control desk, Remote maintenance via VPN gateway
Operator user names and login times	Privacy asset (personal data)	Confidentiality, Integrity	Operator panel at the control desk, Connection to the operator's MES
Network configuration of the cell and the transition to the operator network (gateway, firewall rules)	Network asset (network functions and their configuration)	Integrity, Availability	Connection to the operator's MES, Remote maintenance via VPN gateway

Cybersecurity risk assessment 7 of 7 documented

Article 13(2) and (3) CRA

Last changed: 17/09/2026, 15:41

The CRA does not prescribe a method, but it does prescribe a minimum content. Article 13(2) CRA requires an assessment of the cybersecurity risks and that its outcome be taken into account during the planning, design, development, production, delivery and maintenance phases; Article 13(3) CRA requires the assessment to be documented and updated during the support period. This assessment documents it qualitatively as impact × likelihood in four levels; this follows the definition of cybersecurity risk as a combination of the magnitude of loss or disruption and the likelihood of occurrence (Article 3(37) CRA). This is NOT the risk assessment under EN ISO 12100: health and safety consequences of an attack are part of the impact here under Article 13(2) CRA; the protective measure against the safety-related consequence and its evidence additionally belong in the risk assessment (Annex III No. 1.1.9 of the Machinery Regulation or the state of the art under the Machinery Directive). The two risk numbers must not be confused or added together.

As at 15 September 2026, no harmonised standard for the Cyber Resilience Act has been cited in the Official Journal; there is therefore currently no presumption of conformity under Article 27(1) CRA. Once a standard appears, the method must be aligned with it.

From a risk number of 4, this assessment requires a documented measure. That is a convention of this assessment, not a limit set by the CRA: a risk rated lower must also be minimised under Article 13(2) CRA.

Risk classes (convention of this assessment, not set by the CRA): 1 to 3 low, 4 to 7 medium, 8 to 11 high, 12 and above very high.

Scale

Level	Impact	Likelihood
1	low: no appreciable damage, operation continues	unlikely: only with considerable effort and physical access
2	noticeable: individual functions disrupted, data corrupted or leaked	possible: a targeted attack with expert knowledge is conceivable
3	serious: production stopped, trade secrets or personal data affected	likely: known attack paths, tools freely available
4	very serious: safety function, health or a third-party network affected	very likely: reachable from the network, automated attacks known

Threat 1: Unauthorised access through remote maintenance with stolen credentials; programs or parameters of the standard controller are changed.

via Remote maintenance via VPN gateway; Asset: Control, HMI and gateway software including version and checksums

Category: Unauthorised access

Impact $\times$ likelihood: $3 \times 3 = 9$ (High)

Measures: VPN with multi-factor login and personal accounts; enabling only at the control desk, time-limited, with a "Remote maintenance active" indicator; no remote access path to the safety PLC; every session is logged.

Residual risk: $3 \times 1 = 3$ (Low); Remaining: insiders with a valid account; limited by logging and four-eyes approval of safety-related changes. Safety-related consequences of remote access are assessed in the risk assessment to EN ISO 12100 (hazard no. 44).

Requirements: Part I No. 2(d); Part I No. 2(j); Part I No. 2(l)

Status: complete

Threat 2: A known vulnerability in the VPN gateway firmware is exploited to reach the operator's production network.

via Remote maintenance via VPN gateway; Asset: Network configuration of the cell and the transition to the operator network (gateway, firewall rules)

Category: Vulnerability in a component

Impact $\times$ likelihood: $3 \times 3 = 9$ (High)

Measures: Software bill of materials for every software version; subscription to the gateway supplier's security advisories; check against public vulnerability databases before every delivery; security updates via the customer portal; the gateway does not route traffic between the cell network and the operator network.

Residual risk: $3 \times 1 = 3$ (Low); Remaining: time between disclosure and installation of the update by the operator.

Requirements: Part I No. 2(a); Part I No. 2(c); Part I No. 2(i); Part II No. 1; Part II No. 2

Status: complete

Threat 3: Manipulated order or parameter data from the MES network change welding parameters; the welds become defective.

via Connection to the operator's MES; Asset: Welding programs and process parameters (current, voltage, wire feed, paths)

Category: Manipulation

Impact $\times$ likelihood: $3 \times 2 = 6$ (Medium)

Measures: OPC UA only in Sign & Encrypt mode with certificates; received parameters are checked against released limits; changes to welding programs only with the set-up role.

Residual risk: $3 \times 1 = 3$ (Low); Safety-related consequences of falsified data are also assessed in the risk assessment (hazard no. 42).

Requirements: Part I No. 2(e); Part I No. 2(f)

Status: complete

Threat 4: Malware reaches the operator panel from a USB drive while backups or programs are imported.

via USB port on the operator panel; Asset: Control, HMI and gateway software including version and checksums

Category: Malware

Impact × likelihood: $3 \times 2 = 6$ (Medium)

Measures: USB port usable only after login, autorun disabled; only signed update packages are installed; programs are checked for checksum and format before they are accepted.

Residual risk: $2 \times 1 = 2$ (Low); The operating instructions tell users to use checked storage media only.

Requirements: Part I No. 2(f); Part I No. 2(j)

Status: complete

Threat 5: Passwords are shared or spied out at the operator panel; an operator obtains the rights of a higher role.

via Operator panel at the control desk; Asset: User accounts, roles and VPN certificates

Category: Unauthorised access

Impact × likelihood: $2 \times 3 = 6$ (Medium)

Measures: Personal accounts instead of group accounts; password change enforced at first login; automatic logout; logins and role changes are logged.

Residual risk: $2 \times 2 = 4$ (Medium); Sharing passwords remains an organisational matter for the operator; covered in the operating instructions.

Requirements: Part I No. 2(b); Part I No. 2(d); Part I No. 2(l)

Status: complete

Threat 6: An additional device overloads or disturbs the cell network (denial of service); communication with the safety PLC is lost.

via Cell network to robot, rotary table and welding power source; Asset: Safety functions SF-01 to SF-05 and the safety program of the safety PLC

Category: Availability

Impact × likelihood: $3 \times 2 = 6$ (Medium)

Measures: Cell network inside the locked control cabinet without free ports; separated from the operator network by the gateway; PROFIsafe monitoring switches to the safe state on communication loss, restart only after acknowledgement.

Residual risk: $2 \times 1 = 2$ (Low); Safety-related consequences are assessed in the risk assessment to EN ISO 12100 (hazard no. 38).

Requirements: Part I No. 2(h); Part I No. 2(k)

Status: complete

Threat 7: The safety program is overwritten or put into stop mode through the programming access.

via Programming access to the safety PLC and the robot controller; Asset: Safety functions SF-01 to SF-05 and the safety program of the safety PLC

Category: Manipulation

Impact × likelihood: $4 \times 2 = 8$ (High)

Measures: Programming access only inside the locked control cabinet; individual password for the safety program; version and checksum on the operator panel; acceptance test of the safety functions after every change.

Residual risk: $4 \times 1 = 4$ (Medium); Remaining: intervention by authorised persons; the evidence on protection against corruption is part of the risk assessment (hazard no. 43).

Requirements: Part I No. 2(d); Part I No. 2(f); Part I No. 2(k)

Status: complete

Requirements relating to the properties of the product 14 of 14 documented

Annex I Part I CRA

Last changed: 17/09/2026, 01:18

Annex I Part I No. 1 applies without qualification. The requirements of No. 2(a) to (m) apply “where applicable” on the basis of the cybersecurity risk assessment; whether and how they apply must be stated in the assessment (Article 13(3), third sentence, CRA) and belongs in the technical documentation (Annex VII point 3 CRA). Where one of them is not applicable, this must be clearly justified there (Article 13(4) CRA).

Reference	Requirement	Applicable	Status	Justification	Implementation	Evidence
Part I No. 1	Appropriate cybersecurity level based on risks	always applies	fulfilled		Cybersecurity risk assessment with seven threats across all digital interfaces; the measures are implemented in design, commissioning and service.	CRA report with risk table and requirements matrix
Part I No. 2(a)	No known exploitable vulnerabilities	yes	in progress		The software bill of materials is checked against public vulnerability databases before every delivery; open findings are fixed before delivery.	Vulnerability check report per software version (first report before placing on the market)
Part I No. 2(b)	Secure by default configuration, reset	yes	fulfilled		Delivered with remote maintenance disabled, closed ports on the gateway and an enforced password change; reset to factory settings via the service menu.	Commissioning checklist IBN-SEC-01
Part I No. 2(c)	Security updates, automatic updates with opt-out	yes	fulfilled		Security updates as signed packages via the customer portal, installed by the operator in maintenance mode. Automatic installation is not provided because an update during production would stop the cell; the operator is informed of available updates by e-mail.	Update concept UPD-01
Part I No. 2(d)	Protection from unauthorised access	yes	fulfilled		Personal accounts with roles on the operator panel, VPN with multi-factor login, OPC UA with certificates; failed logins and remote maintenance sessions are logged and shown on the operator panel.	Role concept ROL-01, log extract from acceptance
Part I No. 2(e)	Confidentiality of data	yes	fulfilled		OPC UA in Sign & Encrypt mode, encrypted VPN tunnel; passwords are stored as hashes only.	Configuration record of gateway and OPC UA server
Part I No. 2(f)	Integrity of data, commands, programs, configuration	yes	fulfilled		Signed update packages, checksums of the control software on the operator panel, change log for parameters and programs.	Software version acceptance report

Reference	Requirement	Applicable	Status	Justification	Implementation	Evidence
Part I No. 2(g)	Data minimisation	yes	fulfilled		Only production data and the user names needed for login and logging are processed; no data is sent to the manufacturer outside enabled maintenance sessions.	Data flow diagram DFP-01
Part I No. 2(h)	Availability of essential functions, DoS resilience	yes	fulfilled		Cell network separated from the operator network, bandwidth limit on the gateway; the cell keeps working with the last released programs without MES or internet connection.	Network load and connection loss test, report NET-T-02
Part I No. 2(i)	Minimise impact on other devices and networks	yes	fulfilled		The gateway allows only OPC UA to the MES and the VPN connection to the manufacturer and does not route traffic between the cell network and the operator network.	Firewall rule set FW-01
Part I No. 2(j)	Limit attack surfaces	yes	fulfilled		Unneeded services and ports disabled, programming access inside the locked control cabinet, USB usable only after login.	Hardening checklist HRT-01
Part I No. 2(k)	Exploitation mitigation	yes	fulfilled		No remote access path to the safety controller, safe state on communication loss, backup and restore with checksum comparison.	Validation report of the safety functions, restore test
Part I No. 2(l)	Security logging and monitoring with opt-out	yes	in progress		Event log of logins, role and parameter changes, software uploads and remote maintenance sessions. The design of the opt-out mechanism is still being clarified because the same log provides the evidence under Annex III No. 1.1.9 of the Machinery Regulation (status 17 September 2026).	Logging concept LOG-01 (draft)
Part I No. 2(m)	Secure data deletion and transfer	yes	fulfilled		"Factory settings" permanently deletes user accounts, certificates, programs and logs; backups are written to USB in encrypted form.	Reset test, report RST-01

Third-party components 1 of 5 documented

Article 13(5) and (6) CRA

Last changed: 17/09/2026, 01:18

Anyone integrating components sourced from third parties into a product exercises due diligence: the components must not compromise the cybersecurity of the product. This also applies to free and open-source software that has not been made available on the market in the course of a commercial activity (Article 13(5) CRA). If a vulnerability is identified in a component, it must be reported to the person or entity manufacturing or maintaining the component; a fix developed in-house must be shared with them (Article 13(6) CRA).

Component 1: Controller of the articulated robot

Manufacturer: Robot manufacturer (supplier)

Version: Controller software 5.2

Type: Hardware

CRA status: under review

Class / note: Core functionality robot control; according to the supplier, no category of Annex III or IV.

Evidence of due diligence: Supplier questionnaire on vulnerability handling and support period evaluated; subscribed to the supplier's security advisories; declaration of CRA conformity for deliveries from 11 December 2027 requested.

SBOM reference: Supplier SBOM requested

Last check: 10/09/2026

Component 2: Safety PLC with engineering software

Manufacturer: Controls manufacturer (supplier)

Version: Firmware 3.1

Type: Hardware

CRA status: under review

Class / note: Core functionality safety control, no category of Annex III or IV.

Evidence of due diligence: Manufacturer's security manual evaluated and hardening recommendations applied; subscribed to security advisories; declaration of CRA conformity requested.

SBOM reference: RSZ-2600-SBOM, safety PLC section

Last check: 10/09/2026

Component 3: Industrial router with VPN (remote maintenance gateway)

Manufacturer: Network equipment vendor (supplier)

Version: Firmware 8.4

Type: Hardware

CRA status: under review

Class / note: Important product of class I under Annex III No. 5 (VPN) and No. 12 (routers); for deliveries from 11 December 2027 the supplier must demonstrate a conformity assessment under Article 32(2) CRA.

Evidence of due diligence: Firmware maintenance committed in writing until 2036, replacement with the successor model planned within the support period; hardened according to the supplier's guide.

SBOM reference: RSZ-2600-SBOM, gateway section

Last check: 10/09/2026

Component 4: Operator panel with visualisation software

Manufacturer: Automation manufacturer (supplier)

Version: Runtime 17

Type: Hardware

CRA status: under review

Class / note: Core functionality operating and monitoring, no category of Annex III or IV.

Evidence of due diligence: Supplier questionnaire evaluated; support for the runtime committed until 2037; subscribed to security advisories.

SBOM reference: RSZ-2600-SBOM, operator panel section

Last check: 10/09/2026

Component 5: OPC UA communication library (open source)

Manufacturer: Open-source project
Version: 1.4
Type: Software, free and open-source software
CRA status: not covered by the CRA
Class / note: Free and open-source software not supplied by the project in the course of a commercial activity (Recital 18 CRA); the due diligence obligation when integrating it lies with the manufacturer of the cell (Article 13(5) CRA).
Evidence of due diligence: Version checked against public vulnerability databases; maintenance activity and security policy of the project reviewed; updates are adopted with every software version; vulnerabilities found are reported to the project (Article 13(6) CRA).
SBOM reference: RSZ-2600-SBOM
Last check: 10/09/2026

- No. 1: Open: whether the component meets the requirements has not been established yet (Article 13(5) CRA).
- No. 2: Open: whether the component meets the requirements has not been established yet (Article 13(5) CRA).
- No. 3: Open: whether the component meets the requirements has not been established yet (Article 13(5) CRA).
- No. 4: Open: whether the component meets the requirements has not been established yet (Article 13(5) CRA).

Vulnerability handling 12 of 12 documented

Annex I Part II CRA

Last changed: 17/09/2026, 01:18

Storage location of the bill of materials	Manufacturer's PDM system, document RSZ-2600-SBOM, updated for every released software version
Format of the bill of materials	CycloneDX 1.6 (JSON)
Provision of the bill of materials to the user	no
Contact address for reporting vulnerabilities (Part II No. 6, Article 13(17) CRA)	security@muster-maschinenbau.example
Coordinated vulnerability disclosure policy (Part II No. 5 CRA)	https://www.muster-maschinenbau.example/security/disclosure
Publication of information about fixed vulnerabilities (Part II No. 4 CRA)	https://www.muster-maschinenbau.example/security/advisories

Requirements of Annex I Part II

Reference	Requirement	Status	Implementation	Evidence	Note
Part II No. 1	Identify vulnerabilities and components, SBOM	fulfilled	Software bill of materials in CycloneDX format for every released software version, covering at least the top-level dependencies; component list with suppliers and versions.	RSZ-2600-SBOM	

Reference	Requirement	Status	Implementation	Evidence	Note
Part II No. 2	Remediate without delay, separate security updates	fulfilled	Remediation by severity with fixed target times; where technically feasible, security updates are provided separately from functionality updates.	VA-SEC-04, section 5	Qualification in the wording: security updates need only be delivered separately from functionality updates “where technically feasible”. For subsequent substantially modified versions of a software product, Article 13(10) CRA allows the obligation to be limited to the version most recently placed on the market, provided users of the earlier version have free access to the latest version without additional adaptation costs.
Part II No. 3	Regular security testing and review	in progress	Annual penetration test on a reference cell and a vulnerability check before every delivery; the first test is planned before placing on the market.	Test plan SEC-PP-01	
Part II No. 4	Publish information on fixed vulnerabilities	fulfilled	Security advisories with description, affected versions, impact, severity and remediation at https://www.muster-maschinenbau.example/security/advisories ; publication is delayed only in justified cases until users have been able to install the update.	VA-SEC-04, section 6	Qualification in the wording: in duly justified cases where the risks of publication outweigh the security benefits, publication may be delayed until users have had the opportunity to apply the patch. The justification belongs in the implementation description.
Part II No. 5	Coordinated vulnerability disclosure policy	fulfilled	Coordinated vulnerability disclosure policy published at https://www.muster-maschinenbau.example/security/disclosure .	Published policy, Rev. A	
Part II No. 6	Vulnerability information sharing, contact address	fulfilled	Contact address security@muster-maschinenbau.example ; subscribed to the security advisories of the suppliers of robot controller, safety PLC and gateway.	VA-SEC-04, section 3	
Part II No. 7	Secure update distribution mechanisms	fulfilled	Signed update packages with checksum via the customer portal (TLS); the installer verifies the signature before installing.	Update concept UPD-01	Qualification in the wording: security updates are, where applicable, installed automatically. For products in professional and industrial environments where an automatic update could disrupt operations, users would not normally expect them (see recital 56 CRA); the decision is to be justified here.

Reference	Requirement	Status	Implementation	Evidence	Note
Part II No. 8	Free security updates with advisories	fulfilled	Security updates are free of charge during the support period and come with advisory messages on content and recommended actions, separate from paid feature upgrades.	General service terms, section on security updates	Qualification in the wording: for a tailor-made product, the manufacturer and the business user may agree otherwise on free-of-charge distribution. Any such agreement is to be named here; the duty to distribute without delay together with advisories remains.

- The eight requirements of Annex I, Part II apply without the qualification “where applicable” of Part I (introductory sentence of Annex I, Part II; see recital 54 CRA) and therefore cannot be deselected once the obligations of the Regulation apply to the product; for each point, record how it is implemented and what evidence supports it (Annex VII, point 2(b) and point 6 CRA). Some points carry restrictions in their own wording; they appear as a note on the row and concern the implementation, not the applicability.

Support period 4 of 4 documented

Article 13(8), (9) and (19) CRA

Last changed: 17/09/2026, 01:18

Support period determined	12 years
Check against Article 13(8) CRA	The support period meets the minimum of five years and the expected lifetime. The reasons for setting it belong in the technical documentation (Article 13(8), fifth subparagraph, and Annex VII No. 4 CRA).
Factors taken into account	The support period matches the expected period of use of 12 years. Taken into account were the operators' expectations in series production, the service life of comparable welding cells and the firmware maintenance committed by the suppliers of the robot controller, safety PLC and gateway (evidence in the component list).
Calculated end (assumption of this assessment: start at placing on the market, plus period)	03/2039
End date stated	03/2039
Indication of the end date at the time of purchase	Order confirmation, supplementary plate next to the rating plate and the Cybersecurity chapter of the operating instructions
Availability of security updates already provided (Article 13(9) CRA)	Security updates are provided in the manufacturer's customer portal with release notes and checksum and remain available there for at least ten years after release, and in any case until the end of the support period.

Reporting of actively exploited vulnerabilities and severe incidents 4 of 4 documented

Article 14 CRA

Last changed: 17/09/2026, 01:18

Deadlines under Article 14(2) and (4) CRA: early warning without undue delay and in any event within 24 hours of becoming aware; notification without undue delay and in any event within 72 hours of becoming aware, unless the relevant information has already been provided; final report for a vulnerability within 14 days after a corrective or mitigating measure is available, for a severe incident within 1 month after the notification. The deadlines are calculated without shifting to working days, which is the stricter reading.

Responsible for notifications	Product Security Officer, reachable via security@muster-maschinenbau.example and the service on-call team, including weekends
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Deputy	Head of Electrical Engineering
Member State of the main establishment	Germany
CSIRT designated as coordinator	CERT-Bund at the Federal Office for Information Security (BSI)
Access to the single reporting platform (Article 16 CRA)	set up
Internal procedure	Procedure VA-SEC-04 "Handling vulnerabilities and security incidents", Rev. B
Information to the users concerned (Article 14(8) CRA)	Security advisory by e-mail to the registered contacts of every operator and publication at https://www.muster-maschinenbau.example/security/advisories , also machine-readable in CSAF format

Information and instructions to the user 7 of 7 documented

Annex II, Annex VII No. 1(d) CRA

Last changed: 17/09/2026, 01:18

The following information follows Annex II CRA. For this product (placed on the market before 11 December 2027) it only has to accompany the product after a substantial modification on or after 11 December 2027 (Article 69(2) CRA). For a machine it belongs in the cybersecurity chapter of the instructions for use.

Annex II No. 1 CRA: Name and contact details of the manufacturer

Muster Maschinenbau GmbH
 Beispielstrasse 1, 12345 Musterstadt, Germany
 service@muster-maschinenbau.example
<https://www.muster-maschinenbau.example>

Annex II No. 2 CRA: Single point of contact for vulnerabilities and disclosure policy

security@muster-maschinenbau.example
<https://www.muster-maschinenbau.example/security/disclosure>

Annex II No. 3 CRA: Unique identification of the product

Robotic welding cell RSZ-2600
 RSZ-2600
 Serial number on the rating plate at the control desk; software version on the operator panel under "Info"

Annex II No. 4 CRA: Intended purpose, security environment and security properties

Robot-assisted MAG welding of steel assemblies up to 40 kg in series production, installed stationary in a production hall.
 Operation in a production network separated from the office and internet networks; connection to the MES only through the supplied gateway; remote maintenance only through the VPN gateway after enabling it at the control desk; control cabinet and programming ports locked.
 Control of robot, rotary table, welding process and fume extraction; receiving orders and reporting production data via OPC UA; backups via USB; remote maintenance by the manufacturer.
 Personal user accounts with roles; encrypted and signed OPC UA connection; VPN with multi-factor login; event log of logins, parameter changes and remote maintenance sessions; version and checksum of safety-related software on the operator panel; no remote access to the safety controller.

Annex II No. 5 CRA: Circumstances that may lead to significant cybersecurity risks

Connecting the cell network directly to the office or internet network; remote maintenance left permanently enabled; shared passwords; files from unknown sources via USB; security updates not installed; continued operation after the end of the support period.

Annex II No. 6 CRA: Internet address of the EU declaration of conformity

no entry (where applicable)

Annex II No. 7 CRA: Technical security support and end date of the support period

Security updates for control, HMI and gateway software via the customer portal; security advisories by e-mail; support from the manufacturer's service when integrating the cell into the operator network.

End of the support period: 03/2039

Annex II No. 8 CRA: Detailed instructions

- (a) Secure commissioning and use: Change the initial password at the first login (the controller enforces this) and create personal accounts for all operators; integrate the gateway according to the manufacturer's network plan and allow only OPC UA to the MES and the VPN connection to the manufacturer; back up the accepted configuration and record its checksum in the acceptance report.
- (b) Effect of changes on the security of data: Additional network connections, changed firewall rules, changes to the safety program or connecting further machines can impair cybersecurity and the safety functions. Make such changes only after consulting the manufacturer and test the safety functions afterwards.
- (c) How to install security-relevant updates: Download security updates from the customer portal, compare the checksum and install them in maintenance mode via USB on the operator panel or during an enabled remote maintenance session; then check version and checksum on the operator panel.
- (d) Secure decommissioning and removal of user data: Before decommissioning, back up welding programs and logs, reset the cell via "Factory settings" (this deletes user accounts, certificates, programs and logs) and ask the manufacturer to block the remote maintenance access.

Annex II No. 9 CRA: Access to the software bill of materials, if provided

no entry (where applicable)

- Note: no internet address of the EU declaration of conformity is given; it only has to be stated "where applicable" (Annex II No. 6 CRA). Where the main obligations apply, under Article 13(20) CRA the product is accompanied by a copy of the EU declaration of conformity or a simplified declaration; the simplified declaration states the internet address at which the full text is available (Annex VI CRA).

State of standardisation on the market

Article 27 CRA

As at 15 September 2026 no harmonised standard for the Cyber Resilience Act is cited in the Official Journal of the European Union. There is therefore currently no presumption of conformity under Article 27(1) CRA, and for important products of class I the route via internal control (module A) with harmonised standards applied in full is not yet open in practice. The delegated act designating European certification schemes for the presumption of conformity (Article 27(9) CRA) has not been adopted either. Check the state of the Official Journal before the conformity assessment.

This overview describes the state of standardisation, not the standards applied to this product. The list of harmonised standards, common specifications or other technical specifications applied under Annex VII No. 5 CRA is kept in the checklist of the technical documentation.

Identifier	Title	Source	Note
Standardisation request M/606, C(2025) 618	Commission standardisation request for the Cyber Resilience Act of 3 February 2025	primary source	41 standards, request valid until 30 November 2027; it expressly names machinery (Directive 2006/42/EC and Regulation (EU) 2023/1230).
EN 40000-1-1 to EN 40000-1-4 (drafts)	Horizontal series of standards: vocabulary, principles of cyber resilience, vulnerability handling, generic security requirements	secondary source	Under development; as at 15 September 2026 not cited in the Official Journal, hence no presumption of conformity.
prEN 50770-1 to prEN 50770-6 (drafts)	Vertical standards for operational technology products: firewalls, network management, network interfaces, VPN, routers and switches, SIEM	secondary source	Under development on the basis of the IEC 62443 series; as at 15 September 2026 not cited in the Official Journal.

Identifier	Title	Source	Note
IEC 62443-4-1, -4-2 and -3-3	Secure development lifecycle, component requirements, system requirements	secondary source	Technically central, but as at 15 September 2026 not cited in the Official Journal as a harmonised standard for the Cyber Resilience Act. Usable as another technical specification applied, to be listed in the technical documentation (Annex VII No. 5 CRA), without presumption of conformity.
EN 18031-1, EN 18031-2 and EN 18031-3:2024	Cybersecurity requirements for radio equipment (Radio Equipment Directive)	secondary source	Cited with restrictions under the Radio Equipment Directive (Implementing Decision (EU) 2025/138), relevant until 10 December 2027; not a route to presumption of conformity under the Cyber Resilience Act.

This report documents the manufacturer's information under the Cyber Resilience Act (Regulation (EU) 2024/2847). It is not a risk assessment under EN ISO 12100: safety-related consequences of an attack are listed there with their risk estimation in the hazard list, while the cybersecurity risk assessment under Article 13(2) CRA is kept here. The two risk numbers must not be confused or added.

Calculation rules of this assessment (count of entries, measure threshold, risk classes, deadlines calculated without shifting to working days) are marked as such and are not requirements of the Regulation. Uncertain legal positions carry a status date.

The count of sections and entries is a convention of this documentation, not a requirement of the Regulation; it shows where the documentation still has gaps.