



Operating instructions

Robotic welding cell RSZ-2600 (assembly of machinery)

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Year of construction: 2026

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Original instructions



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1 Important basic information

Parts of this chapter were taken automatically from: AI suggestion.

These operating instructions apply to the Robotic Welding Cell RSZ-2600 (serial number RSZ2600-2026-0001, year of manufacture 2026) and are addressed to the operator as well as to the personnel responsible for operation, set-up, maintenance and dismantling. They form part of the machine, must be accessible to personnel at all times and must be handed over in the event of a change of location or resale. This chapter describes the scope of delivery, the limits of the machine, the external interfaces and the legal basis of this documentation.

1.1 Scope of Delivery and Limits of the Machine

Scope of delivery: The RSZ-2600 is delivered as a fully functional assembly of machinery. The scope of delivery includes:

- Articulated-arm industrial robot with 6 axes (reach 2600 mm, payload 12 kg) including robot controller and teach pendant
- Two-station turntable with fixed central dividing guard, welding protection curtain and pneumatic workpiece clamps
- MAG welding power source 400 A at 60 per cent duty cycle with wire feed unit and torch cleaning station
- Welding fume extraction unit 1800 m³/h with filter cartridge
- Perimeter safety fence 2200 mm with maintenance door, Type 4 light curtain, safety PLC, operator panel and control cabinet
- Operating instructions, EU declaration of conformity, electrical and pneumatic circuit diagrams and test reports

Not included in the scope of delivery:

- Workpiece-specific clamping fixtures (unless separately agreed)
- The customer-supplied shielding gas supply
- The customer-supplied media connections
- An optional exhaust air duct for the extraction unit

Limits of use: MAG welding of steel assemblies (unalloyed and low-alloy steel) up to 40 kg workpiece weight and a maximum installation space of 800 x 600 x 400 mm. Series production exclusively with predefined, approved welding programmes. Manual loading and unloading at the respective front station by trained specialist personnel, cycle time approximately 90 seconds. Not intended for aluminium, galvanised or coated workpieces, not for manual welding inside the cell, and not for workpieces with residual stress from preceding processes.

Spatial limits: Floor area approximately 6.5 x 4.0 m, height 2.6 m. Robot working envelope reach 2600 mm, completely enclosed by safety fence 2200 mm in height and the fixed central dividing guard of the turntable. Swivel range of the turntable 180 degrees. Operating position in front of the

loading station, Type 4 light curtain with 30 mm resolution, safety distance calculated and documented in accordance with EN ISO 13855. One maintenance door at the rear. Interfaces to upstream and downstream processes are exclusively manual.

Time limits: Expected service life 15 years at 2 shifts, annual maintenance by the manufacturer, half-yearly inspection of safety functions, inspection of the guard locking and the light curtain in accordance with EN ISO 14119 and EN ISO 13855 at every maintenance visit. Wear parts: welding torch, contact tips, gas nozzle, wire feed rollers, filter cartridge of the extraction unit, welding protection curtain.

Environmental limits: Dry indoor area of a production hall, 5 to 40 degrees C, relative humidity up to 70 per cent non-condensing, mains supply 400 V AC 50 Hz TN-S, connected load 32 kVA, compressed air 6 bar oil-free, installation on a level industrial concrete floor. No hazardous area, no outdoor use.

Limits of the assembly: The cell comprises the robot (partly completed machinery with declaration of incorporation), turntable, welding power source (CE-marked sub-machine), extraction unit and fence, door and sensor components. The interfaces between these parts have been assessed in the risk assessment of the assembly and taken into account in the EU declaration of conformity of the assembly.

1.2 Responsibilities (Plant Builder / Operator)

The responsibilities between the plant builder (manufacturer) and the operator are delineated as follows:

Responsibilities of the manufacturer: Design, construction and conformity of the assembly of machinery including risk assessment, validation of safety functions and technical documentation; initial commissioning with documented acceptance; annual maintenance in accordance with the agreement; supply of spare parts and technical support.

Responsibilities of the operator: Operation of the machine exclusively within the scope of the intended use; selection and qualification of personnel and their regular, documented instruction (at least annually); provision of personal protective equipment and supervision of its use; workplace-related risk assessment in accordance with ArbSchG and BetrSichV including noise and welding fumes (TRGS 528); periodic inspection of the electrical equipment in accordance with DGUV Vorschrift 3; half-yearly inspection of the safety functions and maintenance in accordance with Chapter 10 including the keeping of maintenance records; provision of customer-supplied media (electrical supply, compressed air, shielding gas) in the required quality; occupational health surveillance in the case of exposure to welding fumes; reporting of safety-relevant events and faults to the manufacturer.

Modifications to the machine: Conversions and retrofits are only permissible following written approval by the manufacturer. Substantial modifications within the meaning of the Machinery Regulation may necessitate a new conformity assessment.

1.3 External Interfaces

The machine has the following supply and media interfaces:

- Electrical power supply: 400 V AC, 3/N/PE, 50 Hz, network type TN-S, connected load 32 kVA, customer-supplied fuse protection 63 A gG, supply at the main switch of the control cabinet.
- Compressed air supply: 6 bar, oil-free, connection G 1/2 at the machine's service unit.
- Shielding gas supply (customer-supplied): Mixed gas M21 in accordance with EN ISO 14175 (82 per cent argon, 18 per cent CO₂), connection at the welding power source, flow rate approximately 15 l/min at the torch.
- Welding fume extraction: Extraction unit integrated into the cell, 1800 m³/h with filter cartridge in recirculation mode; optional customer-supplied exhaust air connection.
- Signal interfaces: Potential-free signalling contacts (operational status and collective fault message) for connection to a higher-level control system. There are no safety-related interfaces to adjacent installations; interlinking with upstream and downstream processes is exclusively manual.

The requirements for the customer-supplied execution of the connections are described in Chapter 7 (Installation Conditions).

1.4 Legal Notes and Applied Standards

The manufacturer declares the conformity of the machine with the following directives:

- Machinery Regulation (EU) 2023/1230
- EMC Directive 2014/30/EU

The protection objectives of the Low Voltage Directive 2014/35/EU are met in accordance with Annex III No. 1.5.1 of the Machinery Regulation. The EU declaration of conformity is enclosed with these operating instructions; the CE marking is affixed to the nameplate.

These operating instructions are the original operating instructions within the meaning of Annex III No. 1.7.4.1 of the Machinery Regulation. In the case of translations, the German version shall prevail; translations must be identified as a translation of the original operating instructions.

Unauthorised conversions and modifications to the machine, in particular to the guards/protective devices and the safety control system, are not permissible. They may invalidate the conformity of the machine and result in the loss of warranty; the manufacturer accepts no liability for damage arising therefrom. Only spare parts that meet the requirements specified by the manufacturer may be used. This documentation is protected by copyright. Reproduction and disclosure to third parties are only permissible to the extent required for the operation, maintenance or resale of the machine.

The complete list of applied standards is set out at the end of this chapter.



1.5 Documentation (Structure, Abbreviations, Technical Terms)

Structure: These operating instructions are divided into 12 chapters and follow the life cycle of the machine from delivery to disposal. Safety-related information is presented together in Chapter 2 and additionally at the beginning of the respective activity chapters.

Presentation of warnings: Warnings are graded according to the level of hazard. DANGER identifies an immediately hazardous situation which will result in death or serious injury. WARNING identifies a potentially hazardous situation which may result in death or serious injury. CAUTION identifies a situation which may result in minor to moderate injury. NOTE identifies information for the prevention of material damage.

Abbreviations: BWS = non-contact protective device; ED = duty cycle; HMI = human machine interface (operator interface); LOTO = lockout/tagout (isolation and securing against re-energisation); MAG = metal active gas welding; MR = Machinery Regulation (EU) 2023/1230; PL = performance level in accordance with EN ISO 13849-1; PPE = personal protective equipment; SLS = safely limited speed; PLC = programmable logic controller; TCP = tool centre point.

Associated documents: Assembly instructions of the robot manufacturer, operating instructions for the welding power source, wire feed unit and welding fume extraction unit, electrical and pneumatic circuit diagrams, EU declaration of conformity and inspection and acceptance reports. These documents must be kept together with these operating instructions.

1.6 Harmonised standards applied

Taken automatically from the project's standards checklist.

Table 1: Applied standards: Type-A standards (basic safety standards)

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

**Table 2: Applied standards: Type-B standards (generic safety standards)**

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	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments	2014/30/EU
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



Standard	Title	Directives
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
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



Standard	Title	Directives
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

Table 3: Applied standards: Type-C standards (product standards)

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

2 Safety

Parts of this chapter were taken automatically from: AI suggestion.

This chapter contains the fundamental safety information for all life phases of the robot welding cell RSZ-2600. It covers:

- the intended use
- the reasonably foreseeable misuse
- the installed guards/protective devices
- the safety labelling on the machine

In addition, the activity-related safety instructions in Chapters 5 to 11 apply. The complete overview of all residual risks with protective measures from the risk assessment is appended at the end of this chapter and must be observed by all persons working at or with the machine.

2.1 Intended Use

The robot welding cell RSZ-2600 is intended exclusively for the automated MAG welding of steel assemblies made from unalloyed and low-alloy steel with a workpiece weight of up to 40 kg and a maximum installation space of 800 x 600 x 400 mm in series production using specified, approved welding programmes. Loading and unloading are carried out manually at the respective front station of the two-station rotary table by trained specialist personnel at a cycle time of approximately 90 seconds. Personnel access to the robot working area is not provided for during automatic operation.

Design 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. (2) Two-station rotary table with a vertical axis of rotation and 180-degree rotation, fixed dividing wall with welding protection curtain, pneumatic workpiece clamps. (3) MAG welding power source 400 A at 60 per cent duty cycle, CE-marked, with wire feed and torch cleaning station. (4) Welding fume extraction 1800 m³/h with filter cartridge. All components are controlled jointly and placed on the market as a single unit.

The intended use also includes compliance with these operating instructions, the specified maintenance intervals, and the ambient and connection conditions set out in Chapters 3 and 7. The machine is intended for stationary installation in a dry production hall indoors. Any other or additional use is considered non-intended; the operator alone is liable for any damage resulting therefrom. Non-intended uses include in particular: welding of aluminium, galvanised or coated workpieces; manual welding inside the cell; machining of workpieces outside the approved geometry and weight limits; operation in potentially explosive atmospheres or outdoors.



2.2 Reasonably Foreseeable Misuse

Entering the robot working area through the loading opening despite the light curtain, for example by climbing over, crawling under or reaching through between the beams; manipulation or bridging of the light curtain, for example by taping over it or fixing an object in the protective field; bypassing the guard locking of the maintenance door using a substitute actuator or by fixing the door position; remaining in the slewing range of the rotary table during rotation; adjusting or reworking the workpiece during automatic operation without stopping the machine; leaving the operating mode selector switch in the Set-up position during production operation; continuous actuation or fixing of the enabling device; working in the cell without personal protective equipment, in particular without a welding protection goggles or protective shield; operation with the welding fume extraction switched off or blocked; cleaning the cell with the system switched on; maintenance work on the pneumatics without pressure relief and without safeguarding against unintentional restart; manual lifting of workpieces exceeding 15 kg without the designated lifting equipment; operation by uninstructed personnel or by temporary workers without induction; insertion of workpieces outside the approved workpiece geometry resulting in collisions; opening the welding power source before the discharge time has elapsed.

2.3 Observance of the Operating Instructions

Familiarity with these operating instructions is a fundamental prerequisite for the safe handling of the machine. Before carrying out any work at or with the machine, the designated personnel must have read and understood the relevant chapter as well as Chapter 2 (Safety). The operating instructions must be kept in the immediate vicinity of the machine and must be accessible to personnel at all times.

Personnel qualifications: Operation by instructed personnel only; set-up, teaching and fault clearance by trained set-up personnel with robot training only; maintenance by qualified specialist personnel only; work on the electrical equipment by electrically skilled persons only; work on the welding equipment and extraction system by personnel qualified for this purpose only. Persons undergoing training may only work on the machine under the constant supervision of an experienced specialist.

The operator must ensure that responsibilities are clearly defined, that instructions are provided regularly and in documented form, and that only authorised personnel have access to the machine. In addition to these operating instructions, the applicable regulations on occupational health and safety and accident prevention as well as the operator's internal instructions must be observed.

2.4 Safety Labelling

The following safety and information signs are permanently affixed to the machine. They must be kept in a legible condition and replaced if damaged.

Warning signs (ISO 7010): Warning of electrical voltage (W012) on the control cabinet and welding power source; warning of hot surface (W017) on the rotary table and torch cleaning station; warning of optical radiation (W027) at the loading opening and maintenance door; warning of automatically starting machinery at all access points to the robot working area.

Prohibition signs (ISO 7010): No entry for unauthorised persons (P006) at the maintenance door; no access for persons with cardiac pacemakers or implanted defibrillators (P007) at all access points, as electromagnetic fields are generated during MAG welding.

Mandatory signs (ISO 7010): Eye protection must be worn (M004) and hearing protection must be worn (M003) at the operating station; foot protection must be worn (M008) throughout the entire working area.

Additional markings: Rating plate with CE marking on the right-hand side of the control cabinet; labelling of the emergency stop command devices; notice regarding the discharge time on the welding power source; centre of gravity and lifting point markings on the transport-relevant assemblies; yellow-and-black floor markings for traffic routes and the slewing range of the maintenance door.

2.5 Guards/Protective Devices

The guards/protective devices described below are permanently installed on the RSZ-2600. They must not be removed, modified or bypassed. The machine may only be operated with all guards/protective devices fully assembled and in working order.

Fixed and movable guards: Peripheral safety fence, height 2200 mm, with welding-light-opaque infill panels and kick plate; design of safety distances in accordance with EN ISO 13857. Maintenance door at the rear as a movable guard with interlock and guard locking in accordance with EN ISO 14119 (de-energisation principle, coded actuator); the guard locking is only released after monitored standstill of the robot and rotary table. Fixed dividing wall of the two-station rotary table with welding protection curtain between the operating station and the welding area.

Non-contact protective device: Type 4 light curtain in accordance with EN 61496-1/-2 with 30 mm resolution at the loading opening, protective field continuously effective without muting; safety distance calculated and documented in accordance with EN ISO 13855. An intrusion into the protective field triggers a safe stop of the robot and rotary table.

Safety control system and safety functions: A safety PLC evaluates all guards/protective devices. Principal safety functions in accordance with EN ISO 13849-1: SF-01 interlock and guard locking of the maintenance door (PL d, Category 3); SF-02 light curtain at the loading opening (PL e, Category 4); SF-03 emergency stop (PL d, Category 3); SF-04 release of the slewing movement of the rotary table (PL e, Category 4); SF-05 safely reduced speed in set-up mode, maximum 250 mm/s at the TCP (PL d). Monitoring of the clamping pressure of the workpiece clamps is integrated as a release

condition into safety function SF-04; the rotary table only slews upon confirmed clamping pressure (see risk assessment No. 5). Validation of the safety functions is documented in accordance with EN ISO 13849-2.

Emergency stop: Emergency stop command devices in accordance with EN ISO 13850 at the control panel, at the maintenance door and at the teach pendant. The emergency stop acts on all sub-machines of the cell (robot, rotary table, welding power source, wire feed) and initiates a controlled stop (stop category 1 in accordance with EN 60204-1). Restart is only possible after unlocking the actuated command device and manual acknowledgement at the control panel.

Operating mode selection and set-up mode: Lockable operating mode selector switch with the operating modes Automatic and Set-up; the key remains with the authorised person. In set-up mode, the speed is safely limited to 250 mm/s and movements are only possible when the three-position enabling device on the teach pendant in accordance with EN ISO 10218-1 is actuated; releasing or fully depressing the device stops the movement immediately.

Restart prevention and start-up warning: After the activation of a protective device, after an emergency stop and after voltage restoration, the restart prevention function prevents automatic restart. Acknowledgement is carried out exclusively at the control panel outside the hazard zone with a line of sight to the loading opening. Before automatic start-up, a start-up warning sounds; the signal column indicates the operating status.

Energy isolation: Main switch with lockable off position in accordance with EN 60204-1 for safe isolation (LOTO); lockable compressed air shut-off valve with exhaust function and residual pressure indicator at the maintenance access point; warning notice regarding the discharge time of the welding power source prior to opening.

Pneumatic safety: Pressure switch on the clamping circuit, which releases the slewing movement of the rotary table only upon confirmed clamping pressure and correctly clamped workpiece; pressure-maintaining valve in the clamping line, which keeps the workpiece clamped in the event of a pressure drop.

Additional protective measures: Collision protection coupling on the welding torch with immediate safety stop in the event of a collision; impact protection in the area of the rotary table; welding fume extraction 1800 m³/h with monitoring of extraction performance; floor markings for traffic routes and cable bridges with over-run protection in the vicinity of the cell.

The effectiveness of the guards/protective devices must be checked in accordance with the requirements set out in Chapter 9 (daily inspections) and Chapter 10 (recurring inspections). Any defects identified must be reported immediately; the machine must be shut down until repairs have been carried out.

2.6 Residual Risks and Protective Measures

Despite the guards/protective devices described, residual risks remain on the machine that cannot be fully eliminated by design. The complete overview of all 33 residual risks, structured by life phase, together with the associated protective measures, has been taken from the risk assessment and is appended at the end of this chapter.

Overview of principal residual risks: Crushing and impact hazard from the robot and rotary table during work with guards/protective devices open (set-up, fault clearance); optical radiation from the arc as well as hot surfaces and weld spatter in the vicinity of the stations; hazard from welding fume with insufficient extraction; electrical hazard at the control cabinet and welding power source; stored pneumatic energy in the clamping circuit; noise exposure at the operating station (84 dB(A)); electromagnetic fields in the vicinity of the welding process.

Personal protective equipment: When operating the machine, the following must be worn as a minimum: safety footwear (S1P or higher), close-fitting flame-retardant work clothing, safety goggles with side protection and hearing protection. When handling workpieces, additionally protective gloves. During set-up, maintenance and cleaning work in the cell, additionally: welding protection goggles or protective shield when in visual contact with the arc, welding protection gloves when working on components that are still warm. The PPE is provided by the operator; its use must be monitored.

Action in the event of danger: In the event of recognisable hazards, immediately actuate the emergency stop, isolate the machine at the main switch and inform the supervisor. Fires at the electrical equipment must only be fought with CO₂ or powder extinguishers, never with water. In the event of accidents, provide first aid and follow the internal emergency response chain.

Taken automatically from the project's risk assessment.

**Table 4: Overview of residual hazards**

No.	Hazard	Life phases	Residual risk
28	Environment 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.	Transport, Assembly	accepted
29	Environment 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.	Assembly, Commissioning	accepted
33	Mechanical 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.	Assembly	accepted
39	Corruption/security 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]	Assembly, Commissioning, Operation	accepted
12	Electrical 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.	Maintenance, Commissioning, Troubleshooting	accepted
30	Combination 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.	Commissioning, Setting up, Maintenance	accepted
31	Combination Hazard from differing safety levels of the partial machines from	Commissioning, Operation,	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

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No.	Hazard	Life phases	Residual risk
	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).	Troubleshooting	
37	Corruption/security 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]	Setting up, Operation, Commissioning	accepted
38	Corruption/security 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]	Operation, Commissioning	accepted
40	Corruption/security 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]	Commissioning, Maintenance, Operation	accepted
43	Corruption/security 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]	Commissioning, Maintenance, Troubleshooting	accepted
1	Mechanical 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	Operation, Setting up, Troubleshooting	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

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As of: 18/09/2026

No.	Hazard	Life phases	Residual risk
	fixed centre wall or the protective fence, in particular when reaching into the turntable during turning to reposition a displaced workpiece (reasonably foreseeable misuse).		
2	Mechanical 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.	Setting up	accepted
4	Mechanical 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.	Operation, Setting up, Troubleshooting	accepted
5	Mechanical 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.	Operation, Setting up, Troubleshooting	accepted
6	Mechanical 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.	Troubleshooting, Maintenance, Setting up	accepted
7	Mechanical 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.	Operation, Setting up, Troubleshooting	accepted
8	Mechanical 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.	Setting up, Maintenance, Cleaning	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

No.	Hazard	Life phases	Residual risk
9	Mechanical 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.	Operation, Setting up	accepted
10	Mechanical 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.	Operation, Setting up, Maintenance, Cleaning, Troubleshooting	accepted
11	Mechanical 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.	Setting up, Maintenance, Troubleshooting	accepted
13	Electrical 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.	Setting up, Operation, Troubleshooting	accepted
14	Electrical 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).	Operation, Setting up	accepted
15	Thermal 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.	Operation, Setting up	accepted
16	Thermal 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.	Operation, Setting up	accepted
17	Thermal Risk of burns from the hot welding torch and torch neck: The torch	Maintenance, Setting up, Cleaning	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

No.	Hazard	Life phases	Residual risk
	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.		
18	Radiation 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.	Setting up, Operation	accepted
19	Radiation 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.	Operation, Setting up, Maintenance	accepted
20	Substances/materials 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.	Operation, Setting up, Maintenance, Cleaning	accepted
24	Noise 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.	Operation, Setting up	accepted
27	Ergonomic 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.	Operation, Setting up, Maintenance, Cleaning	accepted
32	Mechanical 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.	Operation, Setting up	accepted



No.	Hazard	Life phases	Residual risk
36	Corruption/security 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]	Operation, Setting up	accepted
3	Mechanical 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.	Operation	accepted
21	Substances/materials 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.	Operation, Maintenance, Troubleshooting	accepted
34	Thermal 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.	Operation, Maintenance	accepted
35	Ergonomic 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.	Operation	accepted
41	Corruption/security 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]	Operation, Maintenance, Troubleshooting	accepted



No.	Hazard	Life phases	Residual risk
42	Corruption/security 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]	Operation	accepted
44	Corruption/security 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]	Operation, Maintenance, Troubleshooting	accepted
22	Substances/materials 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.	Maintenance, Cleaning	accepted
23	Substances/materials 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.	Maintenance, Troubleshooting	accepted

Life phase: Transport

Environment

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.

Life phases: Transport, Assembly

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Life phase: Assembly

Environment

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.

Life phases: Assembly, Commissioning

PROTECTIVE MEASURES

- 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).
- 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.
- 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/m², 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.

Residual risk: Accepted residual risk.

Mechanical

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.

PROTECTIVE MEASURES

- 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).
- 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.
- 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.

Residual risk: Accepted residual risk.



Corruption/security

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]

Life phases: Assembly, Commissioning, Operation

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Life phase: Commissioning

Electrical

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.

Life phases: Maintenance, Commissioning, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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).
- 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.

Residual risk: Accepted residual risk.

Combination

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.

Life phases: Commissioning, Setting up, Maintenance

PROTECTIVE MEASURES

- 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.
- 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.
- 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).

Residual risk: Accepted residual risk.

Combination

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).

Life phases: Commissioning, Operation, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.

- 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.

Residual risk: Accepted residual risk.

Corruption/security

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]

Life phases: Setting up, Operation, Commissioning

PROTECTIVE MEASURES

- 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).
- 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.
- 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.

Residual risk: Accepted residual risk.



Corruption/security

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]

Life phases: Operation, Commissioning

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Corruption/security

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]

Life phases: Commissioning, Maintenance, Operation

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Corruption/security

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]

Life phases: Commissioning, Maintenance, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Life phase: Setting up

Mechanical

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).

Life phases: Operation, Setting up, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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).
- 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.

Residual risk: Accepted residual risk.

Mechanical

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.

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Operation, Setting up, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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-



Robotic welding cell RSZ-2600 (assembly of machinery)

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

up mode and fault-finding: always keep the enabling device activated, never enter the pivoting area without the enabling device.

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Operation, Setting up, Troubleshooting

PROTECTIVE MEASURES

- 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).
- 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).
- 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.



Robotic welding cell RSZ-2600 (assembly of machinery)

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

PPE: Prescribe the wearing of safety footwear (EN ISO 20345, protection class S2 or S3) at the loading station as residual risk protection.

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Troubleshooting, Maintenance, Setting up

PROTECTIVE MEASURES

- 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).
- 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).

- 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.

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Operation, Setting up, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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).

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Setting up, Maintenance, Cleaning

PROTECTIVE MEASURES

- 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.
- 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).
- 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.

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Operation, Setting up

PROTECTIVE MEASURES

- 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).
- 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.
- 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.

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Operation, Setting up, Maintenance, Cleaning, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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).

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Setting up, Maintenance, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Electrical

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.

Life phases: Setting up, Operation, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.



Electrical

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).

Life phases: Operation, Setting up

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Thermal

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.

Life phases: Operation, Setting up

PROTECTIVE MEASURES

- 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.
- 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).
- 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.

Residual risk: Accepted residual risk.

Thermal

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.

Life phases: Operation, Setting up

PROTECTIVE MEASURES

- 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.
- 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.
- 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).

Residual risk: Accepted residual risk.

Thermal

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.

Life phases: Maintenance, Setting up, Cleaning

PROTECTIVE MEASURES

- 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).
- 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.
- 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.

Residual risk: Accepted residual risk.

Radiation

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.

Life phases: Setting up, Operation

PROTECTIVE MEASURES

- 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.
- 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.
- 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).

Residual risk: Accepted residual risk.

Radiation

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.

Life phases: Operation, Setting up, Maintenance

PROTECTIVE MEASURES

- 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.
- 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.
- 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).



Robotic welding cell RSZ-2600 (assembly of machinery)

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

Residual risk: Accepted residual risk.

Substances/materials

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.

Life phases: Operation, Setting up, Maintenance, Cleaning

PROTECTIVE MEASURES

- 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.
- 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.
- 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).

Residual risk: Accepted residual risk.



Noise

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.

Life phases: Operation, Setting up

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Ergonomic

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.

Life phases: Operation, Setting up, Maintenance, Cleaning

PROTECTIVE MEASURES

- 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.
- 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).
- 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.

Residual risk: Accepted residual risk.

Mechanical

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.

Life phases: Operation, Setting up

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Corruption/security

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]

Life phases: Operation, Setting up

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Life phase: Operation

Mechanical

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.

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Substances/materials

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.

Life phases: Operation, Maintenance, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Thermal

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.

Life phases: Operation, Maintenance

PROTECTIVE MEASURES

- 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.
- 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.
- 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).

Residual risk: Accepted residual risk.

Ergonomic

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.

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

Corruption/security

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]

Life phases: Operation, Maintenance, Troubleshooting

PROTECTIVE MEASURES

- Provide event logging as a fixed function of the control system (not deactivatable by the operator), with a non-volatile memory of sufficient capacity.
- 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.
- 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.

Residual risk: Accepted residual risk.

Corruption/security

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]

PROTECTIVE MEASURES

- 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).
- 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.
- Operating instructions: responsibility of the operator for data quality, description of the checks and notifications, instructions in the event of rejected data sets.

Residual risk: Accepted residual risk.

Corruption/security

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]

Life phases: Operation, Maintenance, Troubleshooting

PROTECTIVE MEASURES

- 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).
- 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.
- 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.

Residual risk: Accepted residual risk.

Life phase: Maintenance

Substances/materials

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.

Life phases: Maintenance, Cleaning

PROTECTIVE MEASURES

- 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.
- 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.
- 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.



Robotic welding cell RSZ-2600 (assembly of machinery)

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

Residual risk: Accepted residual risk.

Substances/materials

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.

Life phases: Maintenance, Troubleshooting

PROTECTIVE MEASURES

- 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.
- 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.
- 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.

Residual risk: Accepted residual risk.

3 Technical data

Parts of this chapter were taken automatically from: Project master data.

- Machine/installation: Robotic welding cell RSZ-2600 (assembly of machinery)
- Type/model: RSZ-2600
- Serial number: RSZ2600-2026-0001
- Year of manufacture: 2026
- Machine type: Assembly of machinery within the meaning of Art. 3 No. 1 lit. d MR
- Operating modes: Automatic operation, set-up / jogging, maintenance mode, transport and installation, cleaning, fault clearance, decommissioning / dismantling
- Nameplate: on the right-hand side wall of the control cabinet; information shown: manufacturer, type, serial number, year of manufacture, electrical connection values, weight, CE marking

3.1 Equipment

Dimensions and weights: Floor area of the cell approximately 6.5 x 4.0 m; height 2.6 m; total weight approximately 4,600 kg. Heaviest individual assemblies: two-station rotary table approximately 1,900 kg, robot with base approximately 850 kg, control cabinet approximately 350 kg, welding power source with wire feeder approximately 120 kg, welding fume extraction unit approximately 250 kg, protective fence segments total approximately 400 kg; enclosure with protective fence, interlinking and media installation approximately 730 kg.

Workpiece data: maximum workpiece weight 40 kg; maximum build envelope 800 x 600 x 400 mm; materials: unalloyed and low-alloy steel; cycle time approximately 90 seconds.

Electrical equipment: rated voltage 400 V AC, 3/N/PE, 50 Hz; network form TN-S; connected load 32 kVA; supply-side fusing 63 A gG; control voltage 24 V DC; residual current protective device Type B; electrical equipment designed in accordance with EN 60204-1.

Welding technology: MAG welding power source 400 A at 60 per cent duty cycle; maximum no-load voltage 80 V; wire feeder for wire diameters 1.0 to 1.2 mm; torch cleaning station with spray unit and wire cutter; shielding gas mixed gas M21 in accordance with EN ISO 14175 (supplied by customer), flow rate approximately 15 l/min.

Robot: articulated-arm industrial robot with 6 axes; reach 2,600 mm; payload 12 kg; repeatability +/- 0.05 mm; safely reduced speed in set-up mode maximum 250 mm/s at TCP.

Rotary table: two-station rotary table with vertical axis of rotation, rotation 180 degrees; load capacity 2 x 40 kg plus clamping fixtures; rotation time approximately 3 seconds; pneumatic workpiece clamps with pressure monitor and pressure-maintaining valve.

Pneumatics: operating pressure 6 bar; compressed air quality oil-free in accordance with ISO 8573-1; connection G 1/2; average air consumption approximately 90 NI/min.



Welding fume extraction: extraction capacity 1,800 m³/h; filter cartridge welding fume class W3 (also covers high-alloy steels; requirement from the risk assessment in accordance with TRGS 528); recirculation mode, optional exhaust air connection; monitoring of extraction capacity with fault message.

Noise emission (declaration in accordance with EN ISO 4871): A-weighted emission sound pressure level at the operator station L_{pA} = 84 dB(A), measurement uncertainty K = 2.5 dB, determined in accordance with EN ISO 11202; A-weighted sound power level L_{WA} = 96 dB(A), determined in accordance with EN ISO 3746. The values stated are emission values and do not necessarily correspond to the immission values at the workplace. The operator is required to provide hearing protection from a daily noise exposure level of 80 dB(A); from 85 dB(A) there is an obligation to wear hearing protection and to provide appropriate marking.

Operating environmental conditions: ambient temperature +5 to +40 degrees C; relative humidity up to 70 per cent, non-condensing; installation altitude up to 1,000 m above sea level; indoor dry locations only; no potentially explosive atmosphere; air velocity in the area of the loading opening below 0.5 m/s so that the shielding gas coverage is not disturbed.

4 Description of the machine

Parts of this chapter were taken automatically from: Project master data.

The RSZ-2600 is a robot-assisted MAG welding cell for arc welding of steel assemblies with a workpiece weight of up to 40 kg in series production. It is designed as a custom machine in single-unit manufacture and is placed on the market as an assembly of machinery with a shared control system as a single unit. The basic principle: whilst the operator loads and unloads workpieces at the front station of the two-station turntable, the robot welds at the second station behind the fixed dividing wall. The 180-degree rotation of the turntable alternates the stations at a cycle time of approximately 90 seconds. This chapter describes the structure of the system with its main assemblies, the operator workstations and the functional sequence.

4.1 Structure and Main Assemblies

The system consists of the following main assemblies:

- (1) Articulated-arm industrial robot: 6 axes, reach 2,600 mm, payload 12 kg, mounted on a steel base; supplied by the robot manufacturer as partly completed machinery with a declaration of incorporation in accordance with Annex V Part B; with robot controller and teach pendant.
- (2) Two-station turntable: vertical axis of rotation with 180-degree rotation, fixed dividing wall with welding protection curtain, pneumatic workpiece clamps with pressure monitor per station; load capacity 2 x 40 kg plus clamping fixtures.
- (3) Welding equipment: MAG welding power source 400 A at 60 per cent duty cycle (CE-marked sub-machine), wire feed unit on the robot arm, hose assembly, welding torch with collision protection coupling, torch cleaning station with nozzle cleaning, spray unit and wire cutter.
- (4) Welding fume extraction: Extraction unit 1,800 m³/h with filter cartridge and capture hood above the welding area; monitoring of extraction capacity.
- (5) Protective enclosure: Continuous protective fence 2,200 mm with weld-light-opaque sheeting and base panel; maintenance door at the rear with interlock and guard locking; type 4 light curtain at the loading opening.
- (6) Control system: Control cabinet with main switch, safety PLC and system controller; signal exchange between all sub-machines via the shared control system.
- (7) Operator panel: HMI panel with programme display, pushbutton for cycle start and acknowledgement, operating mode selector switch, emergency stop; signal tower (green/yellow/red) on the cell roof.
- (8) Media supply: Maintenance unit for compressed air with isolating valve and residual pressure indicator; connection for the customer-supplied shielding gas supply.

4.2 Operator Workstations

Loading station (front side): The operator's workstation for loading and unloading workpieces at the respective front station of the turntable. Access is through the loading opening monitored by the light curtain. The operator stands outside the robot working area; the fixed dividing wall shields against the arc and weld spatter.

Operator panel (adjacent to the loading opening): HMI panel for programme selection and status display, pushbutton for cycle start and acknowledgement, lockable operating mode selector switch, emergency stop control device. There is a line of sight from the operator panel to the loading opening.

Teach pendant (setter): Robot hand-held control device with emergency stop and three-position enabling device for teaching and traversing in setup mode. Use is reserved for the trained setter.

Maintenance access (rear side): Maintenance door with interlock and guard locking; access for maintenance and setup work only when the system has been shut down or in setup mode. No workstation inside the cell is provided during automatic operation.

4.3 Functional Description

Sequence of an automatic cycle:

1. The operator loads the workpiece into the clamping fixture at the front station. The pneumatic clamps close; the pressure monitor confirms the clamping pressure and the correct workpiece position.
2. The operator leaves the protective field of the light curtain and activates the cycle start pushbutton on the operator panel. The control system checks that the protective field is clear and that all safety functions have been acknowledged.
3. After an acoustic start warning, the turntable rotates 180 degrees: the freshly loaded station swings into the welding area and the station with the finished welded workpiece swings towards the operator.
4. The robot executes the released welding programme at the rear station. The welding fume extraction runs under process control; torch cleaning is carried out under programme control at defined intervals.
5. In parallel, the operator removes the finished workpiece at the front station and loads the next blank. The cycle time is approximately 90 seconds.
6. After the programme has ended and the cycle start has been activated again, the sequence repeats. In the event of faults (for example, arc interruption, wire end, extraction fault), the system stops in a controlled manner; the fault is displayed on the HMI and the signal tower switches to red.

In setup mode (key switch), the turntable and robot may only be traversed using the enabling device and at safely reduced speed; the automatic cycle is inhibited.

5 Delivery, transport, unpacking

Parts of this chapter were taken automatically from: AI suggestion.

This chapter describes the safe delivery, in-plant transport and unpacking of the RSZ-2600 robotic welding cell. The system is delivered in the following pre-assembled transport units: (1) robot with steel base in the locked transport position on a transport frame with fork pockets; (2) two-station turntable with secured rotary axis on a transport frame; (3) control cabinet with operator panel; (4) MAG welding power source with wire feeder and torch cleaning station on a pallet; (5) welding fume extraction unit on a pallet; (6) protective fence segments, maintenance door and light curtain in mesh containers. All units are film-wrapped and secured against shifting; small parts and documentation are located in a labelled accessory box in the control cabinet transport frame.

5.1 Safety Instructions for Transport and Handling

Transport and handling of the machine and its assemblies may only be carried out by trained specialist personnel who are familiar with the loads involved. Wear appropriate personal protective equipment for all transport and unpacking work, in particular safety shoes and appropriate protective gloves.

WARNING: When lifting and moving heavy assemblies, there is a hazard from falling, tipping or swinging loads. Never stand beneath suspended loads and secure the transport area against unauthorised access.

Inspect the machine immediately upon delivery for externally visible transport damage and for completeness. Document any damage identified and report it before installation. The exact scope of delivery is to be taken from the shipping documents.

5.2 Weights, Centre-of-Gravity Positions and Transport Equipment

The masses and centre-of-gravity positions of the individual assemblies are decisive for the selection of transport equipment, lifting equipment and lifting accessories:

- Total mass of the system: approximately 4,600 kg (distributed across several transport units)
- Two-station turntable: approximately 1,900 kg, centre of gravity centrally above the rotary axis, centre-of-gravity position marked on the frame
- Robot with steel base: approximately 850 kg, top-heavy; observe the centre-of-gravity marking on the transport frame
- Control cabinet with operator panel: approximately 350 kg
- Welding fume extraction unit: approximately 250 kg
- MAG welding power source with wire feeder: approximately 120 kg
- Protective fence segments total: approximately 400 kg

Permitted transport equipment: forklift truck with sufficient residual load capacity (at least 2.5 t) and sufficient fork length for the turntable and robot; overhead crane with tested lifting accessories (load capacity at least 2 t) for positioning in confined spaces; pallet truck only for pallet units up to 300 kg. Lifting equipment, industrial trucks and lifting accessories must be rated and tested for the actual load to be moved. Use only lifting accessories that are in perfect condition and approved, and observe their load capacity.

5.3 Lifting Points and Safe Lifting

Use only the designated lifting and load attachment points for lifting:

- Robot with base: four marked crane eyes on the steel base; never attach lifting accessories to the robot arm, the cabling or the hose assembly. Alternatively, transport by forklift using the fork pockets of the transport frame.
- Turntable: fork pockets in the base frame or four crane eyes at the frame corners; the centre partition is not load-bearing and must not be used as a lifting point.
- Control cabinet: crane eyes on the top of the cabinet (remove before commissioning and replace with blanking plugs).
- Pallet units (power source, extraction unit): transport by forklift or pallet truck on the pallet.

Attach the load in such a way that tipping, shifting or swinging is ruled out (maximum angle of inclination of lifting accessories 60 degrees, use edge protection). Lift slowly and without jerking, guide the load in a controlled manner and set it down without impact. Secure loads during in-plant transport in accordance with EN 12195-1.

5.4 Transport Securing Devices

All transport securing devices are marked in red. The following must be removed before commissioning: (1) locking bolts of the turntable rotary axis on the base frame; (2) transport locking devices on the robot axes (the robot is in the marked transport position; release is carried out in accordance with the manufacturer's instructions only after the base has been anchored); (3) tensioning straps and edge protection on the transport frames; (4) locking clips on the maintenance door and fence elements. Sequence: remove transport securing devices only after the respective assembly has been aligned and anchored at its final installation location (see Chapter 8). Retain all transport securing devices for a later transport or decommissioning; the designated storage location is the base compartment of the control cabinet.

5.5 Unpacking

Unpack the machine and its assemblies on a suitable, load-bearing and level surface. When opening the packaging, proceed in such a way that neither the machine nor personnel are put at risk, and avoid damage to attachments, lines and guards and protective devices. Dispose of the packaging material properly and in accordance with local regulations. After unpacking, check completeness again against the shipping documents.



5.6 Storage Prior to Installation

If the machine is to be stored temporarily before installation, the permissible storage conditions in accordance with Chapter 6 must be observed: dry, enclosed spaces, -10 to +50 degrees C, maximum relative humidity 60 per cent, non-condensing. The packaging and protective covers must remain on the machine until installation. For a storage period exceeding 12 months, the additional inspections in accordance with Chapter 6.2 apply.

6 Storage conditions

Parts of this chapter were taken automatically from: AI suggestion.

This chapter describes the conditions for the storage of the robotic welding cell RSZ-2600 as well as its components and assemblies between delivery, installation and any subsequent intermediate storage. The aim is to prevent damage caused by inadmissible ambient conditions, corrosion and excessively long standstill periods.

Permissible storage conditions: storage temperature -10 to +50 degrees C; relative humidity maximum 60 percent, non-condensing. The machine is to be stored dry, clean and protected from the weather in enclosed spaces. Condensation, direct moisture, large temperature fluctuations and aggressive atmospheres (for example air containing salt or chlorine) are to be avoided.

The machine contains electrical equipment, pneumatic components as well as a MAG welding power source with wire feed and a welding fume extraction system with filter cartridge. These assemblies are particularly sensitive to moisture and contamination. The robot controller and control cabinet are to be covered against dust; the doors are to be kept closed. During intermediate storage, the protective covers and packaging provided by the manufacturer are to be retained or restored. Welding wire is to be stored dry and in the original packaging.

6.1 Corrosion Protection

Bare and uncoated metal surfaces, in particular the clamping surfaces of the positioner, guides and clamping fixtures, are to be treated with acid-free anti-corrosion oil or preservative wax prior to storage. The corrosion protection is to be renewed if the storage period exceeds 6 months. Any corrosion protection present upon delivery must not be removed without necessity; prior to commissioning it is to be removed without residue from functional surfaces. During extended storage, the condition of the corrosion protection is to be checked quarterly and renewed as required. Humid or saline ambient air is to be avoided.

6.2 Maximum Storage Period and Periodic Inspections

The maximum permissible storage period without special measures is 12 months. During storage, quarterly inspections are to be carried out: condition of the corrosion protection, dryness and cleanliness of the storage location, integrity of packaging and protective covers.

If the storage period of 12 months is exceeded, the following are to be carried out prior to commissioning: visual inspection of all assemblies for corrosion and damage; inspection or replacement of the buffer batteries of the robot controller (loss of axis references possible); insulation measurement of the electrical equipment; inspection of the pneumatic components for hardened seals; functional check of all safety devices in accordance with Chapter 8 (initial commissioning). In case of doubt, the manufacturer is to be consulted.

7 Installation conditions

Parts of this chapter were taken automatically from: Project master data.

Intended installation site: Musterstadt plant, Hall 2. The machine is intended for stationary installation in a dry production hall. This chapter describes the requirements regarding space requirements, foundation, ambient conditions and utility connections that the operator must ensure on the building side prior to delivery.

7.1 Space Requirements and Dimensions

Footprint of the cell: approximately 6.5 x 4.0 m; height 2.6 m. A clear space of at least 1.0 m must be provided all around the cell for operation, maintenance and escape routes; at least 1.2 m in front of the maintenance door at the rear (door swing radius plus working space). In front of the loading opening, an operating and staging area of at least 2.0 m depth must be kept clear for workpiece staging and material flow. Required clear hall height: at least 3.2 m (installation and maintenance work on the cell roof). The access routes must be checked prior to delivery: largest transport unit (tilting table) approximately 2.4 x 1.8 x 2.0 m, 1,900 kg. Traffic routes and hazard areas must be marked in accordance with ASR A1.8.

7.2 Foundation / Load-Bearing Capacity

The machine is installed on a level industrial concrete floor; a separate foundation is not required. Requirements: concrete grade at least C25/30, floor slab thickness at least 200 mm, flatness +/- 5 mm relative to the installation area, area load at least 10 kN/m². The robot base and tilting table base frame are anchored to the floor using heavy-duty anchors (M16, anchorage depth in accordance with the anchor manufacturer's approval); the dynamic forces of the robot (overturning moment at the base up to approximately 8 kNm) must be absorbed by the anchorage. The floor must be free of cracks in the anchorage area; minimum edge distances of the anchors must comply with the anchor approval. Floor coverings or coatings must not impair force transfer. In the event of deviating floor conditions, the load-bearing capacity must be assessed on the building side by a competent person.

7.3 Ambient Conditions

The following ambient conditions must be maintained at the installation site: ambient temperature +5 to +40 degrees C; relative humidity up to 70 per cent, non-condensing; installation altitude up to 1,000 m above sea level; dry indoor environment, no potentially explosive area, no aggressive or heavily dust-laden atmosphere. Draughts in the area of the loading opening must be avoided (air velocity below 0.5 m/s), as they disturb the shielding gas coverage of the welding process and impair the effectiveness of the fume extraction; hall doors and ventilation outlets must be arranged accordingly. The installation area must be low in vibration (no immediate proximity to presses or punching machines with strong floor vibrations), so that the repeatability of the robot and the function of the safety sensors are not impaired.

Electromagnetic environment: The cell is intended for industrial environments (immunity in accordance with EN IEC 61000-6-2, emission in accordance with EN IEC 61000-6-4, evidence in test report RSZ-2600-EMV-001). It is not intended for residential environments or for connection to a public low-voltage network that also supplies residential buildings. Cable routing, cable shield connections and equipotential bonding in accordance with electrical circuit diagram RSZ-2600-EPL-001 may only be changed by qualified personnel with EMC knowledge; welding current cables and control cables remain in separate cable ducts. After replacing the welding power source, the robot controller or safety components, repeat the functional test of safety functions SF-01 to SF-05.

7.4 Utility Connections

The following utility connections must be provided on the building side for the operation of the machine:

- Electrical: 400 V AC, 3/N/PE, 50 Hz, network type TN-S; connected load 32 kVA; building-side fusing 63 A gG; supply cable 5 x 16 mm² Cu (reference value, observe installation method) to the main switch of the control cabinet; clockwise phase rotation required; foundation earth electrode or equipotential bonding in accordance with VDE regulations.
- Compressed air: 6 bar (+/- 0.5 bar), oil-free in accordance with ISO 8573-1; connection G 1/2 at the service unit; minimum flow rate 200 NI/min; building-side shut-off valve near the machine recommended.
- Shielding gas: mixed gas M21 in accordance with EN ISO 14175 (82 per cent argon, 18 per cent CO₂) from a central ring main or cylinder battery; flow pressure 2 to 4 bar, flow rate approximately 15 l/min; secure cylinders against tipping.
- Extraction: The welding fume extraction operates in recirculation mode; optionally, a building-side exhaust air duct (connection DN 250) may be provided. The operator is responsible for ensuring adequate hall ventilation in accordance with TRGS 528.
- Lighting: An illuminance of at least 500 lux must be ensured at the operator station (value from the risk assessment for set-up and inspection tasks; machine-integrated lighting in accordance with EN 1837).

8 Assembly and installation, initial commissioning

Parts of this chapter were taken automatically from: AI suggestion.

Assembly, installation and initial commissioning are carried out by the manufacturer or by specialist personnel commissioned by the manufacturer. This chapter describes the requirements and procedures; it also serves the operator as a reference for a later repositioning within the plant, which may only be carried out in consultation with the manufacturer.

8.1 Safety

Assembly, installation and initial commissioning of the RSZ-2600 robotic welding cell may only be carried out by trained specialist personnel with qualifications in mechanical engineering, electrical engineering, pneumatics and welding technology. The robot is 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; the associated assembly instructions of the robot manufacturer must be observed additionally for all work on this component.

Before commencing all mechanical and electrical work, the machine must be safely isolated from the energy supply: switch off the main switch and secure it in the zero position with a padlock (LOTO), shut off the compressed air at the isolating valve of the service unit and vent it, check for absence of pressure at the residual pressure indicator, and verify that the supply is de-energised by a qualified electrician. The key and lock regime of the operator must be applied.

WARNING: Before the energy supply is connected for the first time, no persons may be present in the robot working area or in the pivoting range of the turntable. During assembly, unexpected movements of robot axes and the turntable can cause serious injuries.

In addition to the electrical hazard, the pneumatic system as a pressurised system, the hazardous substances of the MAG welding process and the noise exposure must also be taken into account. Before work on the clamping circuit and on the pneumatic workpiece clamps, the pneumatic circuit must be depressurised. During the work, at a minimum the following must be worn: safety shoes S1P, protective gloves, and a safety helmet for overhead work; for welding trials, additional welding protective equipment in accordance with Chapter 2.6.

The technical documents required for assembly, in particular the general arrangement drawing and overview drawing, electrical and pneumatic circuit diagrams, and the safety circuit diagrams, must be made available before work commences.

8.2 Assembly and Installation

The RSZ-2600 robotic welding cell is erected as an assembly of machinery. A floor area of approximately 6.5 x 4.0 m with a height of 2.6 m must be provided for installation; the requirements regarding foundation, load-bearing capacity and environment in accordance with Chapter 7 must be met.

Assembly sequence:

1. Align the turntable at the position indicated on the installation plan (check levelness with a precision spirit level) and anchor it with four heavy-duty anchors M16; tightening torque in accordance with the anchor approval (reference value 110 Nm).
2. Position the robot base, measure it relative to the turntable in accordance with the installation plan and anchor it with four heavy-duty anchors M16; only then release the transport locking devices on the robot axes.
3. Install the control cabinet with operator panel as well as the welding power source and extraction unit; mount the torch cleaning station on the base.
4. Assemble the protective fence segments, base panels, maintenance door with interlock/guard locking and light curtain in accordance with the installation plan; maintain safety distances in accordance with EN ISO 13857 and EN ISO 13855 as shown in the drawing.
5. Electrical installation by a qualified electrician in accordance with the circuit diagrams: supply cable to the main switch, equipotential bonding of all assemblies, wiring of the sub-machines and safety circuits; check the direction of rotation.
6. Connect the pneumatics in accordance with the pneumatic diagram (6 bar, connection G 1/2); carry out a leak test.
7. Connect the shielding gas supply and purge the lines; connect the extraction system and align the capture hood.

After all connections have been made, the following must be checked: secure seating of all fastenings and anchorages, complete enclosure, function of the interlocked maintenance door with guard locking, correct alignment of the light curtain, and complete removal of all transport securing devices (Chapter 5.4).

8.3 Initial Commissioning

Initial commissioning may only take place after assembly and installation have been fully completed and all guards and protective devices have been correctly fitted and connected. Before the energy supply is connected for the first time, it must be ensured that no persons are present in the robot working area, in the pivoting range of the turntable or within the protective fence.

As part of initial commissioning, the safety-relevant tests in accordance with the manufacturer's test plan must be carried out and documented in the acceptance report:

- Protective conductor test and insulation measurement in accordance with EN 60204-1 (electrical test report)
- Effectiveness of the emergency stop circuit at all control devices (operator panel, maintenance door, teach pendant)
- Function of the light curtain including overrun measurement and verification of the safety distance in accordance with EN ISO 13855
- Function of the interlocked maintenance door with guard locking and the restart prevention device

- Function of the pressure monitoring on the clamping circuit and of the pressure-holding valve in the clamping line
- Function of the enabling device, operating mode selector switch and safely reduced speed (measurement at the TCP, maximum 250 mm/s)
- Effectiveness of the welding fume extraction system (volumetric flow measurement)
- Validation of all safety functions in accordance with EN ISO 13849-2 (documentation in the safety verification record)

Trial runs then follow: first a dry cycle without a workpiece in set-up mode, then automatic cycles with a workpiece and evaluation of the welding results. The welding programmes used must have been approved; the intended use in accordance with Chapter 2.1 must be observed.

The results of the initial commissioning must be documented in the test and acceptance reports. The machine is handed over to the operator and production operation is commenced only after the successful completion of all safety function tests, documented acceptance and instruction of the operating personnel.

9 Operation

Workpieces exceeding 15 kg must only be handled using the lifting aid available at the loading station (balancer or customer-supplied crane system); the maximum load per workpiece is 40 kg.

This chapter is addressed to the operator and the setter of the robot welding cell RSZ-2600. A documented induction and knowledge of Chapter 2 (Safety) are prerequisites for all activities. The operator works exclusively at the loading station and at the control panel; activities inside the cell are reserved for the setter and maintenance personnel. The prescribed personal protective equipment in accordance with Chapter 2.6 must be worn during all work.

9.1 Safety

The following safety rules apply to operation:

- The machine may only be operated with all guards fully fitted and functional. The daily checks in accordance with the Start-up section must be carried out before the start of each shift.
- Never reach into the robot working area, bypass guards, or tamper with the light curtain. No person shall remain within the slewing range of the turn-over positioner during turning.
- Workpieces shall only be inserted and removed when the front station is stationary. Hot workpieces must only be handled with protective gloves; workpieces may be in excess of 150 degrees C after welding.
- Do not look directly into the arc, including via reflections; the welding protection curtain and the fence screening must be undamaged.
- Operation is only permitted with the welding fume extraction system in effective operation. If an extraction fault message occurs, the cycle shall be completed and the fault rectified.
- Faults, damage, and unusual noises must be reported immediately; the machine must be stopped in the event of safety-relevant deficiencies and secured against restart.
- Only the operator shall remain in the area of the loading opening; other persons must keep the marked operating area clear.

9.2 Controls and Indicators

Main switch (on the control cabinet): disconnects the entire system on all poles; can be locked in the zero position for maintenance and repair.

Control panel adjacent to the loading opening:

- HMI panel: programme selection, piece counter, display of operating status and fault messages in plain text, display of maintenance intervals.
- Cycle start pushbutton (green): starts the automatic cycle when the protective field is clear and no fault is pending.
- Acknowledgement/Reset pushbutton (blue, illuminated): acknowledgement following activation of a guard, after emergency stop unlocking, and after fault rectification; flashes when

acknowledgement is required.

- Emergency stop command device (red on yellow background): stops the entire system in hazardous situations.
- Operating mode selector switch (key switch): positions Automatic and Setting; the key remains with the authorised person.

Signal tower on the cell roof: green = automatic operation running; yellow = system waiting (end of cycle, material shortage, acknowledgement required); red = fault or emergency stop; additionally, an acoustic start-up warning prior to every automatic start.

Teach pendant (setters only): robot hand-held programming device with display, jog keys, three-position enabling device, and its own emergency stop.

Further indicators: pressure gauge of the service unit (compressed air), residual pressure indicator at the maintenance access, flow indicator for the shielding gas at the welding power source, differential pressure indicator of the filter cartridge at the extraction unit.

9.3 Operating Modes

The machine has the following operating modes:

Automatic mode (selector switch in Automatic position): normal operation for series production. All guards are active; the maintenance door is locked; access is exclusively through the light curtain monitored loading opening. The cycle runs automatically after release by the cycle start pushbutton.

Setting/Jogging (selector switch in Setting position, key switch): operating mode for teaching, programme testing, and fault rectification by the trained setter. Movements of the robot and turn-over positioner are only possible with the three-position enabling device on the teach pendant activated and at safely reduced speed (maximum 250 mm/s at the TCP). The key remains with the authorised person; after completing the work, it is mandatory to switch back to the Automatic position.

Maintenance mode: maintenance with the machine isolated and secured against restart (main switch locked, compressed air relieved); see Chapter 10.

The further lifecycle phases of transport and installation (Chapters 5 and 8), cleaning and fault rectification (Chapter 10), and decommissioning and dismantling (Chapter 11) are described in the respective chapters indicated. Cleaning work shall always be carried out with the machine stopped and isolated.

9.4 Start-up and Change-over

Daily start-up (observe the sequence):

1. Visual inspection: safety fence, fence screening, welding protection curtain, light curtain, and maintenance door undamaged; no persons or foreign objects in the cell; operating area clear.
2. Open media supplies: open compressed air isolating valve (6 bar at the service unit), open shielding gas supply (flow approximately 15 l/min), check wire stock.



3. Switch on the main switch; wait for the control system to complete its start-up sequence.
4. Functional check of the light curtain using the test rod (interruption of each beam zone must trigger a message); functional check of one emergency stop command device on a weekly rotation.
5. Switch on the extraction system and verify effectiveness (differential pressure indicator in the green range).
6. Select the welding programme on the HMI, acknowledge fault messages, release the system using cycle start.

Change-over and product change (setters only): programme change on the HMI; replacement of workpiece-specific clamping fixtures only with the system stopped and the clamping circuit depressurised; after every change-over, carry out a first-off inspection and document the approval. Replace wear parts on the torch (contact tip, gas nozzle) according to the specified service life.

Teaching new programmes (setters only): exclusively in setting mode with the enabling device and reduced speed; new programmes must be verified in automatic mode without a workpiece before release; the release must be documented.

9.5 Shutdown

Shutdown during normal operation (end of shift):

1. Allow the current cycle to complete; do not abort mid-welding process.
2. Remove the finished workpiece; move the system to the home position via the HMI.
3. Allow the extraction system to run on (automatic run-on of at least 10 minutes, fire protection requirement of the risk assessment); afterwards carry out a visual check of the filter housing for unusual heating or the smell of burning.
4. Close the shielding gas supply; close the compressed air isolating valve during prolonged standstill.
5. Switch off the main switch. For weekend or operational shutdowns, additionally lock the main switch.

Emergency shutdown: activate the emergency stop command device. All sub-machines are brought to a controlled stop (stop category 1); the signal tower changes to red.

Restart after emergency stop:

1. Identify and eliminate the cause of the hazardous situation; ensure that no persons are inside the cell.
2. Unlock the actuated emergency stop command device (by rotating or pulling).
3. Acknowledge at the control panel; then initiate cycle start. A workpiece for which the welding process was interrupted must be marked as a rework part and inspected.

Behaviour following a power failure: After power is restored, the system remains stopped due to the restart prevention feature. Before acknowledgement, the system status must be checked (workpiece position, torch position, clamping pressure); then acknowledge and restart as after an emergency stop. If the torch is trapped or has collided, call the setter.

10 Maintenance and servicing

Parts of this chapter were taken automatically from: AI suggestion.

This chapter is addressed to the specialist maintenance personnel responsible for the maintenance of the robotic welding cell RSZ-2600. All maintenance work is to be carried out exclusively in maintenance mode and with the machine at a standstill. Before commencing work, the machine is to be isolated via the main switch with a lockable zero position and secured against restart. The pneumatic supply is to be switched to a depressurised state. Additionally, observe the manufacturer's documentation for purchased components, in particular the installation instructions of the robot manufacturer as well as the documentation for the MAG welding power source, the wire feed, the torch cleaning station and the welding fume extraction system.

10.1 Maintenance Record

All inspection, maintenance and repair work carried out is to be documented in a traceable manner. The maintenance record serves as evidence of proper maintenance of the robotic welding cell RSZ-2600 and is to be retained for the entire service life of the machine. For each operation, the following information is to be entered in the maintenance record as a minimum: date, work carried out, spare parts and consumables used, name of the specialist personnel performing the work, and any irregularities identified. Safety-relevant inspections of the guards and protective devices, such as the light curtain, the maintenance door with guard locking and the emergency stop circuit, are to be noted separately. A form for the maintenance record is included in the appendix of these operating instructions; alternatively, an equivalent in-house system (for example maintenance software) may be used. The maintenance record is to be retained at least until the machine is decommissioned; the operator is responsible for this.

10.2 Inspection and Maintenance Schedule

The inspection and maintenance schedule specifies which tasks are to be carried out on the machine and at what intervals. The maintenance requirements of the respective manufacturer's documentation apply additionally for purchased components.

Daily (operator): visual inspection of the guards and protective devices; functional check of the light curtain using a test rod; check of extraction capacity (differential pressure indicator), shielding gas flow rate and compressed air pressure; check torch nozzles for spatter deposits; clean the working area.

Weekly (operator/setter): emergency stop functional check (alternating between each control device); check contact tip and gas nozzle of the torch, replace if worn; clean wire feed rollers and wire guide; drain condensate from the service unit; check welding protection curtain and fence panel for damage.

Monthly (setter/maintenance): clean torch cleaning station and refill spray agent; check pneumatic fittings and hoses for leaks; inspect extraction filter cartridge, replace if differential pressure is in the red zone; functional check of the guard locking of the maintenance door; check robot cables and hose assembly for chafing points.

Every six months (maintenance): documented functional check of all safety functions (SF-01 to SF-05) in accordance with the test plan in the appendix; check anchoring of the robot base and positioner (tightening torques); visual inspection of the electrical equipment.

Annually (manufacturer): major service in accordance with the maintenance contract, including robot maintenance as specified by the manufacturer (gearbox lubrication, robot controller batteries), calibration check of the robot, inspection of the interlock and guard locking in accordance with EN ISO 14119, recalculation or inspection of the safety distance of the light curtain in accordance with EN ISO 13855, inspection of the welding power source in accordance with EN 60974-4.

Additionally, the operator's statutory inspection obligations under BetrSichV and DGUV Vorschrift 3 apply (periodic inspection of the electrical equipment). Damaged or worn components of the guards and protective devices are to be repaired or replaced before the machine is returned to service.

10.3 Lubrication Schedule

The lubrication schedule specifies which lubrication points on the machine are to be supplied at which intervals with which lubricants:

- Robot gearboxes (axes 1 to 6): lubrication exclusively within the scope of the annual manufacturer's service in accordance with the robot manufacturer's specifications (gearbox grease as specified in the robot documentation).
- Slewing ring and bearing of the positioner: lubricate every six months with multipurpose grease KP2K-30 in accordance with DIN 51502 (2 grease nipples on the base frame, approximately 10 g each).
- Guides and joints of the pneumatic workpiece clamps: apply a thin coat of acid-free machine oil monthly; do not use excessive quantities (spatter deposits).
- Hinges and interlock of the maintenance door: lubricate every six months with multipurpose grease.
- Torch cleaning station: refill the spray agent tank monthly (silicone-free anti-spatter agent).

The pneumatic components are designed for oil-free air and are not to be oiled. Use only the lubricants specified or equivalent lubricants approved by the manufacturer. Used consumables and lubricants are to be disposed of properly and in an environmentally responsible manner in accordance with Chapter 11.3. The machine is to be isolated for all lubrication work; wear suitable protective gloves.

10.4 Fault Rectification

Before any fault rectification: isolate the system via the main switch, secure against restart (LOTO) and wait for the discharge time to elapse. Access to the robot working area only via the interlocked maintenance door.

| Fault | Possible cause | Remedy |

| --- | --- | --- |

| System does not start in automatic mode | Safety circuit open (maintenance door, light curtain), emergency stop activated | Close safety doors, clear the light curtain, unlock emergency stop, acknowledge at the operator panel |

| Light curtain triggers for no apparent reason | Contamination or misalignment of the optics | Clean the front and receiver screens, check alignment (alignment indicator), then carry out functional check |

| Positioner does not rotate | Clamping pressure below setpoint, workpiece presence sensor not responding, protective field occupied | Check compressed air supply (6.0 bar), check workpiece clamping, clear the slewing area |

| Guard locking of the maintenance door does not release | Robot has not yet reached safe standstill, residual voltage waiting time running | Wait for standstill to complete (display on operator panel), then request again |

| Weld seam defective (spatter, porosity) | Wire feed disturbed, insufficient shielding gas, torch nozzle worn | Check wire feed and gas flow rate, replace nozzle/contact tip, check welding parameters |

| Extraction without performance / fault message | Filter cartridge saturated, extraction hood displaced | Replace filter cartridge (dust class W3, dispose of as hazardous waste), correct hood position |

| Robot stops with collision message | Collision detection triggered (torque/current monitoring) | Eliminate cause in the working area, check programme path, acknowledge message on the teach pendant |

If a fault cannot be remedied using these measures, the manufacturer is to be contacted (contact details on the title page). Unauthorised interventions in safety functions are not permitted.

11 Dismantling and disposal

Parts of this chapter were taken automatically from: AI suggestion.

This chapter describes the principles for the final decommissioning, dismantling and environmentally sound disposal of the RSZ-2600 robot welding cell. Dismantling is an independent operating mode and may only be carried out by trained, qualified personnel. Also observe the information contained in the associated technical documents, in particular the general arrangement drawing and overview drawing as well as the electrical and pneumatic circuit diagrams.

11.1 Safety Instructions for Dismantling

WARNING: During dismantling, hazards may arise from electrical energy, pressurised pneumatics, stored energies, moving masses as well as from hazardous substances and residues from the welding process.

Before commencing dismantling work, the machine must be safely stopped and disconnected from the energy supply on all poles: switch off the main switch and secure it with a lock in the zero position; have the supply cable isolated by a qualified electrician, secure it against re-energisation, verify that it is de-energised, earth and short-circuit it, and cover adjacent live parts (five safety rules). Wait at least 1 minute before opening (measured discharge time of the welding power source: 1.9 s to ≤ 60 V; the waiting time includes a safety margin).

The pneumatic system must be depressurised: close the shut-off valve, vent the system via the venting position of the service valve, check that pressure has been relieved at the residual pressure indicator; the workpiece clamps must be open and depressurised.

Movable assemblies with possible stored potential energy must be secured against unintentional movement before releasing fastenings: move the robot to the transport position and lock it with the stored transport locking device; lock the tilting table with the locking pin of the rotary axis.

Use suitable lifting and transport equipment as well as personal protective equipment for handling and removal of heavy assemblies. Masses and lifting points of the assemblies: see Chapters 5.2 and 5.3.

11.2 Dismantling Sequence

Dismantling is carried out in the reverse order of assembly (Chapter 8.2):

1. Disconnect utilities: shielding gas, compressed air and extraction connection; drain and label lines.
2. Disconnect electrical connections by a qualified electrician and label them; disconnect supply cable.
3. Dismantle the light curtain, maintenance door and protective fence segments.
4. Remove the welding power source, wire feeder, torch cleaning station and extraction unit.
5. Lock the robot in the transport position, release the anchorage, lift the robot with its base.
6. Lock the tilting table, release the anchorage, lift the tilting table; finally remove the control cabinet and operator panel.

The tightening and loosening torques of the connections are to be taken from the general arrangement drawing and the assembly documents. Chapters 5 and 6 apply to intermediate storage or onward transport.

11.3 Separation and Disposal of Operating Fluids

Prior to material separation, all operating and auxiliary materials must be drained, collected and separated in a proper manner. The following must be taken into account in particular: lubricating greases from the tilting table slewing ring and robot gearboxes; the anti-spatter agent from the torch cleaning station; welding wire residues; the filter cartridge of the welding fume extraction unit as well as deposited welding fume dusts in the housing and pipework.

CAUTION: The filter cartridge and the dust deposits from the extraction unit contain welding fume dusts and must be disposed of in dust-tight packaging as hazardous waste (waste code AVV 10 02 07* or in accordance with the classification of the disposal contractor). When handling the filter cartridge, wear FFP3 respiratory protection and disposable gloves.

Operating fluids, filter residues and components contaminated with hazardous substances must not enter household waste or the environment. Collect these materials separately and dispose of them through an authorised disposal facility. The safety data sheets of the substances used and the requirements of the regionally responsible licensed waste disposal company are applicable.

11.4 Material Separation and Recycling

After removing the operating fluids, the assemblies must be dismantled and the materials separated by type:

- Steel and cast iron (fence, frames, tilting table, base): scrap metal recovery
- Non-ferrous metals (copper cables, welding leads, contact tips): separate collection
- Electrical and electronic equipment (controls, drives, HMI, sensors, welding power source): separate collection and disposal as waste electrical and electronic equipment through authorised collection and recovery facilities
- Batteries and accumulators (buffer batteries of the robot controller): battery take-back system
- Plastics (covers, hoses, curtain): material or energy recovery
- Packaging and insulation material: local recovery channels

Observe the statutory and regulatory requirements applicable at the installation site during dismantling and disposal. In case of doubt, materials and operating fluids must be disposed of through a licensed waste disposal company; disposal must be documented.

12 Drawings and other information

Parts of this chapter were taken automatically from: Technical documentation.

The following documents are included in the Technical Documentation for the project:

- General arrangement drawing / overview drawing
- Circuit diagrams (electrical, pneumatic)
- Safety circuit diagrams / safety functions
- Strength calculations / structural analysis
- Performance Level verification (PLd/PLe)
- EMC test report
- Noise measurement report
- Test reports / test results
- Functional test of safety devices
- Protective conductor test / insulation measurement
- Acceptance report

12.1 Drawings and Spare Parts

The general arrangement drawing with overview drawing, the installation plan and the assembly drawings are included with the Technical Documentation (drawing set RSZ2600-Z-001 ff.).

Spare and wear parts: only original spare parts or equivalent parts approved by the manufacturer may be used. Principal wear parts: contact tips and gas nozzle of the welding torch, wire feed rollers, wire guide liner, welding protection curtain, extraction filter cartridge, base panel brushes and the seal kits for the pneumatic clamps. Ordering information: spare parts list RSZ2600-ET-001 in the Technical Documentation; always state the type and serial number of the machine when placing orders.

Contact for spare parts and technical enquiries: Muster Maschinenbau GmbH, Beispielstraße 1, 12345 Musterstadt, e-mail service@muster-maschinenbau.de.

12.2 Electrical Documentation

The complete electrical documentation in accordance with EN 60204-1 is included with the Technical Documentation: circuit diagrams (plan set RSZ2600-E-001), terminal and cable schedules, control cabinet layout drawing, bill of materials for electrical equipment, PLC and safety PLC programme documentation with signal list, as well as the test reports for the protective conductor test and insulation measurement. One copy of the circuit diagrams is kept in the control cabinet.

Modifications to the electrical installation may only be carried out by qualified electricians and only with the approval of the manufacturer; the drawings are to be updated accordingly when modifications are made.

12.3 Evidence of the risk assessment

Taken automatically from the project's risk assessment.

Table 5: Evidence of the risk assessment

Hazard	Life phases	Risk score	Residual risk
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.	Transport, Assembly	5	accepted
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.	Assembly, Commissioning	4	accepted
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.	Assembly	4	accepted
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]	Assembly, Commissioning, Operation	4	accepted
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.	Maintenance, Commissioning, Troubleshooting	5	accepted
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.	Commissioning, Setting up, Maintenance	5	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

Hazard	Life phases	Risk score	Residual risk
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).	Commissioning, Operation, Troubleshooting	5	accepted
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]	Setting up, Operation, Commissioning	4	accepted
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]	Operation, Commissioning	4	accepted
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]	Commissioning, Maintenance, Operation	3	accepted
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]	Commissioning, Maintenance, Troubleshooting	5	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

Hazard	Life phases	Risk score	Residual risk
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).	Operation, Setting up, Troubleshooting	5	accepted
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.	Setting up	5	accepted
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.	Operation, Setting up, Troubleshooting	5	accepted
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.	Operation, Setting up, Troubleshooting	4	accepted
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.	Troubleshooting, Maintenance, Setting up	5	accepted
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.	Operation, Setting up, Troubleshooting	5	accepted
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.	Setting up, Maintenance, Cleaning	6	accepted



Hazard	Life phases	Risk score	Residual risk
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.	Operation, Setting up	8	accepted
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.	Operation, Setting up, Maintenance, Cleaning, Troubleshooting	6	accepted
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.	Setting up, Maintenance, Troubleshooting	5	accepted
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.	Setting up, Operation, Troubleshooting	4	accepted
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).	Operation, Setting up	4	accepted
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.	Operation, Setting up	6	accepted
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.	Operation, Setting up	4	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

Hazard	Life phases	Risk score	Residual risk
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.	Maintenance, Setting up, Cleaning	3	accepted
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.	Setting up, Operation	4	accepted
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.	Operation, Setting up, Maintenance	4	accepted
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.	Operation, Setting up, Maintenance, Cleaning	6	accepted
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.	Operation, Setting up	6	accepted
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.	Operation, Setting up, Maintenance, Cleaning	2	accepted
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.	Operation, Setting up	5	accepted

**Robotic welding cell RSZ-2600 (assembly of machinery)**

Robot-assisted MAG welding cell for steel assemblies up to 40 kg

Original instructions

As of: 18/09/2026

Hazard	Life phases	Risk score	Residual risk
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]	Operation, Setting up	4	accepted
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.	Operation	5	accepted
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.	Operation, Maintenance, Troubleshooting	4	accepted
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.	Operation, Maintenance	3	accepted
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.	Operation	6	accepted
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]	Operation, Maintenance, Troubleshooting	3	accepted



Hazard	Life phases	Risk score	Residual risk
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]	Operation	3	accepted
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]	Operation, Maintenance, Troubleshooting	4	accepted
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.	Maintenance, Cleaning	3	accepted
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.	Maintenance, Troubleshooting	3	accepted

List of annexes

The following additional documents belong to the machine (annex to these operating instructions):

- Standards analysis (applied standards with justification)
- Risk assessment according to EN ISO 12100 (complete documentation)
- Test reports
- Declaration of Conformity



13 Cybersecurity

This chapter is intended for the operator and for the specialists responsible for networks and maintenance. It describes how the robotic welding cell RSZ-2600 is integrated into the operator's network, how the software version is checked and how remote maintenance and updates work. Where an intervention in the controller affects a safety function, the instructions in the Safety chapter also apply.

13.1 Integration into the operator's network

Connect the cell to the operator's network only through the supplied gateway. Do not connect any further devices or networks to the cell network inside the control cabinet.

- Place the gateway in a dedicated network segment for production equipment, not in the office network.
- Allow only the connections the cell needs: OPC UA from the MES to the cell and the VPN connection to the manufacturer's remote maintenance server.
- Do not set up a direct internet connection for the controller.
- Change firewall rules only after consulting the manufacturer.

13.2 Software version and evidence of interventions

Version and checksum of the safety-related software are shown on the operator panel under "Info" and can be viewed without logging in. Compare them with the acceptance report after every intervention, update and device replacement. The event log lists logins, parameter changes, software uploads and remote maintenance sessions with time stamp and user. If the values differ, do not release automatic mode and inform the manufacturer.

13.3 Remote maintenance

Remote maintenance is disabled on delivery. A session can only be enabled with the key switch at the control desk and ends automatically after four hours; while it is active, the operator panel shows "Remote maintenance active". A responsible person must be available on site. If you suspect unauthorised access, end the session immediately with the key switch and inform the manufacturer via the contact address for security reports.

13.4 Updates

During the support period until March 2039, the manufacturer provides security updates for the control, HMI and gateway software in the customer portal, with release notes and checksum. The manufacturer informs the registered contacts about new updates by e-mail; the security advisories are also published at <https://www.muster-maschinenbau.example/security/advisories>. To install an update:

- Download the update from the customer portal and compare the checksum with the release notes.



- Stop the cell, make sure that no automatic cycle can be started, and install the update via USB on the operator panel or in a remote maintenance session enabled on site.
- Afterwards compare the version and checksum under "Info" with the release notes and record them as the new reference in the acceptance report.
- Before releasing automatic mode, carry out and document the functional test of all safety functions SF-01 to SF-05 in accordance with the test plan in the annex (see chapter Maintenance).

13.5 Retaining logs

The controller protects the event log against deletion and modification and keeps software uploads with the associated data for up to five years after uploading. The log can be exported in readable form at the operator panel. Make sure the date and time of the controller are correct, otherwise the time stamps cannot be used. Pass the logs on to the new operator if the cell is transferred and make them available to an authority upon reasoned request.

13.6 Cybersecurity information

Taken automatically from the project's cybersecurity data.

This section contains the manufacturer's information on the cybersecurity of the machine.

The machine has the following digital interfaces:

**Table 6: Digital interfaces of the machine**

Interface	Protocol	Connection	Updates
Cell network to robot, rotary table and welding power source (Network / fieldbus / line integration)	PROFINET IO with PROFIsafe	On site at the machine only	On site by service personnel
Connection to the operator's MES (Network / fieldbus / line integration)	OPC UA (Sign & Encrypt) over Ethernet	Plant network	On site by service personnel
Remote maintenance via VPN gateway (Remote access / remote maintenance)	IPsec VPN over the operator's internet connection	Connection via the internet	Remotely
Operator panel at the control desk (Operator panel (HMI) with user and parameter management)	Touch operation with roles and user accounts	On site at the machine only	On site by service personnel
USB port on the operator panel (USB / removable media)	USB 2.0 for backups and program import	On site at the machine only	Via removable media
Programming access to the safety PLC and the robot controller (Engineering / programming access)	Engineering port (Ethernet) in the control cabinet	On site at the machine only	On site by service personnel

Name and contact details of the manufacturer

Muster Maschinenbau GmbH

Beispielstrasse 1, 12345 Musterstadt, Germany

service@muster-maschinenbau.example

<https://www.muster-maschinenbau.example>

Single point of contact for vulnerabilities and disclosure policy

Reporting vulnerabilities: security@muster-maschinenbau.example

Coordinated vulnerability disclosure policy: <https://www.muster-maschinenbau.example/security/disclosure>

Unique identification of the product

Product designation: Robotic welding cell RSZ-2600

Type: RSZ-2600

Further identification details: Serial number on the rating plate at the control desk; software version on the operator panel under "Info"



Intended purpose, security environment and security properties

Intended purpose: Robot-assisted MAG welding of steel assemblies up to 40 kg in series production, installed stationary in a production hall.

Security environment provided by the manufacturer: 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.

Essential functionalities: 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.

Security properties: 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.

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.

Technical security support and end date of the support period

Type of technical security support: 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



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.