Instructions for use

Robotic welding cell RSZ-2600 (assembly of machinery)

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

Type / model: RSZ-2600

Year of construction: 2026

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1 Important basic information

These operating instructions apply to the robotic welding cell RSZ-2600 (serial number RSZ2600-2026-0001, year of construction 2026) and are addressed to the user 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 dividing centre wall, welding curtain and pneumatic workpiece clamps
- MAG welding power source 400 A at 60 per cent duty cycle with wire feed unit, water-cooled welding torch with cooling unit, and torch cleaning station
- Welding fume extraction unit 1800 m³/h with pre-spark separator, filter cartridge, temperature monitoring of the filter cartridge, motorised shut-off dampers, and smoke and CO detectors
- Perimeter guard (safety fence) 2200 mm high with maintenance door, Type 4 light curtain, safety PLC, control desk and control cabinet
- Network gateway with firewall and remote maintenance access
- Machine-integrated workplace lighting in accordance with EN 1837 and height-adjustable standing platform at the loading station
- Operating instructions with the accompanying documents listed in Chapter 12 (including the EU declaration of conformity, installation plan, circuit diagrams, pneumatic diagram, spare parts list, test plan for the safety functions and maintenance record form)

Not included in the scope of delivery:

- Workpiece-specific clamping fixtures (unless separately agreed); for the requirements for the user's clamping fixtures see Chapter 3.1
- The customer-supplied shielding gas supply
- The customer-supplied media connections
- An optional exhaust air duct for the extraction unit
- The lifting aid for workpieces over 15 kg at the loading station (customer-supplied, load capacity at least 40 kg)

Limits of use: MAG welding of steel assemblies (unalloyed and low-alloy steel) up to 40 kg workpiece weight and a maximum workpiece envelope of 800 x 600 x 400 mm. Series production exclusively with predefined, approved welding programs. 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 dividing centre wall of the turntable. Rotation range of the turntable 180 degrees. Loading station in front of the loading opening, 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 12 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 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 EU declaration of incorporation), turntable, welding power source (CE-marked equipment), 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 (Manufacturer / User)

The responsibilities of the manufacturer and the user are divided 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 user: 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 the German Occupational Safety and Health Act (ArbSchG) and the German Ordinance on Industrial Safety and Health (BetrSichV), including noise and welding fumes (German Technical Rule for Hazardous Substances TRGS 528); periodic inspection of the electrical equipment in accordance with DGUV Regulation 3 (German accident insurance regulation

on electrical installations and equipment); 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; provision and periodic inspection of a lifting aid for workpieces over 15 kg at the loading station (load capacity at least 40 kg); occupational health surveillance in the case of exposure to welding fumes; forwarding of the fire alarm of the extraction unit (smoke and CO detectors) to a permanently staffed location in accordance with the fire protection concept of the building; 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, TN-S system, 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.
- Data interfaces: OPC UA to the user's MES (receipt of orders, feedback of production data) and VPN remote maintenance by the manufacturer, both exclusively via the gateway supplied; USB port on the HMI panel for data backups and updates. For details see Chapter 13 (Cybersecurity).

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 Union harmonisation legislation:

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

The safety objectives set out in Directive 2014/35/EU are met in accordance with Annex III, section 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 rating plate.

These operating instructions were drawn up in accordance with Annex III, sections 1.7.4 to 1.7.4.2, of Regulation (EU) 2023/1230. This English version is a translation; in case of doubt the German version prevails.

Unauthorised conversions and modifications to the machine, in particular to the guards and protective devices and the safety controller, 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.

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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 13 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. NOTICE indicates information on preventing damage to property.

Abbreviations: CMR = carcinogenic, mutagenic or toxic for reproduction; EMC = electromagnetic compatibility; EMF = electromagnetic fields; ESPE = electro-sensitive protective equipment; HMI = human machine interface (operator interface); LOTO = lockout/tagout (isolation and securing against re-energisation); MAG = metal active gas welding; MES = manufacturing execution system; MR = Machinery Regulation (EU) 2023/1230; OPC UA = Open Platform Communications Unified Architecture (protocol of the data interface to the MES); PL = performance level in accordance with EN ISO 13849-1; PLC = programmable logic controller; PLr = required performance level; PPE = personal protective equipment; SLS = safely reduced speed (Safely-Limited Speed); SRP/CS = safety-related part of a control system; TCP = tool centre point; VPN = virtual private network (encrypted connection for remote maintenance); WLL = working load limit of a lifting accessory.

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

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

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

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

Standard	Title	Listed under
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/EC
EN 60204-1:2018	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	2006/42/EC, 2014/35/EU
EN ISO 11161:2007+A1:2010	Safety of machinery. Integrated manufacturing systems. Basic requirements	2006/42/EC
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)	2006/42/EC
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/EC
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/EC
EN ISO 13849-2:2012	Safety of machinery - Safety-related parts of control systems - Part 2: Validation (ISO 13849-2:2012)	2006/42/EC
EN ISO 13850:2015	Safety of machinery - Emergency stop function - Principles for design (ISO 13850:2015)	2006/42/EC
EN ISO 13854:2019	Safety of machinery - Minimum gaps to avoid crushing of parts of the human body (ISO 13854:2017)	2006/42/EC

Standard	Title	Listed under
EN ISO 13855:2024	Safety of machinery - Positioning of safeguards with respect to the approach of the human body (ISO 13855:2024)	2006/42/EC
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/EC
EN ISO 14118:2018	Safety of machinery - Prevention of unexpected start-up (ISO 14118:2017)	2006/42/EC
EN ISO 14119:2025	Safety of machinery - Interlocking devices associated with guards - Principles for design and selection (ISO 14119:2024)	2006/42/EC
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/EC
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/EC, 2006/42/EC
EN ISO 4414:2010	Pneumatic fluid power - General rules and safety requirements for systems and their components (ISO 4414:2010)	2006/42/EC
EN ISO 4871:2009	Acoustics - Declaration and verification of noise emission values of machinery and equipment (ISO 4871:1996)	2000/14/EC, 2006/42/EC

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

Standard	Title	Listed under
EN ISO 10218-1:2025	Robotics - Safety requirements - Part 1: Industrial robots (ISO 10218-1:2025)	2006/42/EC
EN ISO 10218-2:2025	Robotics - Safety requirements - Part 2: Industrial robot applications and robot cells (ISO 10218-2:2025)	2006/42/EC
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/EC

Table 4: Applied standards: Other applied standards and technical specifications (no presumption of conformity)

Standard	Title	Listed under
EN IEC 61000-6-2:2019	Electromagnetic compatibility (EMC). Part 6-2: Generic standards. Immunity for industrial environments	2014/30/EU
EN IEC 61000-6-4:2019	Electromagnetic compatibility (EMC). Part 6-4: Generic standards. Emission standard for industrial environments	2014/30/EU
EN ISO 7010:2020	Graphical symbols. Safety colours and safety signs. Registered safety signs	

2 Safety

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

- the intended use
- the reasonably foreseeable misuse
- the installed guards and 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 robotic 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 workpiece envelope of 800 x 600 x 400 mm in series production using specified, approved welding programs. Loading and unloading are carried out manually at the respective front station of the two-station turntable 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 an EU declaration of incorporation in accordance with Annex V, Part B, and assembly instructions in accordance with Annex XI. (2) Two-station turntable with a vertical axis of rotation and 180-degree rotation, fixed dividing centre wall with welding 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 user 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 rotation range of the turntable 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 welding 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 user-supplied lifting aid; 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-finding 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 user 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 user'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; Electricity' (W012) on the control cabinet, on the welding power source and at the welding area; 'Warning; Hot surface' (W017) on the turntable, on the torch cleaning station and on the removal side of the loading station; 'Warning; Optical radiation' (W027) at the loading opening and maintenance door; 'Warning; Automatic start-up' (W018) at all access points to the robot working area and at the control desk; 'Warning; Crushing' (W019) at the rotation range of the turntable; 'Warning; Crushing of hands' (W024) on the turntable, at the loading station and on the side plates and frame of the light curtain; 'Warning; Overhead load' (W015) on the turntable, at the loading station and at the lifting points of the transport-relevant assemblies; 'Warning; Sharp

element' (W022) on the torch holder and on the wire feed unit; 'Warning; Magnetic field' (W006) at the maintenance door, at the loading station and on the welding power source; 'Warning; Slippery surface' (W011) at the access to the loading station and to the maintenance aisle; 'Warning; Floor-level obstacle' (W007) at the tripping points in the maintenance aisle.

'General warning sign' (W001) with supplementary text: 'Fire hazard from welding spatter' on the safety fence; 'Harmful welding fume' at the welding area; 'Harmful dust' and 'Fire hazard from sparks in the filter' on the filter housing of the extraction unit; 'Residual pressure in the clamping fixture' on the clamping fixtures and on the compressed air shut-off valve; 'Risk of tipping before anchoring' on two opposite sides of the base frame (for assembly and relocation). At the installation site of the customer-supplied shielding gas supply, the user affixes warning sign W001 with the supplementary text 'Risk of asphyxiation from shielding gas'.

Prohibition signs: supplementary prohibition sign 'No access for unauthorised persons' (German ASR A1.3, D-P006) at the maintenance door and on the control cabinet; 'No access for people with active implanted cardiac devices' (ISO 7010, P007) at all access points, as electromagnetic fields are generated during MAG welding; 'No reaching in' (ISO 7010, P015) on the turntable and at the loading opening.

Mandatory signs (ISO 7010): 'Wear eye protection' (M004) at the loading station and at the maintenance door; 'Wear ear protection' (M003) at the loading station; 'Wear protective gloves' (M009) on the removal side of the loading station and at the maintenance door; 'Wear safety footwear' (M008) throughout the entire working area; 'Wear protective clothing' (M010) at the maintenance door; 'Wear respiratory protection' (M017) at the welding area and on the filter housing of the extraction unit.

Additional markings: Rating plate with CE marking on the right-hand side wall of the control cabinet; labelling of the emergency stop 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 in accordance with the German Technical Rule for Workplaces ASR A1.3 for traffic routes and the swing area of the maintenance door.

Text signs: 'Manual handling up to 15 kg only, use the lifting aid above this' at the loading station; 'Attach your personal padlock before entering' and 'Stop work if the lighting fails' at the maintenance door; 'Check earth clamp before commencing welding' on the clamping fixtures; 'Do not open in the event of a fire alarm' on the maintenance flap of the filter housing; 'Change cable routing only in accordance with electrical circuit diagram RSZ-2600-EPL-001' and 'Parameter changes by authorised specialist personnel only; subsequent validation test required' on the control cabinet; 'Before intervention: vent to 0 bar and lock shut-off valve' on the compressed air shut-off valve; text sign stating the area of effect of the emergency stop devices (the emergency stop acts on all sub-machines of the cell) at the control desk.

2.5 Guards and Protective Devices

The guards and 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 and protective devices fully assembled and in working order.

Fixed and movable guards: Perimeter guard (safety fence), height 2200 mm, with welding-light-opaque infill panels, welding protection viewing windows and base panel; design of safety distances in accordance with EN ISO 13857. Maintenance door at the rear as an interlocking guard with guard locking in accordance with EN ISO 14119 (spring applied, power released; coded actuator); the guard locking is released only once the arc has been extinguished and the robot and turntable are at a monitored standstill. From the inside, the maintenance door can be opened at any time without tools by means of the escape release; actuating it triggers a stop. The door handle is fitted with a lockout device for personal padlocks: each person entering the cell attaches their own padlock while the door is open and takes the key with them. As long as a padlock is attached, the door cannot be closed and automatic mode cannot be started. Movements are then possible only in set-up mode with the enabling device actuated and at safely reduced speed. Fixed dividing centre wall of the two-station turntable with welding curtain between the loading station and the welding area.

Electro-sensitive protective equipment: Type 4 light curtain in accordance with EN IEC 61496-1:2020 and EN IEC 61496-2:2020 with 30 mm resolution at the loading opening; the protective field covers the loading opening completely and is continuously effective (no muting), and the remaining openings are closed off by fixed guards in accordance with EN ISO 13857:2019, Table 4; 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 turntable.

Safety controller and safety functions: A safety PLC evaluates all guards and protective devices. Principal safety functions in accordance with EN ISO 13849-1: SF-01 interlock and guard locking of the maintenance door with safe shutdown of the welding power source when the door is open (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 rotary movement of the turntable (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 turntable only rotates 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 devices in accordance with EN ISO 13850 at the control desk, at the maintenance door and at the teach pendant. The emergency stop acts on all sub-machines of the cell (robot, turntable, welding power source, wire feed) and initiates a controlled stop (stop category 1 in accordance with EN 60204-1). Restart is only possible after resetting the actuated emergency stop device and manual acknowledgement at the control desk.

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 triggers a controlled stop (stop category 1).

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 desk outside the hazard zone with a line of sight to the loading opening. Before automatic start-up, a start-up warning sounds; the signal tower 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 rotary movement of the turntable only upon confirmed clamping pressure; workpiece presence sensor at each station, which reports the workpiece position; pilot-operated non-return valve (pressure-holding valve) in the clamping line, which keeps the workpiece clamped in the event of a pressure drop, with a manual override for controlled pressure release in the event of a fault.

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 turntable and deflector plate below the turntable as a catching device; cooling lockout period for each welding program with red signal light at the removal station; temperature monitoring at the torch neck with release indication on the HMI panel; welding fume extraction 1800 m³/h with monitoring of extraction performance, pre-spark separator, temperature monitoring of the filter cartridge, motorised shut-off dampers, and smoke and CO detectors (operational interlocks without a PL requirement); machine-integrated workplace lighting with failure message on the HMI panel; floor markings for traffic routes and cable bridges with over-run protection in the vicinity of the cell.

The effectiveness of the guards and 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 and protective devices described, residual risks remain on the machine that cannot be fully eliminated by design. The complete overview of all 42 residual risks, structured by life-cycle phase, together with the associated protective measures, has been taken from the risk assessment and is appended at the end of this chapter. The protective measures are listed there for each hazard in the order of EN ISO 12100: inherently safe design (Step 1), safeguarding and complementary protective measures (Step 2), information for use (Step 3).

Overview of principal residual risks: Crushing and impact hazard from the robot and turntable during work with guards and protective devices open (set-up, fault-finding); 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 loading 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: S3 safety footwear in accordance with EN ISO 20345, close-fitting flame-retardant work clothing, safety goggles with side protection and hearing protection. When handling workpieces, protective gloves must also be worn, and heat-protective gloves when removing welded workpieces. Protective gloves do not protect against crushing. Reach into the rotation range only when the turntable has been stopped. During set-up, maintenance and cleaning work in the cell, additionally: welding goggles or protective shield when in visual contact with the arc, welder's gloves when working on components that are still warm. The PPE is provided by the user, who must also supervise its use.

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. A person shut inside the cell leaves it by means of the escape release of the maintenance door. If a person is trapped by the robot or the turntable: actuate the emergency stop and initiate the internal emergency response chain. Without drive power, the robot axes can be moved using the brake release device in accordance with the robot manufacturer's instructions; support the affected axis beforehand, because it can drop once the brake has been released. With the machine isolated, the turntable can be rotated by hand after the motor brake has been released. The rescue is carried out only by instructed set-up and maintenance personnel. Fires at the electrical equipment must only be fought with CO2 or powder extinguishers, never with water. For action in the event of a fire in the extraction unit, see Chapter 9.5. In the event of accidents, provide first aid and follow the internal emergency response chain.

Table 5: Overview of residual hazards

No.	Hazard	Life phases
28	**Mechanical** 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 swing and strike persons.	Transport, Assembly
29	**Mechanical** 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 heavy-duty anchors are not set and tightened as specified, the system may tip over or shift; persons in the vicinity may be struck.	Assembly, Commissioning
39	**Corruption/security** Connection of external devices creates a hazardous situation: A connected external device (the user's higher-level line control system or MES, remote maintenance gateway, user-side signals from the extraction system or the gas supply) 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
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
30	**Combination** Hazard arising from incorrect parameterisation of the robot control system or the safety controller (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 turntable movements.	Commissioning, Setting up, Maintenance
31	**Combination** Hazard from differing safety levels of the sub-machines from different manufacturers (robot, welding power source, turntable, extraction system): missing or incomplete interface interlocking between the sub-machines may result in one sub-machine starting up even though another is in an unsafe condition (EN ISO 11161).	Commissioning, Operation, 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

No.	Hazard	Life phases
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). 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
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
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
1	**Mechanical** Crushing and shearing hazard from the turntable during the automatic rotation: Body parts of the operator (hands, arms) may be drawn in and crushed between the turntable and the fixed dividing centre wall or the safety fence, in particular when reaching into the turntable during rotation to reposition a displaced workpiece (reasonably foreseeable misuse).	Operation, Setting up, Troubleshooting
2	**Mechanical** Crushing and drawing-in hazard from the welding robot (industrial robot) in set-up mode: at reduced speed (hold-to-run control), operators or set-up personnel may be crushed or drawn in between the robot arm and peripheral equipment (safety fence, turntable, welding fixture) by unexpected robot movements.	Setting up
4	**Mechanical** Crushing hazard at the interface between the turntable and the welding robot (transfer area): During the rotation the loaded fixture moves into the working area of the robot; uncoordinated entry of the robot into the rotation range or missing interlock between the turntable movement and the robot enable can lead to collisions and crushing injuries.	Operation, Setting up, Troubleshooting

No.	Hazard	Life phases
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 turntable and strike persons at the loading station.	Operation, Setting up, Troubleshooting
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 hazard zone.	Troubleshooting, Maintenance, Setting up
7	**Mechanical** Missing or uncoordinated emergency stop function between sub-machines (robot, turntable, 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
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 set-up, wire threading or torch cleaning, hands and fingers can be punctured or cut.	Setting up, Maintenance, Cleaning
9	**Mechanical** Ergonomic hazard and crushing hazard during manual loading and unloading of workpieces up to 40 kg: Workpieces up to 15 kg are loaded by hand, workpieces above 15 kg with the user-supplied lifting aid; in the event of reasonably foreseeable misuse (lifting without the lifting aid), musculoskeletal strain arises together with the risk of losing grip, with the subsequent falling of the workpiece onto feet or hands.	Operation, Setting up
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
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 set-up personnel being aware of this; when the robot or the turntable starts up, the second person is struck.	Setting up, Maintenance, Troubleshooting
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
14	**Electrical** EMC interference between welding power source and safety controller (robot	Operation, Setting up

No.	Hazard	Life phases
	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).	
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
16	**Thermal** Burn and fire hazard from welding spatter (flying sparks): 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
17	**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.	Maintenance, Setting up, Cleaning
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
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
20	**Materials/substances** 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
24	**Noise** Hazard from noise during the MAG welding process and from the turntable 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 German Noise and Vibration Occupational Safety and Health Ordinance (LärmVibrationsArbSchV).	Operation, Setting up

No.	Hazard	Life phases
27	**Ergonomic** Insufficient lighting at the loading station and in the maintenance aisle: 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
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 rotation range without the protective function being triggered; the turntable or the robot may start up and trap hands or arms.	Operation, Setting up
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. monitoring of the maintenance door, parameters of the light curtain, speed limit in set-up mode). 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
3	**Mechanical** Impact and crushing hazard from the welding robot during automatic operation in the event of unauthorised access: persons who climb over the safety 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
21	**Materials/substances** Hazard from shielding gas (argon-CO2 mixture M21) in the event of leakage: Argon and CO2 are heavier than air, so the shielding gas 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
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
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
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	Operation, Maintenance, Troubleshooting

No.	Hazard	Life phases
	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]	
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. welding parameters, program number or workpiece assignment) are falsified, outdated or intended for the wrong machine. The machine operates with specifications outside the safe limits or with an incorrect workpiece and program reference. [MR (EU) 2023/1230 Annex III No. 1.1.9 para. 3, 1.2.1 lit. b, 1.2.1 lit. d]	Operation
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 aisle. [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
22	**Materials/substances** 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
23	**Mechanical** 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
33	**Mechanical** Hazard during dismantling of the cell at the end of its service life: When dismantling safety 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.	Decommissioning

Life phase: Transport

Mechanical

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 swing and strike persons.

Life phases: Transport, Assembly

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- All cell components (safety fence segments, control cabinet, robot base frame) are provided with permanently integrated lifting points designed in accordance with applicable standards (e.g. eye bolts in accordance with DIN 580 or eye nuts in accordance with DIN 582) with a clearly marked working load limit (WLL) per lifting point.
- This reduces the probability of a rigging error through the design itself.
- Residual risk from load swing and persons present in the hazard zone:
- Cordoning off the hazard zone: 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.
- 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 German 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.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4.2):
- Include rigging plans with lifting points, centre of gravity position and WLL per component in Chapters 5.2 and 5.3.
- Qualification requirement: crane operations and load rigging may only be carried out by instructed and authorised riggers (qualification in accordance with German DGUV Information 209-013).
- Warning labelling on each component: warning sign 'Warning; Overhead load' (W015 in accordance with EN ISO 7010:2020), indication of the mass and the WLL per lifting point directly on the component.
- PPE specification: safety helmet, safety footwear (S3) and high-visibility vest are mandatory during all transport operations.
- Note: remaining beneath suspended loads is prohibited.

Life phase: Assembly

Mechanical

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 heavy-duty anchors are not set and tightened as specified, the system may tip over or shift; persons in the vicinity may be struck.

Life phases: Assembly, Commissioning

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- 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 6.2.6).
- Provision of a machine-specific installation plan (dimensional drawing with a minimum floor load-bearing capacity of 10 kN/m², flatness tolerance of the substrate and anchor point positions) as part of the delivery documentation, which is to be approved by the user before assembly commences.
- Marking of the anchor points on the base frame by means of permanent markings (arrow or labelling) so that assembly personnel can identify the positions unambiguously.
- For the assembly state before the anchors are set: verification of stability without anchoring (tipping resistance verification, ratio of stabilising moments to tipping moments of at least 1.5 as specified by the manufacturer).
- These measures are not safety functions within the meaning of EN ISO 13849-1 and do not require a PLr.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): Chapter 7 (Installation conditions) and Chapter 8 (Assembly and installation) with binding specifications for: minimum floor load-bearing capacity (at least 10 kN/m²), required flatness of the substrate, obligation to anchor to the floor with 2 × 4 heavy-duty anchors M16 (tightening torque 110 Nm) with specification of the anchor type and embedment depth, and reference to the installation plan.
- Warning marking on the base frame: general warning sign W001 in accordance with EN ISO 7010:2020 with the supplementary text 'Risk of tipping before anchoring' on at least two opposite sides of the base frame, visible during assembly.
- Qualification requirement: installation and anchoring 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.
- PPE notice: safety footwear (EN ISO 20345, protection class S3) and protective gloves during assembly; specification in the operating instructions.

Corruption/security

Connection of external devices creates a hazardous situation: A connected external device (the user's higher-level line control system or MES, remote maintenance gateway, user-side signals from the extraction system or the gas supply) 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 PRESENT ON THE MACHINERY

- 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.

INSTRUCTIONS FOR THE USER

- Operating instructions and interface description for the integrator (signals, states, requirements for the assembly of machinery in accordance with Annex III, section 1.2.4.4), note that the connection of non-approved devices requires a new risk assessment.

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 PRESENT ON THE MACHINERY

- 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, section 1.5.1 (Electrical energy supply) by analogy, as well as EN 60204-1:2018 section 6.2.
- Isolation and de-energisation (LOTO): Main switch with lockable OFF 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 overall installation 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; where this is not achieved, a warning notice stating the discharge time is affixed to the enclosure (EN 60204-1:2018 section 6.2.4).
- Cabinet door interlock: The doors of the main control cabinets are fitted with a lock that can only be opened with a key and prevents unauthorised opening (EN 60204-1:2018 section 6.2.2).
- 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.
- 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 rated residual operating current of 30 mA for circuits on which persons are working; in circuits where an RCD is not compatible with the welding process, insulation monitoring is used instead (EN 60204-1:2018 sections 6.3.3 and 7.7).

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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 the German accident prevention regulation DGUV Regulation 3, or under the supervision of an ESP by electrically instructed persons.
- PPE specification: Insulating gloves (in accordance with EN 60903, class 00 for voltages up to 500 V AC), safety goggles (arc flash protection) and electrically insulating footwear are to be worn when working in an open cabinet.
- Warning labelling: Warning sign W012 'Warning; Electricity' in accordance with EN ISO 7010:2020 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 still carry dangerous voltages (waiting time of at least 1 minute for the welding power source, for the robot drive as specified by the robot manufacturer); absence of voltage must always be verified by measurement.

Combination

Hazard arising from incorrect parameterisation of the robot control system or the safety controller (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 turntable movements.

Life phases: Commissioning, Setting up, Maintenance

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- Safety-relevant parameters (speed limits, protection zones, zone releases) are stored exclusively in the safety controller (safety PLC) and are protected against unauthorised or inadvertent modification by a password-protected, role-based access concept.
- Parameter sets for safety functions SF-01 to SF-05 are stored in the safety controller 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.
- 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 (dual-control principle) before recommissioning.
- The safety controller 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 (verification and validation for integrated manufacturing systems).
- Parameter verification by the safety controller: The safety controller (PLr e for SF-02 and SF-04, PLr d for SF-01, SF-03 and 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).
- 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 controller 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).
- 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 controller.
- Basis: EN ISO 11161:2007+A1:2010.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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.

- Qualification requirement: Parameter changes to the safety controller 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.
- Warning labelling: The warning sign 'Warning; Electricity' (W012 in accordance with EN ISO 7010:2020) and the supplementary prohibition sign 'No access for unauthorised persons' (German ASR A1.3, D-P006) are to be affixed to the safety controller and the control cabinet.
- Additionally, an information sign stating: 'Parameter changes by authorised specialist personnel only; subsequent validation test required'.
- 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).

Combination

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

Life phases: Commissioning, Operation, Troubleshooting

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- System architecture with a single, higher-level 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, turntable end position, extraction system operation, welding power source ready) are routed exclusively via the safety controller.
- No sub-machine drive receives an enable signal unless the safety controller has assessed the overall state as safe.
- The interface definition is carried out in accordance with EN ISO 11161:2007+A1:2010 (system integration, responsibilities, interface description) and is documented in the safety concept of the overall installation.
- Interlock matrix in accordance with EN ISO 11161:2007+A1:2010: 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.
- Safety function SF-04 (enable of the 180-degree rotary movement of the turntable only when the rotation range is clear, PLr e) ensures that the turntable only rotates when the protective field of the light curtain is clear, the clamps are closed and the robot is demonstrably outside the rotation range.
- 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.
- 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 overall installation: a stop signal from one sub-machine triggers the coordinated stop of all sub-machines via the safety controller.
- Stop category 1 in accordance with EN 60204-1:2018 section 9.2.2 applies to the robot and the turntable.
- Emergency stop of the overall installation (SF-03, stop category 1, PLr d) in accordance with EN ISO 13850:2015 acts on all sub-machines simultaneously via the safety controller.
- Emergency stop devices are arranged at the control desk, at the maintenance door and on the teach pendant.
- 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.

- Set-up mode with safely reduced speed (SF-05, 250 mm/s, PLr d) and enabling device in accordance with EN ISO 10218-2:2025 section 5.7.7; in this mode, the robot and the turntable move only with the enabling device actuated and at safely reduced speed, and the welding power source is safely switched off via SF-01 while the maintenance door is open.

INSTRUCTIONS FOR THE USER

- Operating instructions for the overall installation in accordance with (EU) 2023/1230 Annex III, section 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 defined in writing in the safety concept of the overall installation in accordance with EN ISO 11161:2007+A1:2010 and is to be 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 the control desk: warning sign 'Warning; Automatic start-up' (W018 in accordance with EN ISO 7010:2020).
- 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.

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 PRESENT ON THE MACHINERY

- 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, section 1.2.1, point (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.

INSTRUCTIONS FOR THE USER

- 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.

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). 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 PRESENT ON THE MACHINERY

- 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.

INSTRUCTIONS FOR THE USER

- Operating instructions: requirements for the user's network (segmentation, permitted participants, no external devices in the safety segment), description of the behaviour upon communication failure and the restart procedure.

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 PRESENT ON THE MACHINERY

- Information page on the HMI showing the version and checksum of all safety-relevant software components (always easily accessible without login, Annex III, section 1.1.9, fourth paragraph), labelling of safety-relevant data in file names, menus and exports, comparison with the acceptance report at start-up.

INSTRUCTIONS FOR THE USER

- Operating instructions: list of safety-relevant software and data with versions (Annex III, section 1.7.4.2), instructions for retrieving version information, note on the significance for conformity and on the obligation to report deviations.

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 PRESENT ON THE MACHINERY

- 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 as-delivered state, program changes only in the secured stop state of the machine.
- Individual password for the safety program access with mandatory password change at commissioning, write protection and access protection levels of the controller activated, logging of all accesses and program changes with version and checksum, display of the program status on the HMI.

INSTRUCTIONS FOR THE USER

- Operating instructions: Access protection and password management as a user obligation, prohibition of program changes without re-verification and documentation, reference to the requirements for substantial modification.

Life phase: Setting up

Mechanical

Crushing and shearing hazard from the turntable during the automatic rotation: Body parts of the operator (hands, arms) may be drawn in and crushed between the turntable and the fixed dividing centre wall or the safety fence, in particular when reaching into the turntable during rotation to reposition a displaced workpiece (reasonably foreseeable misuse).

Life phases: Operation, Setting up, Troubleshooting

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- Alternatively, keep the gap so small that no part of the body can enter it (opening sizes in accordance with EN ISO 13857:2019 Table 4).
- Where neither of the two gap sizes can be achieved, 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 rotation 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 Step 1: The rotation range remains a hazard zone that must not be entered while the drive is running.
- Technical protective measures:
- Release of the rotary movement only when the rotation range is clear (SF-04, PLr e, EN ISO 13849-1:2023): ESPE (light curtain type 4 in accordance with EN IEC 61496-1:2020) monitors the rotation range completely; arrangement and safety distance in accordance with EN ISO 13855:2024.
- Guard locking of the maintenance door in accordance with EN ISO 14119:2025 with escape release (SF-01, PLr d; stop category 1 in accordance with EN 60204-1:2018).
- Set-up mode: rotary 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).
- 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).
- Energy isolation prior to interventions: isolating valve with mechanical latching (lockout) in accordance with EN ISO 4414:2010; lock the turntable positively in its end position (EN ISO 14118:2018).

INSTRUCTIONS FOR THE USER

- Operating instructions: entering the rotation range 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.

- Warning signs on the machine: the following signs are affixed to the turntable: warning signs W019 'Warning; Crushing' and W024 'Warning; Crushing of hands' and prohibition sign P015 'No reaching in' (in accordance with EN ISO 7010:2020).
- 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.
- Personal protective equipment: protective gloves do not protect against crushing.
- Reach into the rotation range only when the turntable has been stopped.
- Safety footwear S3 in accordance with EN ISO 20345 is mandatory throughout the entire area of the installation.

Mechanical

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

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- 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).
- 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, referred to in this document as safely reduced 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, a category 1 stop in accordance with EN 60204-1:2018 is initiated.
- The set-up personnel carry the teach pendant with them; the teach pendant 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 the maintenance door with guard locking in accordance with EN ISO 14119:2025.
- The guard locking releases the door for set-up mode only once the operating mode 'Set-up' has been selected at the lockable operating mode selector switch.
- Isolation of energy before entering the safeguarded space without the teach pendant: safe isolation in accordance with EN ISO 14118:2018 (lockout/tagout preparation).
- The remaining crushing points were checked against the minimum gaps in accordance with EN ISO 13854:2019 Table 1 during the factory acceptance test.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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 maintenance door: warning sign W018 'Warning; Automatic start-up' in accordance with EN ISO 7010:2020 and note 'Always carry the enabling device'.
- PPE specification: safety footwear S3 (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 teach pendant and without an enabling device is prohibited.

Mechanical

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

Life phases: Operation, Setting up, Troubleshooting

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- The rotation radius of the turntable and the working space boundary of the robot (TCP envelope) are coordinated with each other during the design phase such that the maximum rotation range of the fixture and the minimum robot working space maintain a geometric minimum distance of >= 500 mm (minimum gap to avoid crushing of the body in accordance with EN ISO 13854:2019 Table 1) from each other when both movements would be active simultaneously.
- SF-04 'Enable of the 180-degree rotary movement of the turntable only when the rotation range 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 outside the rotation range and must confirm this via a safe feedback signal (safe output of the robot controller in accordance with EN ISO 10218-2:2025 sections 5.4.7 and 5.5.8) before the turntable enable is granted.
- (b) Turntable enable to the robot: as long as the turntable is not in its end position and locked, the robot controller receives no enable signal for the entry area; the turntable is positively locked in its end position.
- (c) Guard locking of the maintenance door to the rotation range in accordance with EN ISO 14119:2025 with escape release, incorporated in SF-01 (PLr d).
- (d) Emergency stop of the overall installation 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 set-up personnel may enter the rotation range only with the enabling device actuated and at reduced speed.
- The distance of the safety fence from the rotation range complies with EN ISO 13857:2019 Table 2; the safety fence is designed in accordance with EN ISO 14120:2015.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): description of the interlock logic SF-04 and the operating modes Automatic and Set-up; explicit notice that entering the rotation range 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 rotation range: warning signs W019 'Warning; Crushing' and W024 'Warning; Crushing of hands' in accordance with EN ISO 7010:2020; at the maintenance door additionally the supplementary prohibition sign 'No access for unauthorised persons' (German ASR A1.3, D-P006).

- PPE specification in the operating instructions: safety footwear S3 in accordance with EN ISO 20345; in set-up mode additionally close-fitting protective clothing (no entanglement risk from loose clothing).
- Note on residual risk in set-up mode and fault-finding: always keep the enabling device actuated, never enter the rotation range without the enabling device.

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 turntable and strike persons at the loading station.

Life phases: Operation, Setting up, Troubleshooting

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- Use of pneumatically closing clamps with a pilot-operated non-return valve (pressure-holding valve) in the clamping line directly at the clamping cylinder: in the event of compressed air failure or a leak in the supply line, the clamping pressure remains trapped in the cylinder and the workpiece remains clamped; the clamps open only when the valve is actively pilot-opened.
- The clamping force is designed for the maximum workpiece weight of 40 kg plus a safety factor in accordance with EN ISO 4414:2010.
- Additionally: limitation of the operating pressure to the level required for the clamping function, in order to minimise the stored pneumatic energy (EN ISO 4414:2010).
- Clamping pressure monitoring with safety function: a pressure switch in the clamping line monitors the clamping pressure; if the pressure falls below the minimum clamping pressure, the enable for the rotary movement of the turntable is inhibited (linked to SF-04, PLr e in accordance with EN ISO 13849-1:2023).
- As long as the clamping pressure has not been confirmed, the turntable does not rotate.
- Mechanical interlock of the rotary motion: Positive locking of the turntable in the loading position, so that unintended rotation with a clamped or loose workpiece is prevented; the interlock is released only after the clamping pressure has been confirmed (interlocked with SF-04, PLr e).
- Enclosure/catch device: Mechanical catch device (deflector plate) below the turntable, 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.
- Safety distance at the loading station: Arrangement of the loading station such that the hazard zone below the turntable is outside the regular area of presence.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): Description of the clamping principle (pneumatically closing clamps with pressure-holding valve) and the clamping pressure monitoring; prohibition of remaining beneath the turntable 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).
- 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 and EN ISO 14118:2018 (prevention of unexpected restart and unexpected energy release); because of the pressure-holding valve, the clamping pressure remains trapped in the clamping cylinders, so the clamps must be opened and depressurised before any work on the clamping device; provide a shut-off and exhaust valve with lockout facility.

- Warning labelling: Attach warning signs W015 'Warning; Overhead load' and W024 'Warning; Crushing of hands' in accordance with EN ISO 7010:2020 to the turntable and at the loading station.
- Qualification: Fault-finding and set-up work to be carried out by trained specialist personnel only; requirements to be specified in the operating instructions.
- PPE: Prescribe the wearing of safety footwear (S3 in accordance with EN ISO 20345) at the loading station as residual risk protection.

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 hazard zone.

Life phases: Troubleshooting, Maintenance, Setting up

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- No geometric or energetic measure exists that would prevent the restart itself without abolishing the machine function.
- Protection must therefore be achieved entirely through Step 2 measures (control system and interlocking).
- Coordinated restart prevention in accordance with EN ISO 11161:2007+A1:2010: 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 hazard zones.
- The restart command shall not be triggered automatically following acknowledgement of the emergency stop or following fault clearance.
- 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).
- Safety function SF-04 (release of the 180-degree rotary movement of the turntable only when the rotation range is clear, PLr e in accordance with EN ISO 13849-1:2023): the turntable may only execute its rotary movement when the rotation range has been detected as clear by the Type 4 light curtain in accordance with EN IEC 61496-1:2020 (positioned in accordance with EN ISO 13855:2024).
- This function remains active after restart and prevents start-up in the presence of persons.
- 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.
- De-energisation and energy isolation in accordance with EN ISO 14118:2018: before entering the hazard zone 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) shall be dissipated before any intervention; the turntable shall be positively locked in its end position.

- 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).

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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 hazard zones 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.
- Warning labelling at the maintenance door and at the acknowledgement units: warning of unexpected restart (warning sign W018 'Warning; Automatic start-up' in accordance with EN ISO 7010:2020), notice of the obligation to acknowledge from outside.
- 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).
- PPE specification: safety footwear (S3 in accordance with EN ISO 20345) shall be worn when entering the hazard zone for fault-finding or maintenance; additional PPE as determined by the user's workplace risk assessment.

Mechanical

Missing or uncoordinated emergency stop function between sub-machines (robot, turntable, 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 PRESENT ON THE MACHINERY

- Inherently safe design measures exhausted: the coordination of several independent controllers necessarily requires a higher-level control logic.
- A pure design measure (geometry, energy limitation, substitution) cannot replace the missing interconnection of the emergency stop circuits.
- The functional principle of the overall installation 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 devices of the overall installation are integrated into a common, higher-level safety circuit which, on actuation at any point, brings all hazardous sub-machines (robot, turntable, welding power source, pneumatics) to a coordinated standstill; the extraction system runs on for operational reasons.
- 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 turntable brakes actively, the welding power source is de-energised, and the clamps remain clamped by the pressure-holding valve.
- The run-on of the extraction system is not a safety function, but is operationally required.
- Safety function SF-03 is specified with PLr d in accordance with EN ISO 13849-1:2023 and implemented in Category 3 with PL d.
- 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 devices are to be positioned such that at least one emergency stop device is reachable from every operating station without exposure to a hazard (EN ISO 13850:2015).
- Restart interlock: after an emergency stop, a manual reset is required before the installation can restart (EN ISO 13850:2015 section 4.1.4), in order to prevent unexpected restart in accordance with EN ISO 14118:2018.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): description of the emergency stop topology of the overall installation with a layout plan of all emergency stop devices and the area of effect of each emergency stop 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 the maintenance door has been secured against closing (personal padlock in the lockout device).

- Qualification requirement: set-up and fault-finding only by instructed specialist personnel who are familiar with the emergency stop topology.
- Marking at the control desk: text sign stating the area of effect of the emergency stop devices (the emergency stop acts on all sub-machines of the cell), supplemented by warning sign W018 'Warning; Automatic start-up' in accordance with EN ISO 7010:2020.

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 set-up, wire threading or torch cleaning, hands and fingers can be punctured or cut.

Life phases: Setting up, Maintenance, Cleaning

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- Automatic wire retraction after the end of welding: The wire feed control automatically retracts the wire by a defined amount (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.
- In addition: selection of a wire feed system that, in inching mode (set-up), 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.
- 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.
- Inhibit of automatic wire feed: Automatic wire feed is inhibited as soon as the maintenance door is opened; with the door open, the wire can be fed only in inching mode at reduced threading speed.
- Inching mode of the wire feed: inching mode at reduced threading speed is a function of the welding power source, not a safety function; it is designed to prevent unintended rapid wire feed.
- Marking of the hazard point on the torch and wire feed with warning sign W022 'Warning; Sharp element' in accordance with EN ISO 7010:2020.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): Explicit note that the welding wire presents a sharp tip that can pierce the skin even when stationary.
- Description of the safe procedure for threading wire (feed the wire only in inching mode at reduced threading speed, cut the wire end cleanly with side cutters, never probe with the bare hand).
- Warning marking on the torch holder and on the wire feed unit: warning sign W022 'Warning; Sharp element' in accordance with EN ISO 7010:2020.
- 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.
- PPE specification: cut-resistant protective gloves (in accordance with EN 388, puncture resistance of at least performance level 2) 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.
- 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.

Mechanical

Ergonomic hazard and crushing hazard during manual loading and unloading of workpieces up to 40 kg: Workpieces up to 15 kg are loaded by hand, workpieces above 15 kg with the user-supplied lifting aid; in the event of reasonably foreseeable misuse (lifting without the lifting aid), 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 PRESENT ON THE MACHINERY

- Limitation of the manually handled workpiece mass to a maximum of 15 kg.
- The threshold is set by the manufacturer for around 40 lifts per hour and is derived from the reference mass in accordance with EN 1005-2:2003+A1:2008.
- For workpieces above 15 kg and up to 40 kg, the workpiece fixture at the loading station is designed so that loading from above with the user-supplied lifting aid is possible without re-gripping (unobstructed access, insertion depth, geometry of the locating stops).
- The loading station is prepared for a user-supplied lifting aid (lifting aid not included in the scope of supply, load capacity at least 40 kg, operating radius covering the entire loading zone).
- Access from above is unobstructed, so that the operator can reach the loading position without re-gripping or releasing the workpiece.
- Floor marking (yellow/black in accordance with German ASR A1.3) 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.
- 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.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): Clear specification of the handling rule (up to 15 kg by hand, above 15 kg with the user-supplied lifting aid, load capacity at least 40 kg) and of the correct attachment points on the workpiece.
- Specification of body posture during loading in accordance with EN 1005-4.
- Warning labelling at the loading station: Warning signs W015 'Warning; Overhead load' and W024 'Warning; Crushing of hands' and mandatory sign M008 'Wear safety footwear' in accordance with EN ISO 7010:2020.
- Text sign 'Manual handling up to 15 kg only, use the lifting aid above this' directly at the loading station.
- Qualification requirement: Operators must be instructed in the use of the lifting aid and in ergonomically correct handling before commencing work (documented instruction).
- PPE specification: Safety footwear S3 in accordance with EN ISO 20345 and protective gloves (cut-resistant, secure grip) are to be stipulated as minimum PPE for all loading and unloading activities.

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 PRESENT ON THE MACHINERY

- Reduce weld-spatter exposure on the floor by means of design-integrated shielding plates (spatter-protection shields) at the welding station, so that discharge into the operator area is minimised.
- The hall floor is not part of the scope of supply; the requirement for the installation site (anti-slip floor covering) is passed on to the user in Step 3.
- Limit the residual risk from remaining trip and slip hazards by means of the following technical measures:
- Floor markings (yellow/black in accordance with German ASR A1.3) to identify traffic routes and hazard zones in accordance with (EU) 2023/1230 Annex III, section 1.5.15.
- Adequate fixed lighting of the loading station and maintenance aisle in accordance with (EU) 2023/1230 Annex III, section 1.1.4, so that obstacles and wet areas can be detected at an early stage; the machine-integrated lighting in accordance with EN 1837 provides 500 lx at the loading station and 200 lx in the maintenance aisle.
- Spatter-protection mats in the immediate welding area that are easy to remove and clean.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4):
- 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.
- Qualification requirement: all persons entering the loading station and maintenance aisle must have been instructed in the hazards and the traffic-route layout.
- PPE specification: safety footwear with anti-slip soles (S3 in accordance with EN ISO 20345) shall be worn when entering the loading station and maintenance aisle.
- Warning labelling at the access to the loading station and maintenance aisle: affix warning sign W011 'Warning; Slippery surface' and mandatory sign M008 'Wear safety footwear' in accordance with EN ISO 7010:2020.
- Requirement for the installation site: anti-slip floor covering at the loading station and in the maintenance aisle, slip resistance rating of at least R 11 in accordance with German DGUV Rule 108-003.

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 set-up personnel 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 PRESENT ON THE MACHINERY

- Inherently safe design measures 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.
- Protection of persons when several persons enter the cell, in accordance with EN ISO 11161:2007+A1:2010: the maintenance door has a lockout device for personal padlocks.
- Each person entering the cell attaches their personal padlock to the lockout device of the opened door.
- As long as a padlock is attached, the door cannot be closed and automatic mode cannot be started.
- Movements are then possible only in set-up mode, with the enabling device actuated and at safely reduced speed.
- Acknowledgement is possible only from outside, at the control desk.
- Guard locking of the maintenance door in accordance with EN ISO 14119:2025 with escape release from the inside in accordance with EN ISO 14119:2025 section 6.9.1, so that persons trapped inside can leave the cell at any time.
- The enabling of automatic start-up (robot and turntable) is implemented as a safety function: automatic start-up is possible only when the maintenance door is closed and held closed by the guard locking and acknowledgement has been given from outside.
- The access function is SF-01 (safe stop on opening of the maintenance door) with PLr d in accordance with EN ISO 13849-1:2023.
- Independently of this, the release of the turntable rotation remains safeguarded by SF-04 (PLr e).
- 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.
- The cell has exactly one enabling device, on the teach pendant; movements in set-up mode are therefore permitted only when nobody other than the person holding the enabling device is inside the cell (for the procedural instruction, see Step 3).
- The safety distances between the robot working space and areas where persons are present comply with EN ISO 13857:2019 Table 2 and EN ISO 10218-2:2025 sections 5.4.6 and 5.8.9.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): Description of the protection of persons at the maintenance door (one personal padlock per person in the lockout device, escape release from the inside), and of the obligation to attach the padlock before entering and to remove it only after leaving the cell.
- Procedural instruction for multi-person operations (setting up, maintenance, fault-finding) with clear role assignment (responsible person, coordination).
- Warning signs at the maintenance door: warning sign W018 'Warning; Automatic start-up' in accordance with EN ISO 7010:2020, text sign 'Attach your personal padlock before entering'.
- Qualification requirement: Set-up and maintenance personnel must be instructed in the multi-person access concept and the use of the lockout device for personal padlocks and of the escape release.
- The instruction must be documented.
- PPE specification in the operating instructions: Safety footwear S3 in accordance with EN ISO 20345, close-fitting protective clothing (no entanglement risk from loose clothing) when inside the cell.

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 PRESENT ON THE MACHINERY

- Welding power source: The welding power source has protection class I and degree of protection IP23S in accordance with EN IEC 60974-1; 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).
- Monitoring of the earth connection: The earth current monitoring of the welding power source is activated; in the event of interruption or an impermissibly high contact resistance, the welding process is inhibited.
- The function is an operational interlock without a PL requirement (not a safety function within the meaning of EN ISO 13849-1:2023); no risk reduction is credited for it.
- 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).
- 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 turntable (SF-04, PLr e), so that contact with live parts in automatic mode is prevented by both design and control-engineering means.
- 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.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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 intervals for insulation and cable condition (visual inspection every working day, six-monthly insulation measurement by an electrically skilled person, see Chapter 10.2).
- Qualification requirement: Setting up, fault-finding and maintenance on the welding power source and its connections may only be carried out by an electrically skilled person or an electrically instructed person under the supervision of an electrically skilled person (terms as defined in EN 60204-1:2018 section 3.1).
- Warning labelling on the fixture and in the welding area: Attach warning sign W012 'Warning; Electricity' in accordance with EN ISO 7010:2020 at a clearly visible location; attach a text sign 'Check earth clamp before commencing welding'.
- 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

Robotic welding cell RSZ-2600 (assembly of machinery)
Robot-assisted MAG welding cell for steel assemblies up to 40 kg
MUSTER-2026-001-EN-BA · Draft · As of: 29/10/2026

shall be worn.

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 PRESENT ON THE MACHINERY

- Route the welding current return conductor as a dedicated return conductor close to the workpiece, directly back from the welding fixture, so that no large-area current loops are created that act as antennas.
- Route welding current cables and safety signal/control cables in separate cable ducts with a minimum separation of 200 mm (separation distances in accordance with EN 50174-2 and EN 60204-1:2018 Annex H); crossings at right angles only.
- 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:
- 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.
- 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 IEC 61000-6-2:2019 (immunity requirements for industrial environments).
- 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).
- The safety controller and all components of safety functions SF-01 to SF-05 shall demonstrably comply with the immunity requirements of EN IEC 61000-6-2:2019 (the component manufacturers' evidence is on file).
- 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 demonstrate the immunity of the SRP/CS in accordance with EN ISO 13849-1:2023 Annex L and the CCF measures (Annex F).
- Welding power source: CE-marked equipment with an EU declaration of conformity that also covers the EMC Directive 2014/30/EU; emissions of the power source in accordance with EN IEC 60974-10 (EMC of arc welding equipment), emissions of the overall installation in accordance with EN IEC 61000-6-4:2019 (test report RSZ-2600-EMV-001).
- Overall installation: carry out an EMC acceptance test in accordance with EN IEC 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.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4):
- Note that modifications to cable routing (welding current cables, control cables) may only be carried out by qualified skilled personnel with EMC expertise.
- Maintenance instruction: visual inspection of screen terminations, equipotential bonding connections and cable duct separation; inspection interval six months (see Chapter 10.2).
- 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.
- Qualification requirement: set-up personnel (operating mode Set-up, SF-05 active) shall be instructed in EMC-related fault patterns on safety controllers.
- Marking on the control cabinet of the safety controller: text sign 'Change cable routing only in accordance with electrical circuit diagram RSZ-2600-EPL-001'.

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 PRESENT ON THE MACHINERY

- Inherently safe design measures 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 and would not meet the product requirements.
- 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 stored for each welding program; it depends on the workpiece geometry and the heat input.
- 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.
- Warning light / signalling device: Optical indicator (red signal light at the removal station) that is active during the cooling lockout period and extinguishes as soon as the release is granted.
- Thermal shielding: The fixed dividing centre wall with welding curtain between the welding area and the removal station shields the operator from radiant heat (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).

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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.
- Warning labelling at the removal station: Warning sign W017 'Warning; Hot surface' and mandatory sign M009 'Wear protective gloves' in accordance with EN ISO 7010:2020 to be affixed permanently and clearly visible at the loading station (removal side) ((EU) 2023/1230 Annex III, section 1.7.1).
- 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.
- Provision of PPE: The operating instructions must instruct the user to provide suitable heat-protective gloves (EN 407) and to monitor their use.

Thermal

Burn and fire hazard from welding spatter (flying sparks): 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 PRESENT ON THE MACHINERY

- 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.
- Additionally: position the welding area such that no combustible operating materials (oils, lubricants, packaging) are stored or routed within the spatter protection radius of 1 m around the welding area.
- Lines carrying combustible media shall be routed out of the spatter area or provided with non-combustible shields.
- Guard: The welding area is enclosed by the safety fence with welding-light-opaque infill panels and welding protection viewing windows (EN ISO 14120:2015) and by the dividing centre wall of the turntable; the infill panels and the dividing centre wall are non-combustible and resistant to welding spatter.
- This enclosure prevents spatter from escaping into the general working area.
- Towards the loading station, the dividing centre wall of the turntable with its welding curtain in accordance with EN ISO 25980 shields the welding area.
- 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.
- Secure the exclusion zone of 1 m around the safety fence: permanent yellow and black floor marking in accordance with the German workplace rule ASR A1.3 and, where possible, physical barriers; no storage or depositing areas within the zone.
- 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 user (note in the operating instructions, Step 3).
- Safety functions: the maintenance door is integrated into the safety controller via SF-01 (PLr d) and the loading opening via SF-02 (PLr e); welding takes place only with the maintenance door closed and locked.

INSTRUCTIONS FOR THE USER

- Operating instructions (pursuant to (EU) 2023/1230 Annex III, section 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.
- 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).
- Warning signs on the safety fence in accordance with EN ISO 7010:2020: general warning sign W001 with the supplementary text 'Fire hazard from welding spatter'. 'Warning; Hot surface' (W017) in the welding area.
- Mandatory sign M010 'Wear protective clothing' at the maintenance door.
- Qualification requirement: Set-up personnel and operators must be trained in the operation of the welding system and in the handling of fire protection equipment.
- Set-up personnel require a qualification as a welding specialist or equivalent documented instruction.
- PPE specification: During set-up work in the welding area, the following PPE must be worn: flame-retardant welding protective clothing (in accordance with EN ISO 11611), welder's gloves (in accordance with EN 12477), welding face shield or welding helmet with a welding filter in accordance with EN ISO 16321-2 (formerly EN 169).
- In automatic mode with the maintenance door closed, no welder PPE is required; however, entering the welding area during operation is prohibited (operating instructions).

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 PRESENT ON THE MACHINERY

- 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).
- Cooling-time monitoring: a temperature sensor on the torch neck reports to the machine control system; the HMI indicates the release for torch changes and cleaning only once the temperature has fallen below the limit value.
- The function is an operational interlock without a PL requirement under EN ISO 13849-1; no risk reduction is credited to it.
- Guard: the welding area is enclosed by the safety fence with welding-light-opaque infill panels and welding protection viewing windows (EN ISO 14120:2015); access to the torch for maintenance and cleaning is provided exclusively via the secured maintenance door (SF-01, PLr d).
- Provision of a torch rest with a thermally insulated receptacle (ceramic or silicone pad) immediately at the welding station, so that the torch is placed down in a defined manner after the process and is not set down on conductive metal surfaces.

INSTRUCTIONS FOR THE USER

- Operating instructions: state the cooling time after the end of welding explicitly before any torch change, cleaning or set-up work on the torch (reference value as specified by the torch manufacturer); include a procedure for torch changes with the step 'wait for cooling time or check temperature'.
- Warning labelling: permanently and clearly affix the warning sign 'Warning; Hot surface' (W017 in accordance with EN ISO 7010:2020) to the torch area and to the maintenance door.
- Qualification: only instructed persons may carry out torch changes and cleaning; instruction covers the risk of burns, cooling times and correct use of PPE.
- 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 torch; this requirement shall be stated in the operating instructions and indicated by the mandatory sign 'Wear protective gloves' (M009 in accordance with EN ISO 7010:2020) at the maintenance door.

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 PRESENT ON THE MACHINERY

- Inherently safe design measures 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.
- Maintenance door: 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).
- Set-up mode with the maintenance door open: While the maintenance door is open, the welding power source is safely switched off via SF-01 (shutdown path of the safety PLC as for SF-03, PLr d in accordance with EN ISO 13849-1:2023), so that no arc can be ignited with the door open.
- The additional inhibit of the welding enable in the standard controller (welding enable only when the maintenance door is closed and locked) is an operational interlock without a PL requirement.
- The function 'SF-05 Safely reduced speed 250 mm/s with enabling device in set-up mode' (PLr d) applies to the movements of the robot and the turntable.
- With the maintenance door closed, the guard locking (SF-01) protects against arc radiation.
- Radiation protection at the loading opening: the dividing centre wall of the turntable with its welding curtain in accordance with EN ISO 25980 shields the loading station, so that no direct radiation can reach the operator.

INSTRUCTIONS FOR THE USER

- Operating instructions: Note on the radiation hazard from the MAG arc (UV, visible, IR) in accordance with (EU) 2023/1230 Annex III, sections 1.7.4.1 and 1.7.4.2; statement that the welding power source is safely switched off via SF-01 while the maintenance door is open; description of the PPE requirements for set-up and maintenance activities in the vicinity of the welding area.
- Qualification requirement: Set-up and maintenance personnel must have knowledge of the radiation hazard associated with arc welding; instruction in accordance with the German Occupational Safety Ordinance on Artificial Optical Radiation (OStrV) is to be identified in the operating instructions as a user obligation.
- 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 goggles or welding face shield with a welding filter in accordance with EN ISO 16321-2 (formerly EN 169), UV-resistant protective clothing and protective gloves.

- Warning labelling: Warning sign 'Warning; Optical radiation' (W027 in accordance with EN ISO 7010:2020) at the maintenance door and at the loading opening; mandatory signs 'Wear eye protection' (M004) and 'Wear protective clothing' (M010) in accordance with EN ISO 7010:2020 to be affixed at the maintenance door.
- Emission data: Information on the optical radiation of the arc in the operating instructions in accordance with (EU) 2023/1230 Annex III, sections 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).

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 PRESENT ON THE MACHINERY

- 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 at a distance from the loading station and the control desk.
- 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.
- During set-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).
- The welding cables run entirely inside the safety fence, so that persons outside the cell keep their distance from the active cables.

INSTRUCTIONS FOR THE USER

- 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 set-up or maintenance activities in the vicinity of cables, the welding current must be switched off.
- Qualification requirement: Set-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 'Warning; Magnetic field' (W006 in accordance with EN ISO 7010:2020) at the maintenance door, at the loading station and on the welding power source.
- Additionally, attach the prohibition sign 'No access for people with active implanted cardiac devices' (P007 in accordance with EN ISO 7010:2020) at the same locations.
- 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).

Materials/substances

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 PRESENT ON THE MACHINERY

- 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 reduce the emitted pollutant mass and thereby the probability of a harmful exposure; the severity of the possible harm remains unchanged.
- Technical ventilation and extraction in accordance with EN ISO 21904-1:2020 (welding fume extraction): Capture of the welding fume by the capture hood above the welding area with a volumetric flow rate of 1800 m³/h, which 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 or the extraction is faulty; the cell stops in a controlled manner and can be restarted only after the fault has been rectified (operational interlock without a PL requirement under EN ISO 13849-1, no risk reduction is credited to it).
- Shielding of the welding area by the safety fence with welding-light-opaque infill panels (EN ISO 14120:2015) and the dividing centre wall of the turntable, 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 measure by the user.

INSTRUCTIONS FOR THE USER

- Operating instructions (in accordance with (EU) 2023/1230 Annex III, section 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: general warning sign W001 in accordance with EN ISO 7010:2020 with the supplementary text 'Harmful welding fume' and mandatory sign 'Wear respiratory protection' (M017) as residual risk marking.
- PPE requirement: FFP3 particle filtering half mask in accordance with EN 149 or powered air-purifying respirator for set-up, maintenance and cleaning work in the welding area when the

extraction system is switched off.

- Qualification requirement: operators and set-up personnel must be instructed in the hazards of welding fumes and the correct operation of the extraction system (TRGS 528 section 5).

Noise

Hazard from noise during the MAG welding process and from the turntable 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 German Noise and Vibration Occupational Safety and Health Ordinance (LärmVibrationsArbSchV).

Life phases: Operation, Setting up

PROTECTIVE MEASURES PRESENT ON THE MACHINERY

- 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.
- Drive encapsulation and structure-borne noise isolation of the turntable drive: elastic mounting of the drive motor and gearbox on the machine frame in order to reduce structure-borne noise transmission to radiating surfaces.
- 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 Step 2 and Step 3.
- Acoustic shielding of the welding area by the dividing centre wall of the turntable and the closed infill panels of the safety fence between the welding area and the loading station.
- Noise measurement at the loading station in accordance with EN ISO 11202:2010 under representative operating conditions (automatic mode, MAG welding active, turntable in operation) in order to determine the emission sound pressure level LpA (measured: 84 dB(A), K = 2.5 dB).
- The daily noise exposure level LEX,8h is determined by the user in accordance with the German Noise and Vibration Occupational Safety and Health Ordinance (LärmVibrationsArbSchV).
- Note: No safety function in accordance with EN ISO 13849-1 is affected;
- PLr determination does not apply to this hazard.

INSTRUCTIONS FOR THE USER

- Operating instructions (MR (EU) 2023/1230 Annex III, section 1.7.4.2, point (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 user's obligations under the German Noise and Vibration Occupational Safety and Health Ordinance (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).
- Warning labelling at the loading station: Mandatory sign 'Wear ear protection' (M003 in accordance with EN ISO 7010:2020), to be affixed in a clearly visible location.
- Qualification and instruction: Operating personnel are to be instructed by the user on the noise hazard, the action values and the correct use of hearing protection.

- PPE specification: Suitable hearing protection (earmuffs or earplugs) with a sufficient attenuation value (SNR) corresponding to the LEX,8h determined by the user is to be provided by the user; selection in accordance with EN 458.

Ergonomic

Insufficient lighting at the loading station and in the maintenance aisle: 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 PRESENT ON THE MACHINERY

- The design is carried out in accordance with EN ISO 12100:2010 section 6.2.8 (ergonomics) in conjunction with EN 1837 (machine-integrated lighting); the lighting as built provides 500 lx at the loading station, 200 lx in the maintenance aisle.
- The integration into the design 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 aisle areas to be marked with retroreflective yellow and black floor markings in accordance with the German workplace rule ASR A1.3 (trip hazards, aisle boundaries) and with the warning sign W007 'Warning; Floor-level obstacle' in accordance with EN ISO 7010:2020 at trip hazards.
- 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 (Step 3).

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): specification of the illuminance of the workplace lighting: 500 lx at the loading station and 200 lx in the maintenance aisle; notice that work is to be discontinued in the event of failure of the integrated lighting until the lighting has been restored.
- Text sign on the maintenance door: 'Stop work if the lighting fails'.
- 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.

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 rotation range 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 PRESENT ON THE MACHINERY

- Inherently safe design measures exhausted: The loading station requires a permanently open access opening for manual workpiece infeed.
- Minimum distances in accordance with EN ISO 13854:2019 cannot, as a design measure, 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.
- Protective field and under-reach guarding: Position the light curtain (Type 4 in accordance with EN IEC 61496-1:2020, SF-02, PLr e) such that the protective field covers the loading opening completely.
- Remaining openings below and beside the protective field are closed with fixed guards (EN ISO 14120:2015) in accordance with EN ISO 13857:2019 Table 4, so that reaching under or around the protective field is not possible.
- The depth of these flanks must be determined in accordance with EN ISO 13857:2019 Table 4 (safety distance as a function of the opening size) so that the hazard zone cannot be reached from the lateral direction.
- 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, resolution 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).

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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.
- Warning signs (EN ISO 7010:2020): 'Warning; Crushing of hands' (W024) to be affixed on both sides of the flank panels and on the light curtain frame.
- Prohibition sign 'No reaching in' (P015) at the access opening.
- Qualification requirement: In set-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.
- 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.

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. monitoring of the maintenance door, parameters of the light curtain, speed limit in set-up mode). 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 PRESENT ON THE MACHINERY

- 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.

INSTRUCTIONS FOR THE USER

- Operating instructions: network requirements for the user (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.

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 safety 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 PRESENT ON THE MACHINERY

- Inherently safe design measures 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.
- Fixed guard: fixed safety fence with welding-light-opaque infill panels and viewing windows with welding protection filters in accordance with EN ISO 14120:2015 around the entire robot working space, height 2200 mm.
- Interlocked maintenance door with guard locking (SF-01): the maintenance door is an interlocking 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.
- SF-01 is specified with PLr d; integration into the safety controller in accordance with EN ISO 13849-1:2023.
- Tamper protection of the protective devices: the interlocking device of the maintenance door is protected against defeat in accordance with EN ISO 14119:2025 section 8: high-level coded actuator in accordance with EN ISO 14119:2025, switch and actuator mounted with non-detachable fasteners.
- In addition: safety 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.
- Emergency stop devices (SF-03): emergency stop devices at the control desk, at the maintenance door and on the teach pendant in accordance with EN ISO 13850:2015, integrated into SF-03 'Emergency stop of the overall installation, stop category 1', PLr d.
- 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 a control desk located outside the hazard zone.
- 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.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): description of the access rules for the robot working space, prohibition of climbing over the safety 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).
- Warning marking on the safety fence and at the maintenance door: warning sign W018 'Warning; Automatic start-up' in accordance with EN ISO 7010:2020 and supplementary prohibition sign 'No access for unauthorised persons' (German ASR A1.3, D-P006).
- Marking to be affixed so that it is clearly visible and permanent.
- 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).
- 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.

Materials/substances

Hazard from shielding gas (argon-CO2 mixture M21) in the event of leakage: Argon and CO2 are heavier than air, so the shielding gas 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 PRESENT ON THE MACHINERY

- 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 at the supply connection of the cell).
- A lower system pressure reduces the quantity of gas escaping in the event of a fault and thus the potential for accumulation.
- These measures address the energy source (stored pressurised gas) and the hazard location (accumulation zone) directly.
- 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.
- 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.
- Installation of the shielding gas supply provided on site (cylinder bank or withdrawal station) in a ventilated area of the hall, not in pits, basements or confined recesses.
- If installed in poorly ventilated areas, the user 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.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 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).
- Qualification: Work on compressed gas lines and fittings only by instructed specialist personnel; instruction in accordance with DGUV Rule 100-500 Chapter 2.26 and TRGS 528 (user's obligation).
- Warning labelling: general warning sign W001 in accordance with EN ISO 7010:2020 with the supplementary text 'Risk of asphyxiation from shielding gas' at the gas supply installation site; supplementary prohibition sign 'No access for unauthorised persons' (German ASR A1.3, D-P006) on locked supply areas.
- When working in confined or poorly ventilated areas (e.g. cylinder changes in recesses): use a portable oxygen warning device; no lone working.

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 PRESENT ON THE MACHINERY

- Spark reduction at the point of origin through the design of the welding parameters and the extraction geometry: Design the capture hood above the welding area and the duct routing so that sparks drawn in have 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 an integral part of the extraction system design, not a downstream protective device.
- The remaining residual risk of a filter fire is limited by the following technical protective measures:
- 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 as an operational interlock without a PL requirement under EN ISO 13849-1, no risk reduction is credited to it; the cell stops in a controlled manner and can be restarted only after the fault has been rectified.
- Extinguishing device at the filter housing: at least one closable extinguishing agent inlet opening (extinguishing lance) on the housing; an automatic extinguishing device is not part of the scope of supply and, if required, is added by the user in line with the user's fire protection concept.
- 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 machine control system as an operational interlock without a PL requirement.
- 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 (user's responsibility, to be agreed with the building fire protection concept).
- Run-on time of the extraction fan after the end of welding: program 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.

INSTRUCTIONS FOR THE USER

- Operating instructions (in accordance with (EU) 2023/1230 Annex III, section 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 an ineffective shut-off damper.
- 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:
- General warning sign W001 in accordance with EN ISO 7010:2020 with the supplementary text 'Fire hazard from sparks in the filter' on the filter housing and maintenance opening.
- Text sign 'Do not open in the event of a fire alarm' on the maintenance flap 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 (user'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).

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 PRESENT ON THE MACHINERY

- Height-adjustable loading station (height-adjustable standing platform for the operator), designed for the body height range P5 to P95 of the operating population in accordance with EN ISO 14738:2008 and EN 1005-4 (working height for assembly/handling: approximately 900 to 1100 mm above standing surface, individually adjustable).
- Workpiece weight and handling frequency have been assessed using the reference mass in accordance with EN 1005-2:2003+A1:2008: for around 40 lifts per hour, the manufacturer has set a threshold of 15 kg for manual handling; heavier workpieces of up to 40 kg are loaded using a lifting aid.
- For workpieces over 15 kg, a lifting aid (balancer, vacuum lifter or slewing jib crane) with a load capacity of at least 40 kg must be used at the loading station.
- The lifting aid is provided on site by the user and is not part of the scope of supply; the clearance required for its use is provided at the loading station.
- The machine control system does not impose a forced cycle: the next cycle starts only when the operator presses the cycle start pushbutton, so that micro-breaks are possible.
- 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.

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): Specification of the workpiece mass/masses, of the assessment of manual handling of loads in accordance with EN 1005-2:2003+A1:2008 and of working postures in accordance with EN 1005-4; instructions on the correct adjustment of the working height with a setting guide.
- Ergonomic instruction for operators: correct lifting technique, use of the lifting aid, recognition of overload signals.
- Reference in the operating instructions to the user's obligation regarding occupational health surveillance in accordance with the German Ordinance on Occupational Health Care (ArbMedVV), that is, the offer of health surveillance for activities involving heavy physical work.
- Warning labelling at the loading station: text sign 'Manual handling up to 15 kg only, use the lifting aid above this'.
- Qualification requirement: Operators must be instructed in ergonomically correct operation and in the adjustment of the standing platform.

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 PRESENT ON THE MACHINERY

- 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, section 1.2.1, point (f)).

INSTRUCTIONS FOR THE USER

- Operating instructions: Access to and export of logs, user's retention obligations when the machine is transferred, procedure in the event of a regulatory request, note on storage capacity and time synchronisation.

Corruption/security

Falsified production or recipe data from MES or cloud: Order and recipe data taken from MES, ERP or cloud platform (e.g. welding parameters, program number or workpiece assignment) are falsified, outdated or intended for the wrong machine. The machine operates with specifications outside the safe limits or with an incorrect workpiece and program 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 PRESENT ON THE MACHINERY

- Limit safety boundaries independently of transferred recipe data in the safety controller; recipe data shall control process parameters only within these limits (Annex III, section 1.2.1, point (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.

INSTRUCTIONS FOR THE USER

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

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 aisle. [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 PRESENT ON THE MACHINERY

- 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 HMI 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 hazard zone (Annex III, section 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 HMI 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, section 1.2.1, point (f).

INSTRUCTIONS FOR THE USER

- Operating instructions (Chapter 13.3): 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.

Life phase: Maintenance

Materials/substances

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 PRESENT ON THE MACHINERY

- 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):
- Labelling of the filter unit: General warning sign W001 in accordance with EN ISO 7010:2020 with the supplementary text "Harmful dust" to be permanently affixed to the filter housing.

INSTRUCTIONS FOR THE USER

- Operating instructions (Chapter 10.2): 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).
- Qualification requirement: Filter change to be carried out only by trained specialist personnel who have been informed of the hazard from welding fume dusts.
- PPE specification: During the filter change, the following must be worn as a minimum: FFP3 particle filtering 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' (M017 in accordance with EN ISO 7010:2020) on the filter housing.
- Reference to occupational health and safety legislation: The user is to be advised of their obligations under TRGS 528 (welding operations) and the German Hazardous Substances Ordinance (GefStoffV), in particular regarding the risk assessment for CMR dusts and the provision of suitable PPE.

Mechanical

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 PRESENT ON THE MACHINERY

- Before any intervention, the trapped clamping pressure is released by opening the clamps; in the event of a fault it is released in a controlled manner using the manual override of the pressure-holding valve.
- Note: The severity of a remaining residual energy event is reduced by this measure, as the kinetic energy of the clamping elements is considerably lower with a small residual volume and throttled venting.
- Maintenance shut-off valve with venting function (lockout/tagout-capable) in accordance with EN ISO 4414:2010 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).
- 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).
- Residual pressure indicator at the maintenance access: before any intervention, the absence of pressure is checked at the residual pressure indicator; the indicator is an operational device without a PL requirement under EN ISO 13849-1:2023.
- Guard: the clamping fixtures are located inside the safety fence (EN ISO 14120:2015); access for maintenance and fault clearance is via the maintenance door with guard locking in accordance with EN ISO 14119:2025 (SF-01, PLr d).

INSTRUCTIONS FOR THE USER

- Operating instructions ((EU) 2023/1230 Annex III, section 1.7.4): Work instruction for maintenance and fault clearing on the pneumatic clamping device with an explicit step-by-step procedure: (a) remove the workpiece and open the clamps, (b) shut off the compressed air supply at the maintenance shut-off valve and wait for venting, (c) in the event of a fault, release any trapped residual pressure using the manual override of the pressure-holding valve, then check that the residual pressure indicator shows 0 bar, (d) attach the lockout padlock, (e) only then intervene in the system.
- Include a note on the hazard from residual pressure and ejected workpieces.
- Warning labelling on the clamping device and on the shut-off valve: general warning sign W001 in accordance with EN ISO 7010:2020 with the supplementary text 'Residual pressure in the clamping fixture'; information sign 'Before intervention: vent to 0 bar and lock shut-off valve'.

- Qualification requirement: maintenance and fault-clearing work on the pneumatics only by instructed specialists with knowledge of pneumatic safety rules (EN ISO 4414:2010).
- PPE specification: prescribe safety goggles (eye protection against flying parts) and protective gloves when opening pneumatic connections.

Life phase: Decommissioning

Mechanical

Hazard during dismantling of the cell at the end of its service life: When dismantling safety 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 PRESENT ON THE MACHINERY

- Energy isolation and de-energisation prior to commencing dismantling: 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), and lock them in a secured, de-energised state before commencing dismantling (lockout/tagout procedure in accordance with EN ISO 14118:2018).
- Verify absence of voltage by measurement before opening the control cabinet and line connections.
- 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 operating instructions, Chapters 5.2 and 5.3).
- Safe distance during lifting: Prohibition on remaining beneath suspended loads in accordance with the operating procedure; barrier around the dismantling area.

INSTRUCTIONS FOR THE USER

- Operating instructions (Chapter 11, (EU) 2023/1230 Annex III, section 1.7.4): Step-by-step dismantling instructions with a defined sequence (energy isolation and venting first, then mechanical dismantling); 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 sign 'Warning; Electricity' (W012 in accordance with EN ISO 7010:2020) and an information sign indicating possible residual pressure in the pneumatic lines.
- Qualification requirement: Dismantling 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 S3 (EN ISO 20345), safety helmet when using lifting equipment.

3 Technical data

- Machine/installation: Robotic welding cell RSZ-2600 (assembly of machinery)
- Type/model: RSZ-2600
- Serial number: RSZ2600-2026-0001
- Year of construction: 2026
- Machine type: Assembly of machinery within the meaning of Article 3(1)(d) MR
- Operating modes: Automatic, Set-up
- Rating plate: on the right-hand side wall of the control cabinet; information shown: manufacturer, type, serial number, year of construction, 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 turntable approximately 1,900 kg, robot with base approximately 850 kg, control cabinet approximately 350 kg, welding power source with wire feed unit approximately 120 kg, welding fume extraction unit approximately 250 kg, safety fence segments total approximately 400 kg; control desk, cabling, media installation and small parts approximately 730 kg.

Workpiece data: maximum workpiece weight 40 kg; maximum workpiece 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; TN-S system; 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; protection class I, degree of protection IP23S; wire feed unit for wire diameters 1.0 to 1.2 mm; water-cooled welding torch with cooling unit and temperature monitoring at the torch neck; 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.

Turntable: two-station turntable with vertical axis of rotation, rotation 180 degrees; load capacity 2 x 40 kg plus clamping fixtures; rotation time approximately 3 seconds; pneumatically closing workpiece clamps with pressure switch, pilot-operated non-return valve (pressure-holding valve) and workpiece presence sensor at each station.

Workpiece-specific clamping fixtures of the user: maximum 60 kg per station; interfering contour in accordance with installation plan RSZ-2600-LAY-001; electrically insulated from the table frame; clamps pneumatically closing with pressure-holding valve and connected to the clamping pressure monitoring (SF-04); the manufacturer approves new fixtures before they are first used.

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 Nl/min.

Workplace lighting: machine-integrated in accordance with EN 1837; 500 lx at the loading station, 200 lx in the maintenance aisle; failure message on the HMI panel.

Welding fume extraction: extraction capacity 1,800 m³/h; filter cartridge welding fume class W3 (separation efficiency at least 99 per cent, tested in accordance with EN ISO 21904-2; requirement from the risk assessment in accordance with the German Technical Rule for Hazardous Substances TRGS 528); recirculation mode, optional exhaust air connection; monitoring of extraction capacity with fault message; pre-spark separator upstream of the filter cartridge; temperature monitoring of the filter cartridge, motorised shut-off dampers, and smoke and CO detectors in the filter housing and in the exhaust air duct; filter housing with bag-in/bag-out change system for replacing the cartridge; run-on of the extraction fan for at least 10 minutes after the end of welding.

Noise emission (declaration in accordance with EN ISO 4871): A-weighted emission sound pressure level at the loading station LpA = 84 dB(A), measurement uncertainty K = 2.5 dB, determined in accordance with EN ISO 11202; A-weighted sound power level LWA = 96 dB(A), uncertainty KWA = 3 dB, determined in accordance with EN ISO 3746 (accuracy grade 3). Operating conditions during the measurement: automatic mode with an approved welding program at a cycle time of approximately 90 seconds, welding fume extraction in operation, maintenance door closed; the measuring position is the loading station in front of the loading opening (standing person). The C-weighted peak sound pressure level at the loading station does not exceed 130 dB(C). The figures quoted are emission levels and are not necessarily safe working levels. The user 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

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 a one-off special-purpose machine 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 centre 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 an EU 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 centre wall with welding curtain, pneumatically closing workpiece clamps with pressure switch, pilot-operated non-return valve (pressure-holding valve) with manual override and workpiece presence sensor at each station; deflector plate below the turntable as a catching device; load capacity 2 x 40 kg plus clamping fixtures (maximum 60 kg per station, for requirements see Chapter 3.1).

(3) Welding equipment: MAG welding power source 400 A at 60 per cent duty cycle (CE-marked equipment), wire feed unit on the robot arm, hose assembly, water-cooled welding torch with cooling unit, temperature monitoring at the torch neck and 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 pre-spark separator, filter cartridge and capture hood above the welding area; monitoring of extraction capacity; temperature monitoring of the filter cartridge, motorised shut-off dampers, and smoke and CO detectors in the filter housing and in the exhaust air duct; filter housing with bag-in/bag-out change system for low-dust cartridge replacement and with a closable extinguishing agent inlet opening.

(5) Guards and protective devices: Perimeter guard (safety fence) 2,200 mm high with welding-light-opaque infill panels, welding protection viewing windows and base panel; maintenance door at the rear with interlocking, guard locking, escape release from the inside and lockout device for personal padlocks; type 4 light curtain at the loading opening.

(6) Control system: Control cabinet with main switch, safety PLC, system controller and network gateway with firewall for the data connection and remote maintenance (see Chapter 13); signal exchange between all sub-machines via the shared control system.

(7) Control desk: HMI panel with program display, pushbutton for cycle start and acknowledgement, operating mode selector switch, remote maintenance key switch, emergency stop device; signal tower (green/yellow/red) on the cell roof; red signal light for the cooling lockout period at the removal station.

(8) Media supply: Compressed-air service unit with lockable maintenance shut-off valve with exhaust function and residual pressure indicator; connection for the customer-supplied shielding gas supply with solenoid valve (normally closed), which shuts off the gas supply on a machine stop, on an emergency stop and during breaks in operation.

(9) Workplace lighting: machine-integrated lighting in accordance with EN 1837 with 500 lx at the loading station and 200 lx in the maintenance aisle; failure message on the HMI panel.

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 centre wall shields against the arc and weld spatter. A height-adjustable standing platform adapts the working height to the body height of the operator (working height approximately 900 to 1100 mm above the standing surface); before starting work, adjust the platform so that the gripping points are at about elbow height.

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

Teach pendant (set-up personnel): Hand-held unit of the robot controller with emergency stop and three-position enabling device for teaching and traversing in set-up mode. Use is reserved for trained set-up personnel.

Maintenance access (rear side): Maintenance door with interlock and guard locking; access for maintenance and set-up work only when the system has been shut down or in set-up 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 switch confirms the clamping pressure and the presence sensor confirms the workpiece position.

2. The operator leaves the protective field of the light curtain and presses the cycle start pushbutton at the control desk. 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 rotates into the welding area and the station with the finished welded workpiece rotates towards the operator.

4. The robot executes the released welding program at the rear station. The welding fume extraction runs under process control; torch cleaning is carried out under program control at defined intervals.

5. In parallel, the operator removes the finished workpiece at the front station and loads the next blank. Removal is released only once the cooling lockout period stored for the welding program has elapsed and the red signal light at the removal station has gone out. The cycle time is approximately 90 seconds.

6. After the program has ended and the cycle start has been actuated 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 set-up 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. When the maintenance door is open, the welding power source is safely shut down (SF-01); wire can then be fed only in inching mode at reduced threading speed.

5 Delivery, transport, unpacking

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 control desk; (4) MAG welding power source with wire feed unit and torch cleaning station on a pallet; (5) welding fume extraction unit on a pallet; (6) safety 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 S3 safety footwear in accordance with EN ISO 20345 and suitable protective gloves.

> **WARNING**
> Falling, tipping or swinging loads when heavy assemblies are lifted and moved. Death or serious injury may result. 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: approximately 350 kg
- Welding fume extraction unit: approximately 250 kg
- MAG welding power source with wire feed unit: approximately 120 kg
- Safety fence segments, total: approximately 400 kg
- Control desk, cabling, media installation and small parts: approximately 730 kg (distributed across several packages)

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 dividing centre wall 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.

> **NOTICE**
> Lifting accessories attached to the robot arm, the cabling, the hose assembly or the dividing centre wall of the turntable. Gear units, cables and the dividing centre wall will be damaged. Use only the marked crane eyes and fork pockets.

Attach the load in such a way that tipping, shifting or swinging is ruled out (sling angle of the lifting accessories not more than 60 degrees to the vertical, use edge protection). Lift slowly and without jerking, guide the load in a controlled manner and set it down without impact. Secure the load against slipping and tipping during in-plant transport. Load securing in accordance with EN 12195-1 applies to transport on road vehicles.

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

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 per cent, 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 turntable, 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.

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

Installation site: at the user's plant in accordance with installation plan RSZ-2600-LAY-001. 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 user must ensure on site 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. In this area the user provides a lifting aid with a load capacity of at least 40 kg for workpieces over 15 kg (for example a balancer or a pillar jib crane); it is not part of the scope of delivery. 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 (turntable) approximately 2.4 x 1.8 x 2.0 m, 1,900 kg. Traffic routes and hazard zones must be marked in accordance with the German Technical Rule for Workplaces 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 turntable 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 site by a competent person engaged by the customer.

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 by the customer on site for the operation of the machine:

- Electrical: 400 V AC, 3/N/PE, 50 Hz, TN-S system; connected load 32 kVA; fusing 63 A gG provided by the customer on site; 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 Nl/min; shut-off valve provided by the customer on site 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 bank; 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, an exhaust air duct (connection DN 250) may be provided by the customer on site. The user is responsible for ensuring adequate hall ventilation in accordance with the German Technical Rule for Hazardous Substances TRGS 528.
- Lighting: The user provides the hall lighting on site. The workplace lighting of the cell is part of the scope of delivery (machine-integrated in accordance with EN 1837, 500 lx at the loading station, 200 lx in the maintenance aisle, failure message on the HMI panel).

8 Assembly and installation, initial commissioning

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 user as a reference for a later relocation 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 an EU 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 OFF 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 have an electrically skilled person verify the absence of voltage. The user's key and lock procedure must be applied.

> **DANGER**
> Electrical voltage of 400 V at the supply cable, control cabinet and welding power source. Touching live parts will result in death or serious injury. Work on the electrical equipment may be carried out only by electrically skilled persons and only after isolating, securing against re-energisation and verifying the absence of voltage; after isolating, wait at least 1 minute for the welding power source to discharge; for the robot drives, the waiting time specified by the robot manufacturer applies.

> **WARNING**
> Unexpected movements of the robot axes and the turntable when the energy supply is connected for the first time and during assembly. Death or serious injury may result. Before switching on, make sure that no persons are present in the robot working area or in the rotation range of the turntable.

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 clamps must be opened first, because the pressure-holding valve traps the clamping pressure in the cylinder; the pneumatic circuit must then be depressurised and the residual pressure indicator checked for 0 bar.

During the work, at a minimum the following must be worn: S3 safety footwear in accordance with EN ISO 20345, 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 control desk as well as the welding power source and extraction unit; mount the torch cleaning station on the base.
4. Assemble the safety 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 an electrically skilled person 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 phase sequence (clockwise rotating field).
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).

Reduction of noise and vibration: fit the fence infill panels, the base panels and the cover of the turntable drive completely; they are part of the noise reduction. Do not bridge the elastic bearing elements of the turntable drive with rigid connections. No further measures against noise or vibration are required during installation.

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 rotation range of the turntable or within the safety 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 emergency stop devices (control desk, 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, of the escape release, of the lockout device for personal padlocks and of the restart prevention function
- Function of the pressure monitoring on the clamping circuit, of the pressure-holding valve in the clamping line with its manual override, and of the workpiece presence sensors
- 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) and function of the temperature monitoring of the filter cartridge, the shut-off dampers, the smoke and CO detectors and the run-on
- Function of the cooling lockout period with signal light at the removal station, of the temperature monitoring at the torch neck and of the workplace lighting (500 lx at the loading station, 200 lx in the maintenance aisle, failure message)
- 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 programs 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 user 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

This chapter is addressed to the operator and the set-up personnel of the robotic 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 desk; activities inside the cell are reserved for set-up 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 Chapter 9.4 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 one may remain within the rotation range of the turntable while it is rotating. Protective gloves do not protect against crushing; reach into the rotation range only when the turntable has been stopped.
- Workpieces shall only be inserted and removed when the front station is stationary. Remove welded workpieces only after the cooling lockout period has elapsed (red signal light at the removal station has gone out) and handle them only with heat-protective gloves; in the weld seam area they reach several hundred °C after welding.
- Handle workpieces up to 15 kg by hand and workpieces over 15 kg only with the user-supplied lifting aid at the loading station (for example a balancer or crane system, load capacity at least 40 kg); the maximum mass per workpiece is 40 kg.
- Do not look directly into the arc, including via reflections; the welding curtain, the infill panels of the safety fence and the viewing windows must be undamaged.
- Operation is only permitted with the welding fume extraction system in effective operation. If the extraction system develops a fault, the cell stops in a controlled manner; it cannot be restarted until the fault has been 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.

> **WARNING**
> Hot workpieces and clamping fixtures after welding (several hundred °C in the weld seam area). Serious burns to the hands and forearms may result. Remove workpieces only after the cooling lockout period has elapsed and only while wearing heat-protective gloves, and do not touch them with unprotected skin.

The cooling lockout period is stored for each welding program. While it is running, removal remains inhibited and the red signal light at the removal station is lit.

9.2 Controls and Indicators

Main switch (on the control cabinet): disconnects the overall installation on all poles; can be locked in the OFF position for maintenance and repair.

Control desk adjacent to the loading opening:

- HMI panel: program 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 resetting the emergency stop device, and after fault rectification; flashes when acknowledgement is required.
- Emergency stop device (red on yellow background): stops the overall installation in hazardous situations.
- Operating mode selector switch (key switch): positions Automatic and Set-up; the key remains with the authorised person.
- Remote maintenance key switch (positions Off and Enable): enables a remote maintenance session by the manufacturer (see Chapter 13.3); the key remains with the person responsible at the user's company.

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 (set-up personnel only): hand-held unit of the robot controller 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; red signal light at the removal station (lit during the cooling lockout period); on the HMI panel, the release indication for torch replacement and torch cleaning (temperature monitoring at the torch neck) and the messages for failure of the workplace lighting and for overtemperature or fire alarm of the extraction unit.

9.3 Operating Modes

The machine has the operating modes Automatic and Set-up. They are selected with the operating mode selector switch:

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.

Set-up mode (selector switch in Set-up position, key switch): operating mode for teaching, program testing and fault-finding by trained set-up personnel. Movements of the robot and turntable are only possible with the three-position enabling device on the teach pendant actuated and at safely reduced speed (maximum 250 mm/s at the TCP). When the maintenance door is open, the welding power source is safely shut down (SF-01); wire can then be fed only in inching mode at reduced threading speed. The key remains with the authorised person; after completing the work, it is mandatory to switch back to the Automatic position.

> **WARNING**
> Movements of the robot and turntable while persons are inside the cell in set-up mode. Crushing and impact with serious injury may result. Enter the cell only with the teach pendant in your hand, secure the maintenance door against closing with your personal padlock in the lockout device, and do not actuate the enabling device until no other person is within the range of movement.

Maintenance (not an operating mode): mechanical, electrical and pneumatic maintenance work is carried out with the machine isolated and secured against restart (main switch locked, compressed air relieved); see Chapter 10.

The further life-cycle phases of transport and installation (Chapters 5 and 8), cleaning (Chapter 10.2) and fault-finding (Chapter 10.4), 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 with infill panels and viewing windows, welding curtain, light curtain, and maintenance door undamaged; no persons or foreign objects in the cell; operating area clear; workplace lighting working (no failure message on the HMI panel); standing platform adjusted to your own body height.
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); once a week, additionally a functional check of one emergency stop device (a different device each time, see Chapter 10.2).
5. Check that the extraction system is ready for operation (no fault message on the HMI, differential pressure indicator in the green range); the extraction system starts under process control.
6. Select the welding program on the HMI, acknowledge fault messages, release the system using cycle start.

Change-over and product change (set-up personnel only): program change on the HMI; replacement of workpiece-specific clamping fixtures only with the system stopped and the clamping circuit depressurised (first open the clamps, then shut off and vent the compressed air, see Chapter 10.4);

use only clamping fixtures approved by the manufacturer in accordance with Chapter 3.1; 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 programs (set-up personnel only): exclusively in set-up mode with the enabling device and reduced speed; new programs must be verified first in set-up mode at reduced speed and then in an automatic cycle without a workpiece; 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: actuate the emergency stop 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. Reset the actuated emergency stop device (by rotating or pulling).
3. Acknowledge at the control desk; 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 set-up personnel. The rescue of a trapped person is described in Chapter 2.6.

Action in the event of compressed air failure: The pressure-holding valve keeps the workpieces clamped; the pressure switch inhibits the rotary movement of the turntable and the machine stops in a controlled manner. Stop the machine, restore the compressed air supply (6 bar at the service unit) and remove the workpiece only once the clamping pressure has been confirmed again. Then acknowledge and restart as after an emergency stop.

> **WARNING**
> Fire in the filter housing of the extraction unit caused by sparks and glowing particles, possibly with a delay after the end of the shift. Serious burns and smoke poisoning may result. Do not open the filter housing in the event of a fire alarm, leave the area and call the fire service.

Fire in the extraction unit: If the temperature monitoring of the filter cartridge or a smoke or CO detector responds, the control system switches off the extraction fan, closes the motorised shut-off dampers and stops the cell in a controlled manner. Leave the area immediately, call the fire service and inform your supervisor. Do not open the filter housing, because incoming air can fan smouldering material into flame; extinguishing agent is introduced only by the fire service through the closable extinguishing agent inlet opening of the filter housing. Restart is permitted only after the fault has been rectified and the maintenance department has given its approval. The extraction unit must not be operated with a defective temperature sensor or an ineffective shut-off damper.

10 Maintenance

This chapter is addressed to the specialist maintenance personnel responsible for the maintenance of the robotic welding cell RSZ-2600. Maintenance work is to be carried out with the machine at a standstill. Before mechanical, electrical and pneumatic work, the machine is to be isolated via the main switch, which can be locked in the OFF position, and secured against restart; the pneumatic supply is to be depressurised. Before work on the clamps, the clamps are to be opened first, because the pressure-holding valve traps the clamping pressure in the cylinder; the compressed air is then to be shut off and vented and the residual pressure indicator checked for 0 bar. If a clamp cannot be opened, the pressure is to be released in a controlled manner using the manual override of the pressure-holding valve (for the procedure see Chapter 10.4). The functional checks of the protective devices in accordance with Chapter 10.2 are carried out with the machine switched on, from outside the cell. Additionally, observe the manufacturer's documentation for purchased components, in particular the assembly 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.

> **DANGER**
> Electrical voltage of 400 V in the control cabinet and in the welding power source. Touching live parts will result in death or serious injury. Work on the electrical equipment may be carried out only by electrically skilled persons; beforehand, switch off and lock the main switch, wait at least 1 minute for the welding power source to discharge (robot drives: waiting time specified by the robot manufacturer) and verify the absence of voltage.

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 (RSZ-2600-WNW-001) is supplied with the machine (see Chapter 12); 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 user 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; check the shielding gas hoses, the welding and earth cables and the earth clamp for damage and secure seating; check that the workplace lighting is working; clean the working area and remove spatter from the floor at the loading station.

Weekly (operator/set-up personnel): emergency stop functional check (alternating between each emergency stop 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 the welding curtain, the infill panels of the safety fence and the viewing windows for damage.

Monthly (set-up personnel/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, the escape release and the lockout device of the maintenance door; check robot cables and hose assembly for chafing points; empty the pre-spark separator of the extraction unit (treat the dust as when replacing the filter cartridge); check the coolant level of the cooling unit and, if necessary, top up with coolant as specified by the torch manufacturer.

Every six months (maintenance): documented functional check of all safety functions (SF-01 to SF-05) in accordance with the enclosed test plan for the safety functions (RSZ-2600-PPS-001, see Chapter 12); check anchoring of the robot base and turntable (tightening torques); visual inspection of the electrical equipment; visual inspection of the screen terminations and the equipotential bonding; insulation measurement of the welding circuit by an electrically skilled person; functional check of the temperature sensor and the shut-off dampers and of the smoke and CO detectors of the extraction unit.

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.

> **WARNING**
> Welding fume dust when the filter cartridge is replaced. Inhalation can cause permanent damage to the respiratory tract. Wear an FFP3 particle filtering half mask in accordance with EN 149, safety goggles and disposable gloves; do not raise dust.

Replacing the filter cartridge (maintenance): wait for the extraction run-on to finish, then isolate the machine; using the bag-in/bag-out change system of the filter housing, remove the saturated cartridge into the change bag and seal the bag tightly straight away; clean the filter housing with an industrial vacuum cleaner of dust class H in accordance with EN 60335-2-69, do not blow it out and

do not sweep; fit a new cartridge of welding fume class W3 and check that the seal is seated correctly; after switching on again, check the differential pressure indicator; disposal in accordance with Chapter 11.3.

Cleaning the cell (set-up personnel/maintenance): only with the machine isolated and secured against restart; remove spatter mechanically; pick up dust with an industrial vacuum cleaner of dust class H, do not blow it off with compressed air and do not sweep; do not use flammable cleaning agents; clean the viewing windows and the front screens of the light curtain with a soft cloth; after cleaning, carry out the functional check of the light curtain.

Additionally, the user's statutory inspection obligations under the German Ordinance on Industrial Safety and Health (BetrSichV) and DGUV Regulation 3 (German accident insurance regulation on electrical installations and equipment) 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 turntable: 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-finding

Diagnosis: fault messages are read from outside the cell, with the machine switched on, at the HMI panel, the signal tower and the indicators. Interventions inside the cell with the machine switched on (for example moving the robot clear or checking the program path) are permitted only for set-up personnel in set-up mode with the enabling device and safely reduced speed. Access is exclusively

via the maintenance door; each person entering secures the door with their personal padlock in the lockout device. Mechanical, electrical and pneumatic work starts only after isolation: for work on the clamps, first remove the workpiece and open the clamps; switch off and lock the main switch (LOTO); shut off the compressed air at the maintenance shut-off valve, wait for venting to finish, check that the residual pressure indicator shows 0 bar and secure the valve with a padlock; wait at least 1 minute for the welding power source to discharge; for the robot drives, the waiting time specified by the robot manufacturer applies.

> **WARNING**
> Unexpected start-up of the robot and turntable and stored compressed air in the clamping circuit during fault-finding. Crushing with serious injury may result. Before entering the cell, stop the machine and secure the maintenance door with your personal padlock. Before working on the clamps, open the clamps first, because the pressure-holding valve traps the clamping pressure in the cylinder. Then shut off and vent the compressed air and check that the residual pressure indicator shows 0 bar. If a clamp cannot be opened, release the pressure in a controlled manner using the manual override of the pressure-holding valve.

Fault	Possible cause	Remedy
System does not start in automatic mode	Safety circuit open (maintenance door, light curtain), emergency stop actuated	Close the maintenance door, clear the light curtain, reset the emergency stop device, acknowledge at the control desk
Light curtain triggers for no apparent reason	Contamination or misalignment of the optics	Clean the front screens of the transmitter and receiver, check alignment (alignment indicator), then carry out functional check
Turntable 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 rotation range
Compressed air failure (clamping pressure drops, fault message on the HMI panel)	On-site compressed air supply failed, shut-off valve closed, leak in the clamping circuit	Stop the machine; the pressure-holding valve keeps the workpieces clamped. Restore the compressed air supply (6.0 bar), check for leaks, remove the workpiece only once the clamping pressure has been confirmed, then acknowledge at the control desk
Guard locking of the maintenance door does not release	Robot or turntable has not yet reached safe standstill, arc not yet extinguished	Wait for standstill to complete (display at the control desk), 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
Insufficient extraction / fault message	Filter cartridge saturated, capture hood displaced	Replace filter cartridge (welding fume class W3, procedure in accordance with Chapter 10.2, disposal as hazardous waste in accordance with Chapter 11.3), correct hood position
Robot stops with collision message	Collision protection coupling on the torch or collision detection of the robot triggered (torque/current monitoring)	Eliminate cause in the working area, check the torch and the collision protection coupling for damage, check program path, acknowledge message on the teach pendant
Removal remains inhibited, red signal light at the removal station is lit	Cooling lockout period of the welding program is running	Wait for the cooling lockout period to elapse; do not bypass the lockout period

Fault	Possible cause	Remedy
Fault message for torch cooling, or no release for torch replacement	Coolant level too low, cooling unit faulty, torch neck still too hot	Check the coolant level and top up, check the cooling unit and hose assembly; replace the torch only after the release indication on the HMI panel
Overtemperature or fire alarm of the extraction unit	Glowing particles in the filter; temperature sensor, smoke detector or CO detector has responded	Proceed in accordance with Chapter 9.5 (Fire in the extraction unit); do not open the filter housing
Message: failure of the workplace lighting	Luminaire defective	Stop work in the affected area, have the luminaire repaired by an electrically skilled person

If a fault cannot be remedied using these measures, the manufacturer is to be contacted (for contact details see Chapter 12.1). Unauthorised interventions in safety functions are not permitted.

11 Dismantling and disposal

This chapter describes the principles for the final decommissioning, dismantling and environmentally sound disposal of the RSZ-2600 robotic welding cell. Dismantling is a separate life-cycle phase of the machine 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**
> Stored energy (electrical energy, compressed air, moving masses) as well as hazardous substances and residues from the welding process. Death or serious injury may result. Before dismantling, isolate the machine, wait for the discharge time to elapse, vent the pneumatic system and lock movable assemblies in position.

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 OFF position; have the supply cable isolated by an electrically skilled person, secure it against re-energisation, verify the absence of voltage, earth and short-circuit it, and cover adjacent live parts (the five safety rules of EN 50110-1). Wait at least 1 minute before opening the welding power source and the control cabinet (measured discharge time of the welding power source: 1.9 s to ≤ 60 V; the waiting time includes a safety margin); for the robot drives, the waiting time specified by the robot manufacturer applies.

The pneumatic system must be depressurised: open the workpiece clamps before isolating the machine, because the pressure-holding valve traps the clamping pressure in the cylinder; then close the maintenance shut-off valve, vent the system via its exhaust position and check at the residual pressure indicator that the pressure has been relieved. If a clamp cannot be opened, release the trapped pressure in a controlled manner using the manual override of the pressure-holding valve.

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 turntable 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. Have the electrical connections disconnected and labelled by an electrically skilled person; disconnect the supply cable.

3. Dismantle the light curtain, maintenance door and safety fence segments.
4. Remove the welding power source with cooling unit, wire feed unit, 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 turntable, release the anchorage, lift the turntable; finally remove the control cabinet and control desk.

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 turntable slewing ring and robot gearboxes; the anti-spatter agent from the torch cleaning station; the coolant from the cooling unit and hose assembly of the water-cooled welding torch (collect it and dispose of it in accordance with the safety data sheet, do not discharge it into the sewer system); welding wire residues; the filter cartridge of the welding fume extraction unit as well as deposited welding fume dusts in the housing, pre-spark separator and pipework.

> **WARNING**
> Welding fume dust in the filter cartridge and in the dust deposits of the extraction unit. Inhalation can cause permanent damage to the respiratory tract. When handling the filter cartridge, wear an FFP3 particle filtering half mask in accordance with EN 149 and disposable gloves, and do not raise dust. Dispose of the filter cartridge and the dust deposits in dust-tight packaging as hazardous waste (code 15 02 02* of the European List of Waste, in Germany AVV 15 02 02*: filter materials contaminated by hazardous substances, or as classified by the disposal contractor).

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 (safety fence with infill panels, frames, turntable, 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

The following documents are supplied with the machine:

- Installation plan (RSZ-2600-LAY-001)
- Circuit diagrams of the electrical equipment (RSZ-2600-EPL-001)
- Pneumatic diagram (RSZ-2600-PPL-001)
- Spare parts list (RSZ-2600-ET-001)
- Test plan for the safety functions SF-01 to SF-05 (RSZ-2600-PPS-001)
- Maintenance record form (RSZ-2600-WNW-001)
- EU declaration of conformity

The user receives the acceptance report of the initial commissioning, with the reference versions and checksums of the safety-related software (program of the safety PLC, safety configuration of the robot controller, parameterisation of the light curtain; see Chapter 13.2), at handover.

12.1 Drawings and Spare Parts

The installation plan (RSZ-2600-LAY-001) is supplied with the machine. The manufacturer provides the general arrangement drawing and the assembly drawings (drawing set RSZ-2600-ZG-001 ff.) on request for maintenance and for ordering spare parts.

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 curtain, extraction filter cartridge, base panel brushes and the seal kits for the pneumatic clamps. Ordering information: enclosed spare parts list RSZ-2600-ET-001; 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, Germany, e-mail service@muster-maschinenbau.example.

12.2 Electrical Documentation

The electrical documentation in accordance with EN 60204-1 is supplied with the machine: circuit diagrams (electrical circuit diagram RSZ-2600-EPL-001), terminal and cable schedules, control cabinet layout drawing, bill of materials for electrical equipment, PLC and safety PLC program 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 electrically skilled persons and only with the approval of the manufacturer; the drawings are to be updated accordingly when modifications are made.

12.3 Record of the risk assessment

The risk assessment to EN ISO 12100, covering all 42 hazards, their evaluation and the protective measures taken, forms part of the manufacturer’s technical documentation. It is submitted to the market surveillance authorities upon reasoned request. The residual hazards relevant to operation and the instructions derived from them are given in the chapter “Safety”.

13 Cybersecurity

This chapter is intended for the user and for the specialists responsible for networks and maintenance. It describes how the robotic welding cell RSZ-2600 is integrated into the user'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 Chapter 2 (Safety) also apply.

13.1 Integration into the User's Network

Connect the cell to the user'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 HMI panel under "Info" and can be viewed without logging in. The safety-related software comprises the program of the safety PLC, the safety configuration of the robot controller and the parameterisation of the light curtain; the reference versions and checksums are recorded in the acceptance report. 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 remote maintenance key switch at the control desk and ends automatically after four hours; while it is active, the HMI panel shows "Remote maintenance active". A responsible person must be available on site. If you suspect unauthorised access, end the session immediately with the remote maintenance 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, select set-up mode, keep the maintenance door closed and install the update via USB on the HMI 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 enclosed test plan RSZ-2600-PPS-001 (see Chapters 10.2 and 12).

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 HMI 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 user if the cell is transferred and make them available to an authority upon reasoned request.

13.6 Cybersecurity information

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, turntable 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 user'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 user's internet connection	Connection via the internet	Remotely
HMI 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 HMI 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 on the right-hand side wall of the control cabinet; software version on the HMI 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, turntable, 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 HMI 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 user 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 via USB on the HMI panel with the cell stopped, set-up mode selected and the maintenance door closed, or during an enabled remote maintenance session; then check version and checksum on the HMI 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.

List of annexes

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

- Declaration of Conformity

This document was prepared with AI assistance. Review of and responsibility for its content lie with the manufacturer.
#ce-copilot:ki-unterstuetzt; ai-disclosure=ai-assisted; generator=CE-Copilot; digitalsourcetype=compositeWithTrainedAlgorithmicMedia