X Series collaborative robot Explosion-Proof Function Manual

V2.0

Guangzhou Auctech Automation Technology Ltd

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1 Introduction

1.1 Target readers

This document provides instructions for the use of the X-Ex (explosion-proof) collaborative robot, allowing the users to understand the basic information of the robot in detail and to use the robot in a safer and more convenient manner. Please be sure to carefully read and fully understand this document before operating the robot.

This document is primarily intended for the following users:

- Field engineers for the robot
- Software engineers for the robot
- Hardware installation engineers
- Field maintenance engineers
- System maintenance engineers

Only operators with basic training are allowed to operate this robot.

1.2 Symbol convention

The following symbols may appear in this document and what they mean is described as follows:

Symbol	Interpretation
 Danger	For warning of an urgently hazardous situation which, if not avoided, will result in death or serious personal injury.
 Warning	For warning of potentially hazardous situation that, if not avoided, could result in death or serious personal injury.
 Careful	For warning of potentially hazardous situations that, if not avoided, could result in moderate or minor personal injury.
 Caution	For communicating equipment or environmental safety warning messages that, if the relevant situation is not avoided, such situation could result in equipment damage, data loss, reduced equipment performance, or other unforeseen results. "Caution" does not involve personal injury.
 Tip	For highlighting important/critical information, best practices, tips, etc. “Tip” is not a safety warning message and does not involve information related to the personal injury, equipment or environmental harm.

1.3 Special declaration

This manual is intended only as a guide to use, and the content provided in this manual is of general guidance, and does not ensure coverage of all application scenarios for all product models. Due to version upgrades, inconsistent equipment models, etc., the content provided in the manual may not be consistent with the user's equipment. Please refer to the information of the user's equipment, and this manual will not explain each and every difference caused by the aforementioned circumstances.

The maximum values provided in this manual are the maximum values achieved by the equipment in specific laboratory scenarios (e.g., constant temperature and humidity without interference, typical working conditions, etc.) that meet the corresponding standards. In actual working conditions, such reasons as working environment, specific working conditions, test methods and so on may cause the maximum test value tested of the equipment and the data provided in the manual are not consistent.

1.4 Revision history

The revision history contains a description of each update of this document. The latest version of this document contains updates from all previous document versions.

Document Version V1.0 (2022-08)

First release

2 Safety

2.1 Overview

This product is designed and manufactured in accordance with GB/T 3836 and related standards, and has been tested and qualified by the quality supervision and test departments authorized by the State, with the product explosion proof certificate. As for the product explosion-proof marking, Ex db eb pxb IIC T4 Gb and Ex pxb tb IIIC T130 ℃ Db for the robotic arms; Ex db eb mb pxb IIC T4 Gb and Ex mb pxb tb IIIC T130 ℃ Db for the control cabinet. The product can be utilized in the explosive gas environment in Zone I of petroleum, chemical, metallurgy, pharmacy and other fields. In such environment, there are Class IIB Group T4 and below explosive gas mixtures in the air. Reference standards are listed as follows:

Standard number	Title
GB 5226.1	General Technical Specifications for Mechanical and Electrical Equipment
GB/T 15706	General Principles for the Safe Design of Machinery: Risk Assessment and Risk Reduction
GB 11291.1	Robot safety requirements
GB 11291.2	Safety Requirements for the Robot System and Integration
GB/T 17799.2	General Standard for Electromagnetic Compatibility: Immunity Tests in Industrial Environment
GB 17799.4	General Standard for Electromagnetic Compatibility: Emissions in Industrial Environment
GB 16754	Safety of Machinery: design principles for emergency stop
GB/T 16855.1	Safety related to the control system in machinery safety: general principles for design
GB/T 3836.1	Explosive environment Part 1: General requirements for the Equipment
GB/T 3836.5	Explosive environment Part 5: Equipment protected by positive-pressure enclosures "p"
GB/T 4208	Degrees of protection provided by enclosure(IP code)
ISO 13849-1	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
ISO 13849-2	Safety of machinery -Safety-related parts of control systems Part 2: Validation
ISO 13850	Safety of machinery - Emergency stop - Principles for design
ISO 12100	Safety of machinery - General principles for design - Risk assessment and risk reduction
ISO 10218-1	Robots and robot equipment - Safety requirements for industrial robots Part 1: Robots
ANSI/RIA R15.06	Industrial Robots and Robot Systems - Safety Requirements
CAN/CSA Z434-14	Industrial Robots and Robot Systems - General Safety Requirements
IEC 61000-6-2	Electromagnetic compatibility (EMC) Part 6-2: Generic standards - Immunity for industrial environments

IEC 61000-6-4	Electromagnetic compatibility (EMC) Part 6-4: Generic standards - Emission standard for industrial environments
IEC 61326-3-1	Electrical equipment for measurement, control and laboratory use - EMC requirements
IEC 60947-5-5	Low-voltage switchgear and controlgear Part 5-5: Control circuit devices and switching elements - Electrical Emergency stop device with mechanical latching function
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60320-1	Appliance couplers for household and similar general purposes Part 1: General requirements
ISO 9409	Manipulating industrial robots - Mechanical interfaces Part 1: Plates
IEC 61140/A1	Protection against electric shock - Common aspects for installation and equipment
IEC 60068-2-1	Environmental testing Part 2-1: Tests - Test A: Cold
IEC 60068-2-2	Environmental testing Part 2-2: Tests - Test B: Dry heat
IEC 60068-2-27	Environmental testing Part 2-27: Tests - Test Ea and guidance: Shock
IEC 60068-2-64	Environmental testing Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance
IEC 61784-3	Industrial communication networks - Profiles Part 3: Functional safety fieldbuses - General rules and profile definitions
IEC 60204-1/A1	Safety of machinery - Electrical equipment of machines Part 1: General requirements
IEC 60664-1	Insulation coordination for equipment within low-voltage systems Part 1: Principles, requirements and tests
IEC 60664-5	Insulation coordination for equipment within low-voltage systems Part 5: Comprehensive method for determining clearances and creepage distances equal to or less than 2 mm
ISO 9787	Manipulating industrial robots, coordinate systems, and motion nomenclatures
ISO 9283	Manipulating industrial robots, performance criteria, and related test methods
EN 614-1	Safety of machinery - Ergonomic design principles - Part 1: Terminology and general principles
ANSI/UL 1740	Safety standard for robots and robotic equipment

Before performing any operation, make sure that you have read all the operating instructions supplied with the equipment, especially the instructions on dangers, warnings and cautions that may endanger personal safety and the safety of the equipment, in order to minimize the chances of accidents. In the event of a discrepancy between the contents of this document and the documentation shipped with the equipment, the documentation shipped with the equipment shall prevail.

The personnel responsible for installing and maintaining the equipment must be trained specialists who have learnt the correct methods of operation and all safety precautions. Only trained and qualified personnel may perform installation and maintenance operations.

- Prior to use, it is necessary to ensure that the explosion-proof cabinet control cabinet has been purged for at least approximately 30 minutes, and the robotic arms have been purged for at least 30 minutes, and that a normal positive-pressure environment has been established, before allowing the robot to be powered up, etc.

- It is strictly prohibited to open the explosion-proof control cabinet with electricity, if you need to open such cabinet for inspection or maintenance, the main power supply shall be cut off beforehand.

- The air source for the positive pressure control system must be purified compressed air or other non-flammable gas.

- Components and structures that affect explosion-proof performance shall not be replaced, altered or adjusted at will.

2.2 Operating environment

This product is permitted to be used in the following environmental conditions (please consult your dealer for use in other environmental conditions):

a) Site of use: indoor or covered outdoor;

b) Ambient temperature: -20°C to 45°C;

c) Humidity: 93% (25°C), no condensation;

d) Vibration: 5 to 55Hz (1.5mm/s²);

e) Shock: less than 25g (control cabinet only);

f) In zone I environment with IIC group T4 explosive gases (or liquids, vapour);

g) Altitude not greater than 2000m.

2.3 Special operating conditions

- To avoid the danger of static electricity, it is strictly prohibited to use a dry cloth to wipe the non-metallic housing part of the robotic arms.

Product explosion-proof certificate number suffix "X" indicates that the product has special requirements for safe use, the specific content is described as follows:

- For flame-proof electrical equipment equipped, repairs involving flame-proof joints must be made by contacting the manufacturer of the product.
- The gas source at the product installation site shall be able to ensure the provision of 0.2Mpa to 0.8Mpa pressure.
- The user shall ensure that the individually certified auxiliary electrical equipment is suitable for use in the environment in which the entire product is installed and shall strictly observe the respective operating instructions, special conditions and limitations for safe use for each auxiliary electrical equipment.
- There is a potential risk of static ignition when the product is in use and the product shall only be wiped with a damp cloth.
- Product operating environment temperature: -20℃～+45℃.

2.4 Description of effective scope and responsibilities

This information does not cover how to design, install and operate a complete robot system, nor does it cover all peripheral equipment that can affect the safety of the entire system. A well-designed system is necessary to protect the safety of personnel, and such system must be installed in accordance with the safety requirements set forth in the standards and regulations of the country in which the robot is to be installed.

The robot integrator shall be responsible for ensuring that the robot system complies with the applicable safety laws and regulations of the country or region in which it is located, and that the necessary safety equipment for the protection of the operator of the robot system is properly designed and installed.

This specifically includes, but is not limited to, the following:

- Ensure that the robot system meets all essential requirements;
- Perform a risk assessment of the complete system;
- Ensure that the entire system is designed and installed accurately and correctly;
- Make appropriate safety settings in the software and ensure that such settings are not modified by the user;
- Develop detailed operating instructions;
- Issuance of a declaration of conformity;
- Collect all information in the technical document;
- Label the installed robot system with the integrator's logo and contact information.

Guangzhou Auctech Automation Technology Ltd is committed to providing reliable security information. Unless Guangzhou Auctech Automation Technology Ltd has intentional or gross negligence in providing reliable security information, Guangzhou Auctech Automation Technology Ltd shall not be held responsible for it. It shall be made clear that even if everything is operated in accordance with safe practices, there is no guarantee that the robot system will not cause damage to the user's person or property.

Guangzhou Auctech Automation Technology Ltd will not be held responsible for any user losses caused by the following reasons:

- Force majeure events (e.g., natural disasters, fires, wars, etc.);
- Natural damage or wear and tear to the robot system;
- The field operating environment (e.g., voltage, temperature, humidity, etc.) or external factors (e.g., external interference, etc.) can not meet the environmental requirements for normal operation that have been indicated;
- Robot system is not installed correctly (including not being re-installed correctly after relocation);
- As a result of intentional or negligent use, misuse (including use by the user not in accordance with this manual and/or other requirements of Guangzhou Auctech Automation Technology Ltd) or vandalism by the user or a third party.

Unless otherwise agreed, Guangzhou Auctech Automation Technology Ltd shall not be liable for indirect, special, or incidental damages arising from the use of the robot system, including, but not limited to, loss of revenue, loss of actual or expected earnings, loss of business, loss of opportunity, loss of goodwill, loss of reputation, loss of, damage to or disclosure of data.

2.5 Risk assessment

Risk assessment is one of the most important tasks an integrator must complete. The robot itself is a partially completed machine, and the safety of a robot installation depends on how that robot is integrated (e.g., tools, obstacles, and other machinery).

It is recommended that the integrator performs the risk assessment as specified in standards ISO12100 (GB 15706) and ISO10218-2 (GB 11291.2). Alternatively, the technical specification ISO/TS 15066 (GB/ T 36008) can be selected as an additional guideline. For occasions with explosion risk, the integrator also needs to comply with the relevant provisions of GB/T 3836.1 and GB/T 3836.5, and can only be put into production after being examined and inspected by the inspection department designated by the State and obtaining the "explosion-proof certificate".

The integrator performing the risk assessment shall consider all work processes throughout the application life of the robot, including but not limited to:

- Teaching robot during development of the robot installation;
- Fault diagnosis and maintenance;
- Normal operation of the robot installation.

The risk assessment must be carried out before the robotic arm is energized for the first time. Part of the risk assessment performed by the integrator is to identify the correct safety configuration settings, as well as to determine if additional emergency stop buttons and other protective measures are required.

The following identifies the significant hazards that the integrator must consider. Please note that there may be other significant hazards associated with specific robot equipment.

- Risk of explosion.
- The fingers are held between the joint 4 and joint 5 of the robot.
- Sharp edges and points on tools or tool connectors pierce the skin.
- Sharp edges and points on obstacles near the robot's trajectory pierce the skin.
- Sprains or fractures due to impact between the robot payload and a solid surface.
- The consequences caused by the loosening of bolts used to secure robotic arms or tools.
- Objects fall off the tool, e.g. due to poor clamping or power failure.
- Operating errors due to different emergency stop buttons on different machines.

  If the robot is installed in a non-collaborative robot application where the risks cannot be adequately eliminated with its internal safety functions (e.g. use of hazardous tools), the system integrator must install other protective devices based on a risk assessment (e.g. use of protective devices that can protect the integrator during installation and programming). Guangzhou Auctech Automation Technology Ltd will not be liable for loss caused by failure to install protective devices.

2.6 Safety functions of explosion-proof positive pressure system

The robot and control cabinet adopt positive pressure system to realize the explosion-proof function, i.e. the protective gas is provided into the respective positive pressure chamber, so that the pressure inside the positive pressure chamber is higher than that outside the positive pressure

chamber, creating a safe environment with minimal positive pressure, thus preventing the entry of flammable hazardous gases into the positive pressure chamber, and guaranteeing the safe operation of the robot and the control system in an explosive environment. Among them, the safety functions are described as follows:

High pressure alarm function:

When the positive pressure chamber pressure of the explosion-proof cabinet is higher than 400Pa or the positive pressure chamber pressure of the robotic arm is higher than 1000Pa, the red light of the explosion-proof sound and light alarm will flash and the alarm will sound to remind the staff to check the positive pressure system and troubleshoot the fault. When the fault is troubleshooted and the positive pressure chamber pressure of the explosion-proof cabinet is restored to below 400Pa and the positive pressure chamber pressure of the robotic arm is restored to below 1000Pa, the alarm will be canceled.

Under-pressure alarm function:

When the positive pressure chamber pressure value of the explosion-proof cabinet is lower than 70Pa or the positive pressure chamber pressure value of the robotic arm is lower than 200Pa, the red light of the explosion-proof sound and light alarm will flash and the alarm will sound to remind the staff to check the positive pressure system and troubleshoot the fault. When the fault is troubleshooted and the positive pressure chamber pressure of the explosion-proof cabinet is restored to 70Pa or above and the positive pressure chamber pressure of the robotic arm is restored to 200Pa or above, the alarm will be canceled.

Low pressure cut-off function:

When the pressure in the positive pressure chamber of the explosion-proof cabinet falls below 50Pa, the positive pressure system will cut off the input power to the control cabinet, and the robotic arm and the control cabinet of the robotic arm will be powered down at the same time to ensure that there is no explosion hazard. The input power to the control cabinet will remain cut off until the positive pressure system of the explosion-proof cabinet is restarted and the ventilation is completed.

When the positive pressure chamber pressure of the robotic arm falls below 100Pa, the positive pressure system will cut off the input power to the robotic arm and the robotic arm will be powered down to ensure that there is no explosion hazard. When the positive pressure system of the robotic arm is restarted and the ventilation is completed, the robotic arm can be powered up.

Positive pressure part	High pressure alarm	Under-pressure alarm	Low pressure cut-off
Explosion-proof cabinet	400 Pa	70 Pa	50 Pa
Robotic arm	1000 Pa	200 Pa	100 Pa

2.7 Safety functions of the robot

2.7.1 Introduction to safety functions

The GCR series robots are equipped with a wide range of built-in safety functions as well as safe I/O, digital and analogue control signals of the emergency electrical interfaces for connecting to other robots and additional protection devices.

A more detailed description of the robot's safety functions can be found in *the Product Hardware Manual*.

Caution	• The use and configuration of safety functions and interfaces must follow the risk assessment procedure for each robot application program. • If the robot detects a fault or violation in the safety system (e.g., a wire is cut in the emergency stop circuit or a safety limit violation occurs), a category 0 stop will be initiated. • Stopping time shall be considered as part of the application risk assessment.

Warning	• The used safety configuration parameters that differ from those identified in the risk assessment can result in hazards that cannot reasonably be eliminated or risks that cannot be adequately reduced. • Ensure that the tool and gripper are connected correctly to avoid danger in the event of a power failure. • The end-effector is not protected by the GCR safety system. The function of the end-effector and/or the connecting cable is not monitored

2.7.2 Emergency stop of the robot

Robot emergency stop is a state that takes precedence over all other robot control operations and will cause all controlled hazards to stop, remove motor power from the robot drive, remain active until reset, and can only be reset by manual operation.

An emergency stop condition means that the power system is disconnected and the robot cannot move. The user must perform a restoration procedure, i.e. reset the emergency stop button and press the "On" button on the teach pendant to restore normal operation. The emergency stop cannot be used as a risk reduction measure, but can be used as a secondary protection device.

Emergency stop must not be used for normal program stops, as such doing may cause additional unnecessary wear and tear on the robot.

2.7.3 Type of stop

Depending on the situation, the robot can activate three stop types defined according to IEC 60204-1. These types are defined in the table below.

Type of stop	Description
0 (SS0)	Immediately cut off power to the robotic arm.
1 (SS1)	Immediately reduce the speed of each joint to 0 at the fastest acceleration, pop up the holding brake after the joints come to a standstill, and cut off the robot's power supply
2 (SS2)	The robot is decelerated to a standstill while maintaining the trajectory, and after the standstill the joints remain enabled and the holding brake is inactive.

Switching between stop types:

When a type 1 stop is performed, a timer is triggered at the same time. If the robot's speed still exceeds the set safe speed after 500ms has been elapsed, it will switch to a type 0 stop.

2.7.4 Safety functions

The table below lists the GCR robot safety functions that are located in the robot but are intended to control the robot system, i.e., the tool/end-effector to which the robot is connected. The robot safety functions are used to reduce the risk to the robot system as determined during the risk assessment. Position and speed are related to the base of the robot.

Safety function	Description
Emergency stop (ES)	Execution of SS1
Protective stop	Execution of SS2
Safe Operating Stop (SOS)	After SS2 execution is completed, SOS monitoring will be triggered to monitor the current robot position offset, and triggering SS0 if violated
Joint Safe limited position (SLP)	According to the threshold value setting, SS2 is triggered when the joint position reaches the threshold value. ss0 is triggered directly if the joint limit is triggered.
Joint Safe limited speed (SLS)	According to the threshold value setting, SS2 is triggered when the joint speed reaches the threshold value. ss0 is triggered directly if the joint speed limit is triggered.
TCP position limit	Safety planes can be set to limit the robot's working area, according to the threshold value setting, when the threshold value is reached, SS2 will be triggered. If the safety plane is triggered, the safety controller will trigger ss0 directly. Up to 6 safety planes and 3 TCP coordinate systems are allowed to be set.
Tcp speed limit	According to the threshold value setting, SS2 is triggered when the threshold value is reached. If the Tcp speed limit is triggered, the safety controller directly triggers ss0

elbow pos limit	According to the threshold value setting, SS2 is triggered when the threshold value is reached. If the elbow position limit is triggered, the safety controller triggers ss0 directly.
elbow speed limit	According to the threshold value setting, SS2 is triggered when the threshold value is reached. If the elbow speed limit is triggered, the safety controller triggers ss0 directly.
Joint force limit	According to the threshold value setting, SS2 is triggered when the threshold value is reached. If the joint torque limit is triggered, the safety controller triggers ss0 directly.
tcp force limit	According to the threshold value setting, SS2 is triggered when the threshold value is reached. if the endpoint force limit is triggered, the safety controller triggers ss0 directly.
elbow force limit	According to the threshold value setting, when the threshold value is reached, SS2 is triggered. If the elbow force limit is triggered, the safety controller directly triggers ss0.

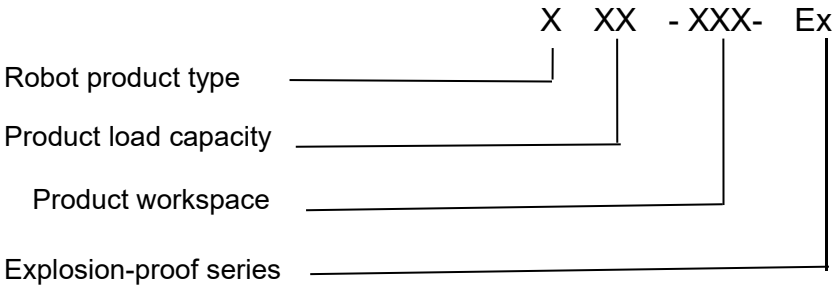
Safety function	Description
power limit	According to the threshold value setting, SS2 is triggered when the threshold value is reached. If the power limit is triggered, the safety controller directly triggers ss0
mode switch input	You can choose whether to enable it or not, and when disabling this physical input, it can be switched via the UI; but both of them can not be valid at the same time. SS2 is triggered when mode is switched, if the script is currently running, the script is in pause state, and can continue to run subsequently.
enable device input	You can choose whether to enable this input or not. This input is only valid in manual mode, and is not valid in auto mode. Violation triggers SS2.
protective stop input	It is valid in all modes. It triggers SS2. If the safety protection reset input is not activated, it is automatically reset when the signal disappears, otherwise it can be reset only when the safety protection input is triggered.
protective stop reset input	You can select whether to reset this signal input or not. If the safety protection reset is activated, when the safety protection stop triggered stops and the trigger signal disappears, movement can be continued only this channel signal is input. The rising edge is active, and the high level needs to be held for 500ms.
automatic protective stop input	It is valid only in auto mode, and it triggers SS2. Safe mode restored to be normal after signal disappears
automatic protective stop reset input	Similar to protective stop reset input, except that it is valid for protective stops triggered by the automatic protective stop input.

system emergency stop output	This signal is only output if the system emergency stop is triggered
protective stop output	Protective stop output, which is output when the protective stop input is triggered.
automatic protective stop output	Protective stop output in auto mode, it is only output if the protective stop occurs in auto mode.
reduce mode	It triggers the reduce mode, the parameters related to the reduce mode are utilized.
reduce mode output	The signal can be output in all global situations.
recovery mode	When the joint limit or TCP limit is exceeded, a restart is required to enter recovery mode. In recovery mode, the joint speed is limited to no more than 30deg/s and end speed is limited to no more than 250mm/s

3 Product Description

3.1 Product model

Explosion-proof robot product models consists of the following information:



The specific product models are listed as follows:

X3-618-Ex: 3kg 6-axis collaborative robot (Explosion-proof series)

X5-910-Ex: 5kg 6-axis collaborative robot (Explosion-proof series)

X10-1300-Ex: 10kg 6-axis collaborative robot (Explosion-proof series) b

X10-2000-Ex: 10kg 6-axis collaborative robot (Explosion-proof series)

X16-960-Ex: 16kg 6-axis collaborative robot (Explosion-proof series)

X14-1400-Ex: 14kg 6-axis collaborative robot (Explosion-proof series)

X20-1100-Ex: 20kg 6-axis collaborative robot (Explosion-proof series)

X25-1800-Ex: 25kg 6-axis collaborative robot (Explosion-proof series)

3.2 Operating principles of the explosion-proof positive pressure system

Explosion-proof cabinet consists of explosion-proof cabinet body, positive pressure gas circuit system, flame-proof electrical box and other components. Explosion-proof cabinet shell is made of cold rolled thin steel plate by folding, welding and becomes a gas-tight shell. Because it can keep the pressure of the internal protective gas higher than the pressure of the surrounding explosive gas environment, thus it can effectively prevent the external explosive gas mixture into the shell. Positive pressure gas circuit system is arranged on the outside of the explosion-proof cabinet. It can make the compressed air at site or other non-combustible gases after decompression into the pure gas with minimal pressure into the explosion-proof cabinet, after a given period of time to purge, it can clear away the explosive gases in the cabinet, and it can continue to maintain a positive pressure, so that the inside of the explosion-proof cabinet

becomes a safe place. Flame-proof electrical box is responsible for providing power supply to the explosion-proof cabinet, when the explosion-proof cabinet is purged for a given time and the cabinet pressure is greater than the given pressure, Flame-proof electrical box provides power supply to the control cabinet of the robotic arm.

The pressure inside the explosion-proof cabinet is monitored by a pressure transmitter installed inside the cabinet, and controlled by precision regulators, throttle valves, pressure relief valves and exhaust ports in a linkage, so that the pressure inside the cabinet is stable between 70Pa and 400Pa.

The robotic arm consists of base, joints J1 to J8, end and so on. The overall protection level of the robotic arm is IP66, with certain sealing and pressure preservation. The base of the robotic arm is equipped with an air inlet and a pressure detection port, and the end is equipped with an exhaust port. The joint chambers inside the robotic arm are connected to each other, and the protective gas enters from the base, passes through the joint chambers, and then exits from the end, forming a unidirectional air flow inside the robotic arm. As the robotic arm can keep the pressure of the internal protective gas higher than the pressure of the surrounding explosive gas environment, thus effectively preventing the external explosive gas mixture from entering the robotic arm.

The pressure inside the robotic arm is monitored by an explosion-proof pressure transmitter mounted on the explosion-proof cabinet, and is controlled by the precision regulators, the throttle valves and exhaust ports in linkage, so that the pressure in the chamber is stable between 200Pa and 1000Pa.

3.3 Overview of explosion-proof robot system

The explosion-proof robot system consists of the following main components:

1. Explosion-proof robotic arm
2. Explosion-proof cabinet
3. Explosion-proof Pad (optional)
4. Robotic arm control cabinet (installed in positive pressure chamber of explosion-proof cabinet)
5. Software
6. Other optional parts, accessories

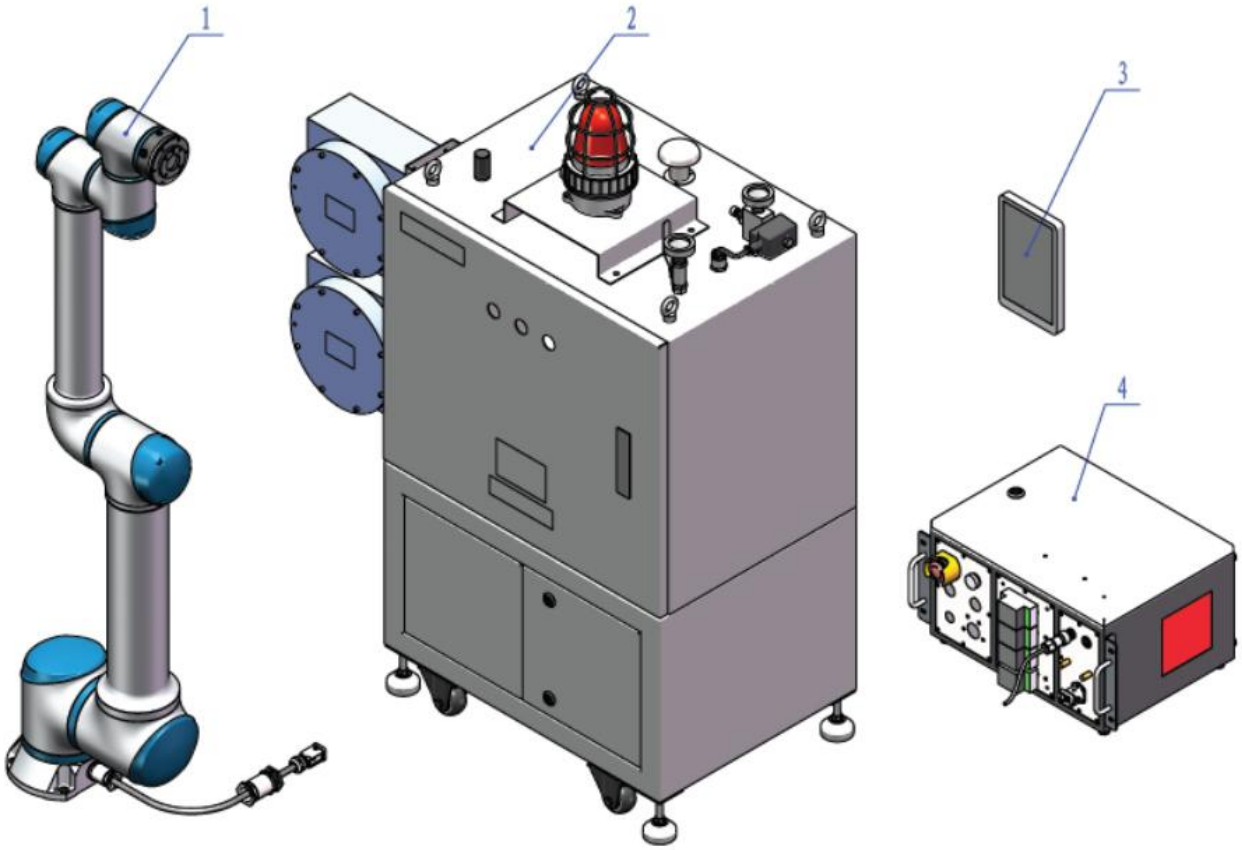


Figure 2 Robot system overview

Main system parameters	
Protection class: IP65	Explosion-proof level: Ex db eb mb pxb IIC T4 Gb Ex mb pxb tb IIIC T130℃ Db
Collaborative robot robotic arm air source: Category: Clean Air Air source pressure: 0.2 ~ 0.8 MPa Operating positive pressure: 200 Pa～1000 Pa Low pressure alarm: 200Pa Low pressure cut-off: 100 Pa	
Collaborative robot positive pressure cabinet air source: Category: Clean Air Air source pressure: 0.2 ~ 0.8 MPa Operating positive pressure: 70 Pa～400 Pa Low pressure alarm: 70Pa Low pressure cut-off: 50 Pa	

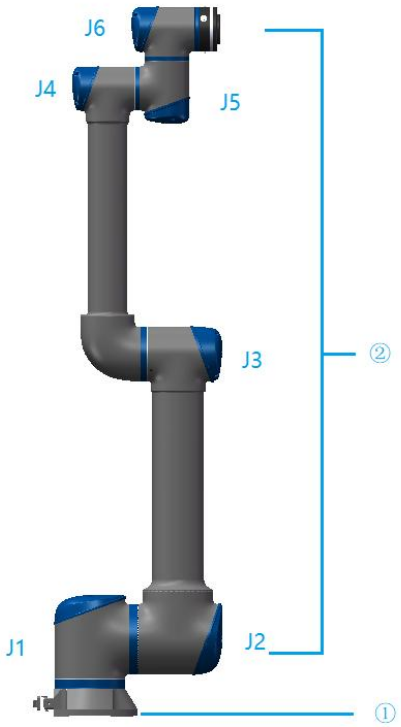
3.4 Description of explosion-proof robotic arms

3.4.1 Overview of explosion-proof robotic arms

The collaborative robot consists of 6 modularly designed joints with functions such as traction teaching and collision detection. The robot can be mounted in any direction.

Each joint of the robot is equipped with position sensors to detect the running position of the joints, and a reliable brake is equipped to stop the joint in time.

The explosion-proof robotic arm is mainly composed of the following components:



①	Base module
②	Joint module

Figure 3 Collaborative robots

Base module

The base module is located at the bottom of the robot, and the robot cable is connected to the control cabinet through the base module interface board for power supply and data transmission for the robot.

Joint module

Each robot consists of 6 joints with built-in independent drive modules, and the shell is made of aluminum alloy casting.

Electrical system

The electrical system consists of all the electrical components (including drivers, connectors, cables, etc.) that provide power supply for the joint motors and control the joint motors.

Wrist flange

Module located at the end of the robot for connecting the end tool.

Positive pressure system for robotic arms

The robotic arm base is provided with an air inlet and a pressure detection port, and an exhaust port is provided at the end.

3.4.2 Description of the base module

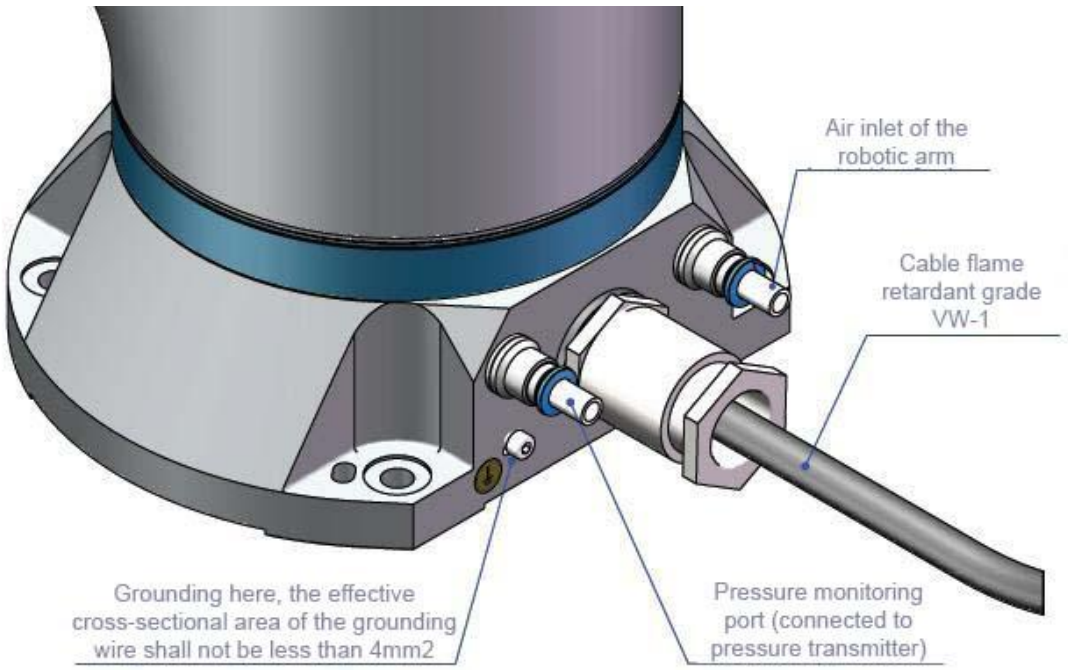
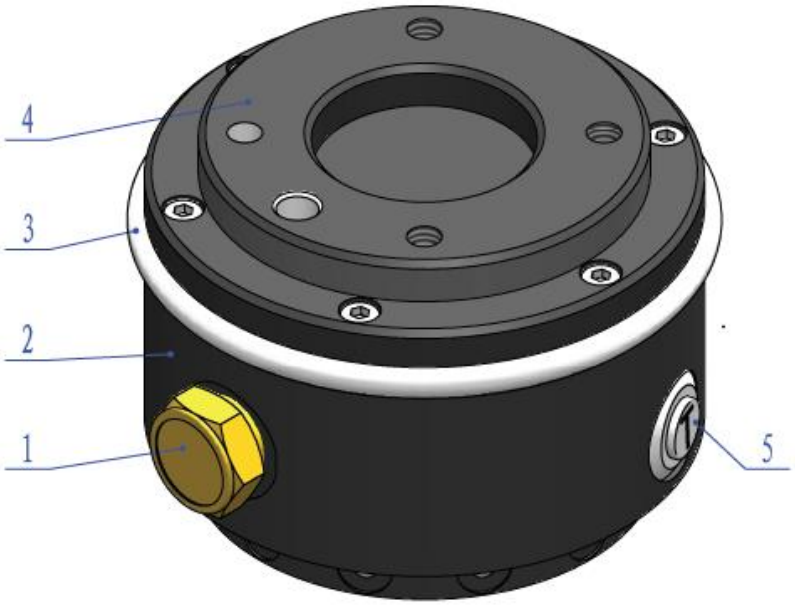


Figure 4 Schematic diagram of the base input panel

The base panel is located at the bottom of the robot and contains a communication and power supply interface: for connecting cables for providing power supply and data transmission to the robot; an air inlet and a pressure detection port of the positive pressure system of the robotic arm; and grounding screw.

3.4.3 Description of the wrist flange

The end of the robot has a wrist flange (in accordance with GB/T 14468.1-50-4-M6 and ISO 9409-1-50-4-M6) with screw holes and pin holes for mounting the end tool. The end flange also has a positive pressure system air outlet.



①	Vent silencing device
②	End flange body
③	Sealed light strip
④	End flange end cap
⑤	T/S button

Figure 5 Schematic diagram of end flange

3.5 Description of the explosion-proof cabinet

3.5.1 Overview of the explosion-proof cabinet

Positive-pressure explosion-proof electrical control cabinet (box) (hereinafter referred to as explosion-proof cabinet) is the positive pressure type explosion-proof electrical control cabinet according to the provisions under GB/T 3836.1 the Electrical Equipment for Explosive Gas Environments-Part 1: General Requirements, GB/T 3836.2 the Electrical Equipment for Explosive Gas Environments-Part 2: Flame-proof type "d", GB/T 3836.3 the Electrical Equipment for Explosive Gas Environments-Part 3: Increased Safety Type "e" and GB/T 3836.5 the Electrical Equipment for Explosive Gas Environments-Part 5: Equipment Protected by Positive Pressure Shell Type "p", GB12476.1 the Electrical equipment for Combustible Dust environments-Part 1: General Requirements, GB12476.5 the Electrical equipment for Combustible Dust environments-Part 5: Shell Protection Type "tD", GB12476.7 the Electrical equipment for Combustible Dust environments-Part 7: Positive Pressure Protection Type "pD", GB/T3836.15 the Explosive Environment-Part 15: Design, Selection and Installation of electrical Devices. This explosion-proof cabinet is mainly suitable for petroleum, chemical, metallurgy, pharmacy and other fields with I zone explosive gas environment, where there is explosive gas mixture of IIC class T4 group and below in the air, and such cabinet is used for electrical control.

Explosion-proof cabinet consists of explosion-proof cabinet body, positive pressure gas circuit system, flame-proof electrical box and other components. Explosion-proof cabinet shell is made of cold rolled thin steel plate by folding, welding and becomes a gas-tight shell. Because it can keep the pressure of the internal protective gas higher than the pressure of the surrounding explosive gas environment, thus it can effectively prevent the external explosive gas mixture into the shell.

Positive pressure gas circuit system is arranged on the outside of the explosion-proof cabinet. It can make the compressed air at site or other non-combustible gases after decompression into the pure gas with minimal pressure into the explosion-proof cabinet, after a given period of time to purge, it can clear away the explosive gases in the cabinet, and it can continue to maintain a positive pressure, so that the inside of the explosion-proof cabinet becomes a safe place.

Flame-proof electrical box is responsible for providing power supply to the explosion-proof cabinet, when the explosion-proof cabinet is purged for a given time and the cabinet pressure is greater than the given pressure, Flame-proof electrical box provides power supply to the control cabinet of the robotic arm.

The positive pressure chamber door of the explosion-proof cabinet is equipped with emergency stop and switch, etc. The positive pressure control system adopts the external hanging structure, the enclosure protection level is IP65, and there is a robotic arm control cabinet inside, such control cabinet is responsible for controlling the robot to achieve the movement and other functions.

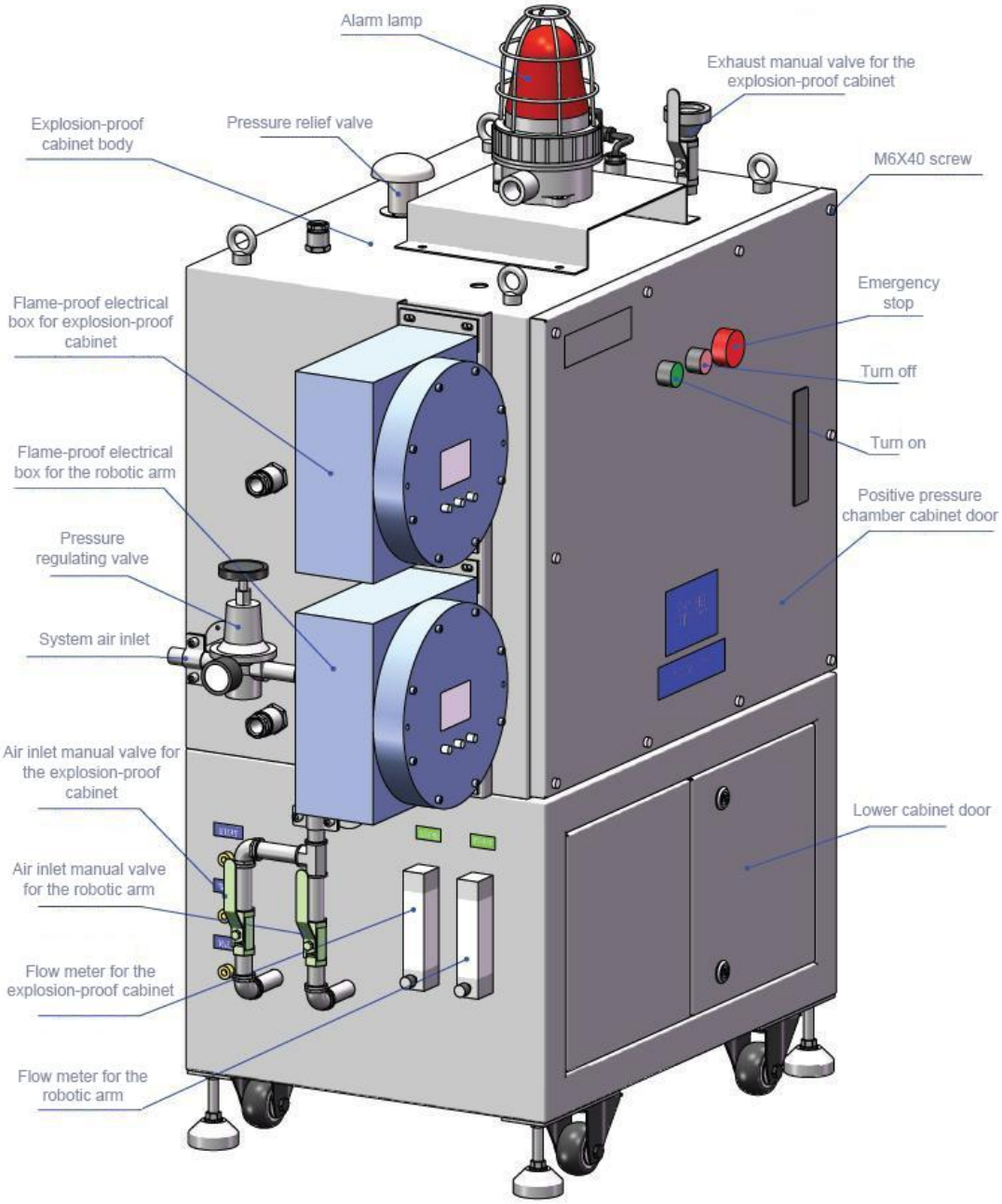


Figure 6 Explosion-proof cabinet structure

3.5.2 Power access

When the control cabinet adopts 220V power supply, the maximum power is 3000W, and the standard 16A power plug is chosen as the power cord plug of the control cabinet. The standard power cord length of the control cabinet is 5m, and power cords of other standard lengths are available for purchase.

Control cabinet power supply input is: 200-240VAC, 47-63HZ, 16A.

3.5.3 Bottom interface

There are 12 explosion-proof cable glands on the bottom plate of the positive pressure chamber of the explosion-proof cabinet, including 6 G1/2" cable glands and 6 G3/4" cable glands, of which 4 G1/2" cable glands and 4 G3/4" cable glands are available for users to connect external cables. G1/2" cable glands are suitable for cables with outside diameters from 6mm to 10mm, and G3/4" cable glands are suitable for cables with outside diameters from 10mm to 14mm.

When using explosion-proof cable glands for cable connection, make sure that the sealing rings are pressed tightly, otherwise the seal will fail and it will lead to leakage.

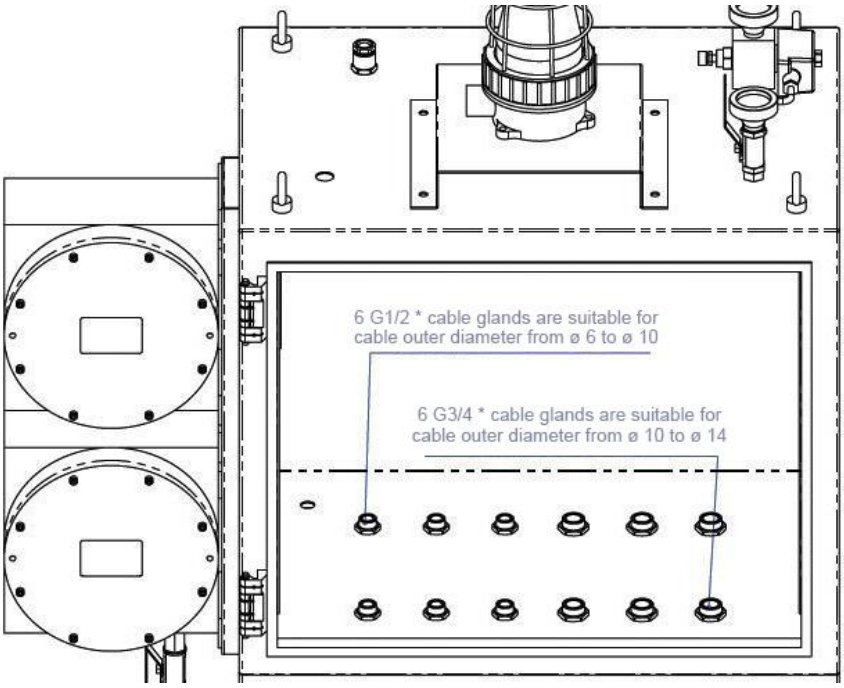


Figure 7 Positive pressure chamber bottom interface

Figure 8 Structure of the explosion-proof cable gland

3.6 Overview of robot control system

The robot control system can be equipped with an optional explosion-proof Pad to control the robot to achieve the following functions:

- System operation interface, human-computer interaction function
- Generation, correction, archiving and maintenance of programs
- Robot motion control
- Robot trajectory planning and algorithm implementation
- Robot power supply control
- Robot motion state monitoring
- Components of the electronic safety circuit
- Communication with peripheral devices (other control systems, lead computer, network)

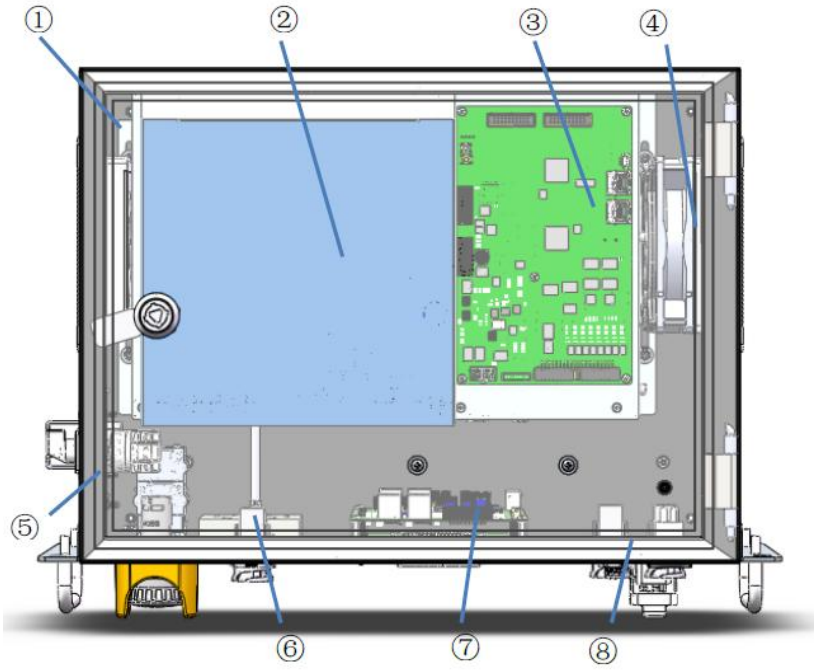


Figure 9 Schematic diagram of the control system

①	Encapsulated power supply
②	Main controller
③	Safety controller
④	Fan
⑤	AC incoming line
⑥	Left interface panel
⑦	Middle interface panel
⑧	Right interface panel

3.7 Explosion-proof pad (optional)

Explosion-proof Pad can be used for key and display functions required during operation and programming of the robot system.

Figure 10 Explosion-proof Pad

3.8 Nameplate

The robotic arms and explosion-proof cabinets are fitted with nameplates and labels, the nameplates contain the use requirements and necessary information for the product, the nameplates cannot not be removed or make them unrecognizable. Unrecognizable nameplates and labels must be replaced.

4 Installation, Commissioning and Ventilation

This chapter contains assembly instructions and information on installing the robot at the job site. It focuses on the basic things to keep in mind when installing the components of an explosion-proof robot system.

4.1 Installation of the explosion-proof cabinet

The explosion-proof cabinet shall be placed on a flat and stable floor. It shall be properly installed by a qualified installation technician in accordance with the installation instructions in this manual.

Explosion-proof cabinets shall be installed to avoid moisture, seawater, wind, rain, sun and other direct attacks, if necessary, measures shall be taken.

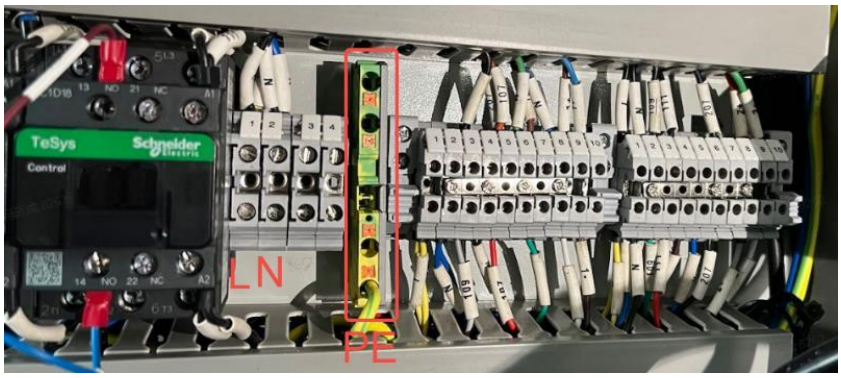
After the position of the explosion-proof cabinet is fixed, the grounding part of the explosion-proof cabinet shall be grounded.

Caution	● **Before installation, check whether the power supply voltage, and environmental conditions are consistent with the requirements on the nameplate.**

4.2 Commissioning of the explosion-proof cabinet

Before the explosion-proof cabinet is used for the first time, commissioning shall be conducted to check whether the electrical system and gas circuit system can work properly, and **note that it shall ensure that the commissioning shall be carried out when there are no dangerous gases in the surrounding area.**

Before preparing for installation and commissioning, press one end of the 220V power cable onto the tube terminal and connect it to the terminal block on the left side of the explosion-proof cabinet. The wiring position of the 220V power cable is shown in the following figure, with serial number 1 connecting to L, serial number 2 connecting to N, and the green terminal block on the right side connecting to PE.



Explosion-proof cabinet power cord wiring position

After the explosion-proof cabinet is connected to the main power supply, the display screens of two flame-proof electrical box light up and show the boot interface, with the button at the lower part of the screen, select the "commissioning" mode according to the prompts on the display screen, when the two flame-proof electrical boxes have been successfully set to "commissioning" mode, the power supply of the control cabinet and the robotic arm of the robot system is switched on, and you can press the "on" button on the panel of the explosion-proof cabinet to start the robot system and carry out the commissioning of the robot system.

After the commissioning is finished, with the button at the lower part of the screen to select "Back to Home" according to the prompts on the display screen. When setting of the two flame-proof electrical boxes has been completed, the power supply of the control cabinet and the robotic arm of the robot system is turned on switched off, and the commissioning process is finished.

Disconnect the main power supply of the explosion-proof cabinet, the display of the flame-proof electrical box is turned off, and the system is turned off.

Danger	• **This state is only allowed in the testing phase and in a safe environment.**

Figure 11 Preparing for commissioning

Figure 12 Enter the commissioning interface

4.3 Installation of the robot

4.3.1 Base installation

The explosion-proof robotic arm is mounted and positioned with four M8 or M10 (grade 10.9 and above) bolts, two Ø6 pins via four through-holes and two pin holes in the robot base. The M8 bolts are recommended to be tightened with a torque of 35 N·m and the M10 bolts are recommended to be tightened with a torque of 65N·m.

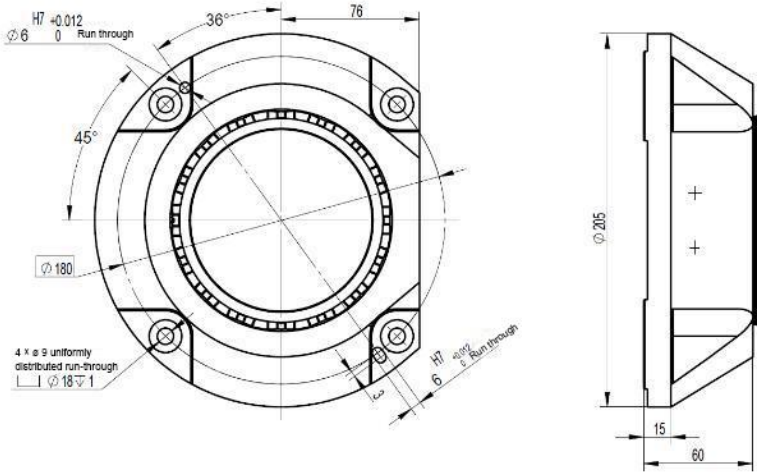


Figure 13 Robot base mounting holes fixed with M8 bolts (in mm)

The robot must be mounted on a solid surface that shall be sufficient to withstand at least 10 times of the full torsional force of the base joints and at least 5 times of the weight of the robotic arm. In addition, the surface shall be free of vibration. If the robot is mounted on a linear axis or on a movable platform, the acceleration of the movable mounting base shall be very low; high acceleration can cause the robot to trigger a protective stop.

Danger	• **Ensure that the robotic arm is properly and safely mounted in place. The mounting surface must be shockproof.** • **After the installation of the robotic arm, the grounding part of the base should be grounded.**

4.3.2 Tool installation

The robot tool flange has four M6 threaded holes for connecting the tool to the robot. These holes need to be tightened with a torque of 10N·m. If the tool position needs to be adjusted very accurately, Ø6 holes can also be drilled and pins are used for fixing purpose.. Figure 14 shows the drilling positions and screw mounting positions.

Danger	• **Ensure that the tools are correctly and safely installed in place.** • **Ensure that the tool is safely fastened so that no parts can accidentally fall and cause a hazard.**

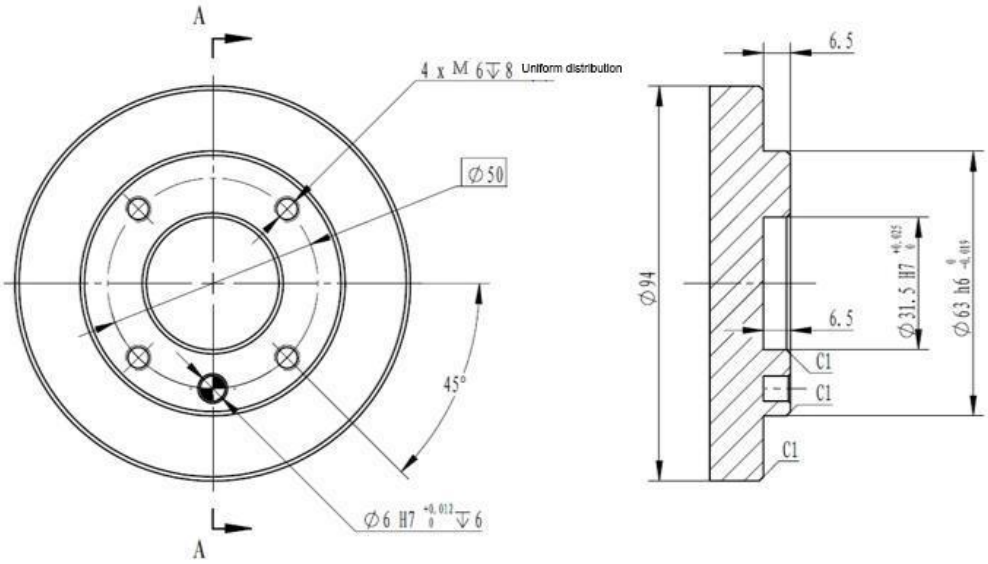


Figure 14 Tool output flange (Conforming to GB/T 14468.1-50-4-M6 and ISO 9409-1-50-4-M6 standards)

4.4 Ventilation

Before the explosion-proof robot system is powered on and used normally, it must ventilate the explosion-proof cabinet and the robotic arm simultaneously.

Danger	● **When the explosion-proof system has fault, after cutting off the power supply or gas source, it is necessary to ventilate the explosion-proof cabinet and the robotic arm before the explosion-proof system is used again.**

state check:

Check that whether the grounding parts of the explosion-proof cabinet and robotic arm are grounded or not, and if not, ground them.

Check that whether ten M6X40 hexagonal socket head cap screws on the positive pressure chamber door of the explosion-proof cabinet are tightened or not, if not, tighten them with a torque of 10Nm.

Check that whether the air inlet manual valve for the robotic arm, the air inlet manual valve for the explosion-proof cabinet and the exhaust manual valve for the explosion-proof cabinet on the explosion-proof cabinet are closed or not. If not, close them.

Figure 15 Closed state of the explosion-proof cabinet air inlet valve

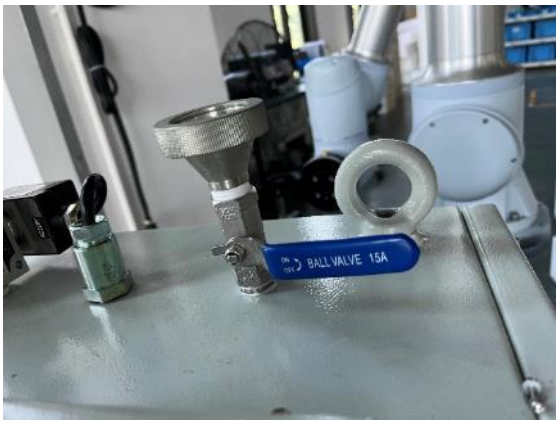


Figure 16 Closed state of the exhaust valve at the top of explosion-proof cabinet

Check whether the main power supply to the system on the explosion-proof cabinet is disconnected or not, and if not disconnected, disconnect it.

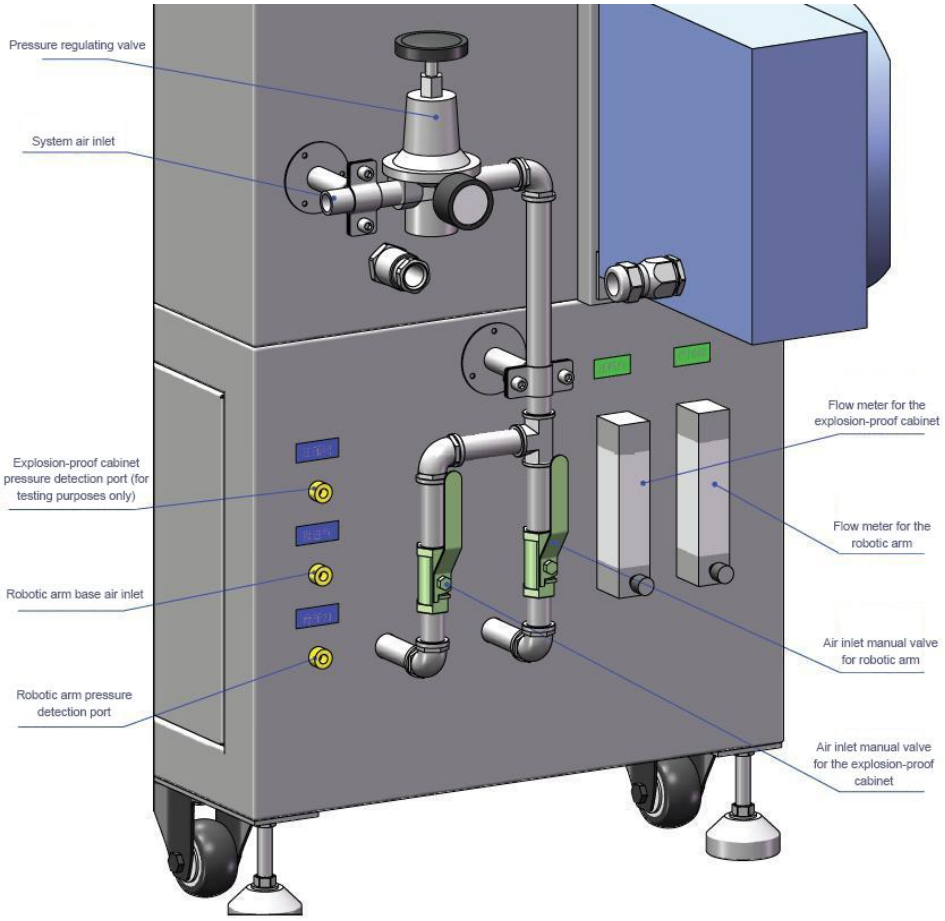


Figure 17 Air inlet part of the air circuit system of the explosion-proof cabinet

Air circuit connection:

Connect the air inlet of the robotic arm base on the lower left corner of the lateral side of the explosion-proof cabinet to the air inlet on the robotic arm base with an air pipe with the outer diameter of 8mm, and connect the pressure detection port of the robotic arm to the pressure detection port on the robotic arm base with an air pipe with the outer diameter of 8mm. The length of the air pipe shall be determined according to actual needs, generally not greater than 10m.

The pressure detection port on the lower left corner of the lateral side of the explosion-proof cabinet is equipped with a plug with the outside diameter of 8mm by default. Users shall ensure that the plug on this interface is installed in place and is not damaged during normal use. The other side of the interface is connected to the inside of the positive pressure chamber of the explosion-proof cabinet. If the plug is not installed in place or is damaged, it will cause gas leakage from the positive pressure chamber of the explosion-proof cabinet, resulting in too low chamber pressure.

Connect the system air inlet on the explosion-proof cabinet to a gas source, and the gas source can guarantee to provide the pressure of 0.2Mpa to 0.8Mpa.

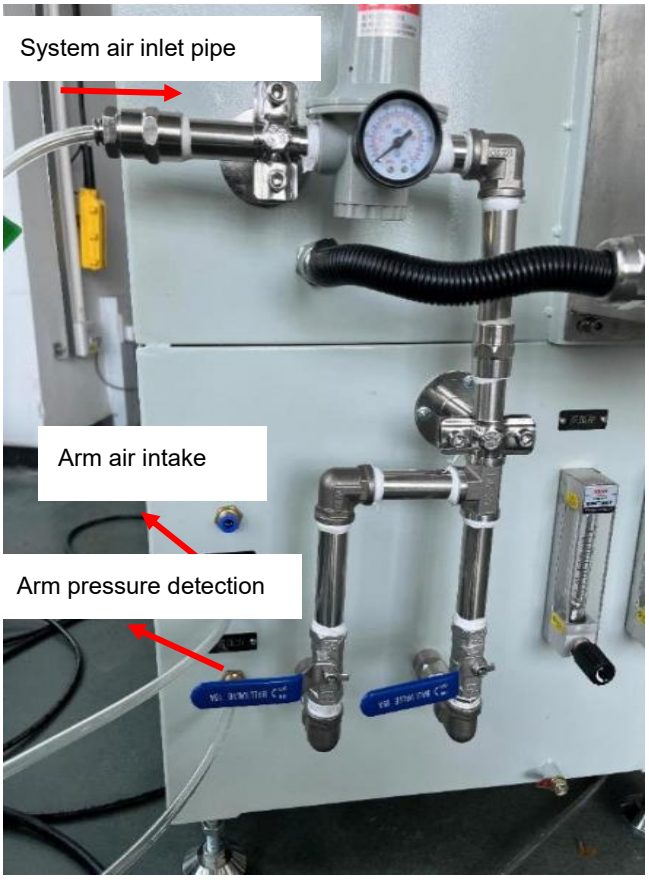


Figure 18 Air pipe connection for the explosion-proof cabinet

Flow regulation:

Open the air source, adjust the pressure regulating valve behind the system air inlet on the explosion-proof cabinet, so that the pressure is stable at about 0.2Mpa. Slowly open the air inlet manual valve for the robotic arm and the air inlet manual valve for the explosion-proof cabinet, and keep the exhaust valve of the explosion-proof cabinet closed. Use the adjusting knob at the bottom of the flow meter to adjust the air inlet flow, the recommended air inlet flow is 15L/min for the robotic arm and 35L/min for the explosion-proof cabinet.

Figure 19 Intake pressure stabilized at around 0.2Mpa

Figure 20 Air inlet valves of the robotic arm and explosion-proof cabinet are in open state

Figure 21 Air intake flows of the robotic arm and explosion-proof cabinet

Cabinet: 35L/min, Arm: 15L/min

Ventilation:

After the gas source is connected, and then connect to the main power supply of the explosion-proof cabinet, the display screens of two flame-proof electrical boxes light up and show the boot interface, with the button at the lower part of the screen, select "positive pressure start"

according to the prompts on the display screen, the explosion-proof cabinet can be set via the flame-proof electrical box and robotic arm flame-proof electrical box.

Figure 22 Positive pressure start

After the ventilation starts, the system enters the ventilation state. At this time, it is necessary to observe the explosion-proof cabinet chamber pressure and the robotic arm chamber pressure displayed on the display screens of the two electrical boxes.

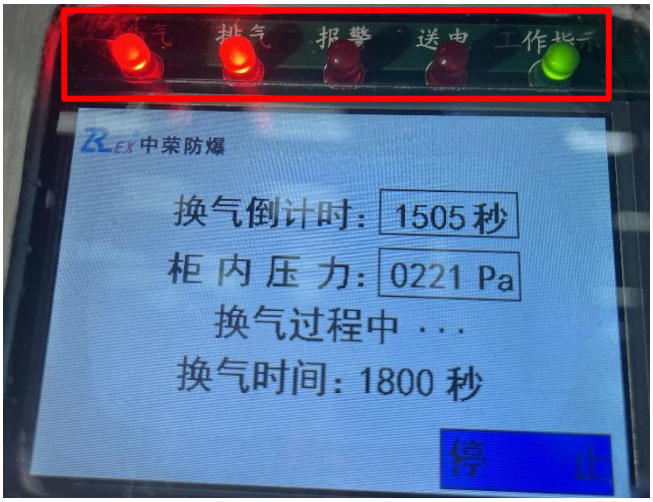


Figure 23 Ventilation state and display lamp state

If the explosion-proof cabinet chamber pressure is too high or too low, you shall first check whether the gas circuit system has obvious air leakage or not and repair the gas leakage problem, when the gas circuit system does not have air leakage and then check whether the explosion-proof cabinet electromagnetic exhaust valve has fault or not and repair the fault. When

it is determined that the explosion-proof cabinet gas circuit system and electromagnetic exhaust valve do not have fault, it can fine tune the exhaust volume through the flow control knob of the electromagnetic exhaust valve on the top of the explosion-proof cabinet until the chamber pressure returns to the normal range.

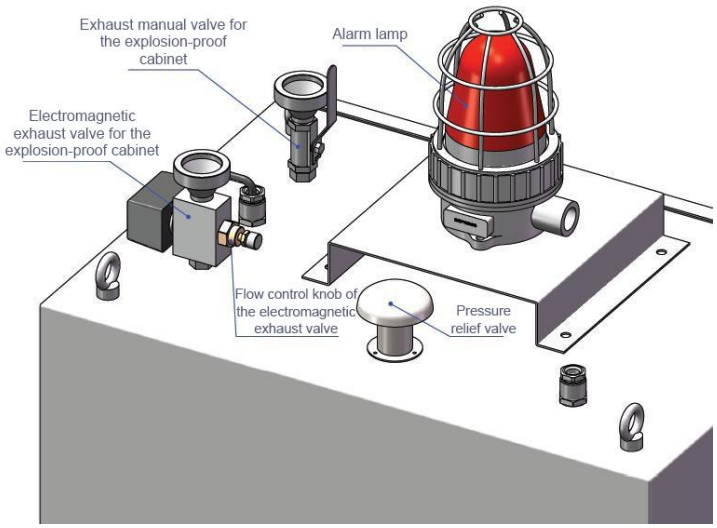


Figure 24 Exhaust part of the gas circuit system of the explosion-proof cabinet

If the chamber pressure in the robotic arm is too high or too low, you shall first check whether the earth wire on the base has been fastened by the screws, and then check the air tightness of the main frame and the back cover of each joint of the robotic arm. The main frame and back cover of the joints are installed with special design and special technology, and the robotic arm has been tested for air-tightness at the factory, so if the user disassembles the back covers of the joints privately, it may lead to the loss of air-tightness of the joints and result in air leakage, and thus it will lead to too low chamber pressure in the robotic arm. If the joints are not airtight, it is necessary to contact the manufacturer's personnel for repair.

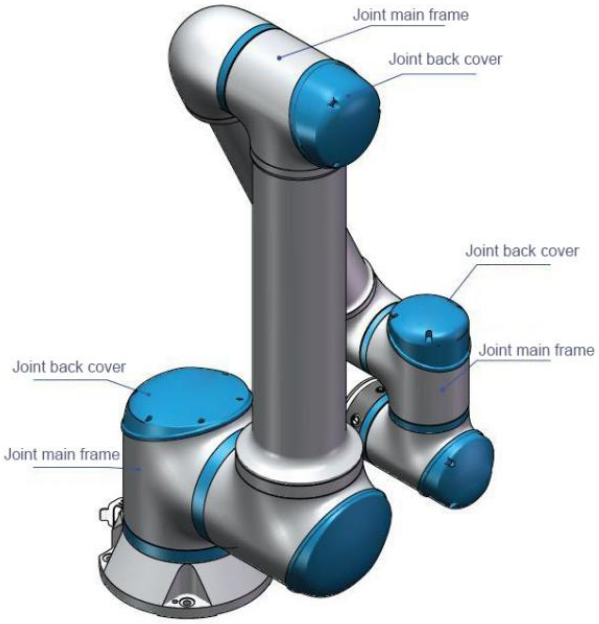


Figure 25 Joint main frame and back cover of the robotic arm

After the start of ventilation, the system begins timing, ventilation process of the explosion-proof cabinet and robotic arm takes 30min, when the ventilation of the explosion-proof cabinet and the robotic arm is completed respectively, you can hear an "dong" sound from the explosion-proof cabinet respectively, such sound is the sound of the relay opening and closing inside the explosion-proof cabinet. The second "power on" light on the right side of the electrical box of the explosion-proof cabinet lights up, indicating that power can be switched on. At this time, pressing the green "start" button on the explosion-proof cabinet door can perform normal operations such as powering on the robot control cabinet inside the explosion-proof cabinet. After powering on, the green "start" button remains on. For the power-on of the robotic arm, it requires to use the robot teach pendant that is operated as required.

Figure 26 Display light state after successful ventilation

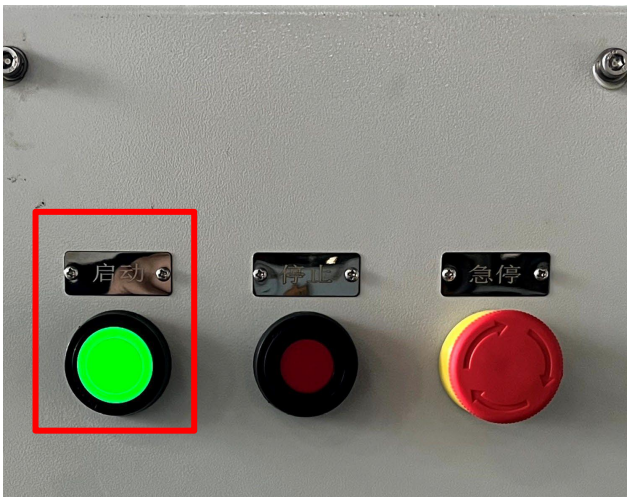


Figure 27 The explosion-proof cabinet is successfully powered on

4.5 Connecting the robot controller

Remote operation of the robot can be realized with an explosion-proof PAD or laptop computer through the control cabinet WIFI connection, the specific steps are described as follows:

1) Use your PAD to find and connect to a wireless network, the name of the wireless network is DucoCobot_XXXX, and the WIFI password is 1234567890.

Note: After the wireless network name, there will be a random number, please refer to the searched and found network.

2) Enter http:duco-cobot.com:7000 in the browser address bar

(3) If the screen displays the robot startup interface, the connection is successful. (For specific operation, please refer to the software user manual)

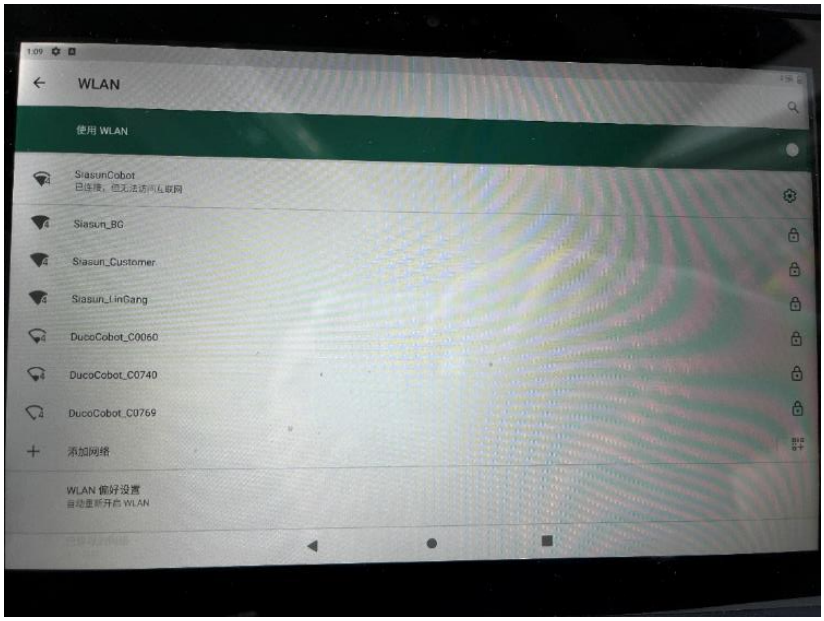


Figure 28 PAD network connection

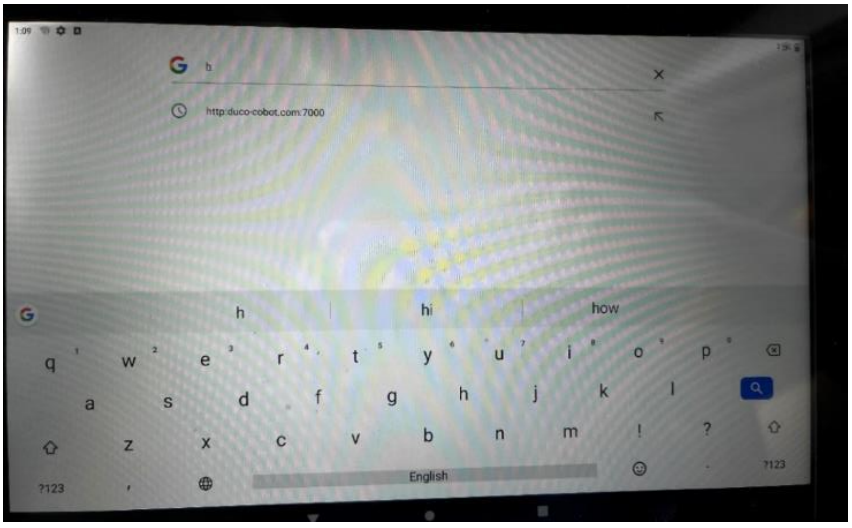


Figure 29 Connecting the robot controller

5 Transport and Storage

5.1 Transport

Robotic arm:

Keep the original package in good condition during transport and store the packaging material in a dry place. It may be necessary to pack and move the robot later. Raise the robotic arm tube while moving the robot from the robot packaging materials to the installation position. Hold the robot until all bolts on the robot base are tightened. The robot shall remain in the packed position throughout transport until it is fixed properly.

Explosion-proof control cabinet:

Explosion-proof control cabinets shall be kept upright during transport and placement, and vibration and collision shall be avoided during transport to avoid damage to the control system.

	• **Ensure that the installation instructions in Chapter 4 are strictly followed when installing the robot.** • **Please refer to the technical parameters for vibration requirements during transport.**

5.2 Storage

The following points must be observed when storing the robot for long periods of time:

- The storage place shall be dry and dust-free
- Avoid temperature fluctuations
- Avoid formation of condensation water
- Avoid direct sunlight
- Avoiding air flow
- Select reasonable storage temperature range
- Select a storage place where the package will not be damaged
- Robot control system can only be stored in enclosed spaces

6 Maintenance and Repair

Maintenance and repair work must strictly adhere to all safety instructions in this manual.

Maintenance, calibration and repair work must be performed in accordance with the latest service manual.

6.1 Safety instructions

After maintenance and repair, the safety level of the system must be rechecked. Such recheck must be done in compliance with valid standards as well as safety laws and regulations. All safety functions shall also be tested to ensure that they work properly.

The purpose of maintenance and repair work is to ensure that the system is functioning properly or, in the case of a faulty condition, to help restore the system to its normal state of operation. Repair includes fault diagnosis and actual repairs.

Safety measures to be taken during repair and maintenance operations include:

Primary condition before maintenance:

- In the state of cutting off the power supply, it shall regularly check the use of explosion-proof control cabinet, found abnormalities shall be repaired in a timely manner to ensure that the explosion-proof control cabinet is in a normal working condition.
- Check the sealing condition of electrical cabinets, and replace deteriorated rubber gaskets in a timely manner.
- For explosion-proof control cabinet gas circuit system, it shall do the following inspection and maintenance:
- 1. Remove the accumulated water from the filter pressure reducing valve. Adjust the outlet pressure of the pressure reducing valve to the appropriate position;
- 2. Adjust the outlet flow of the throttle valve to the appropriate position.
- Maintenance of the pneumatic system: Air pressure remains after the main power to the robot is switched off. The fixture must be installed or repaired after the robot has been powered off and the pressure has been relieved.
- The robot must also remain switched off, and have protection measures against accidental restarts.
- Remove the main power supply and disconnect the other energy sources connected. Take preventive measures to avoid the system energy being reconnected during repair.
- Check whether the ground connection is good or not before restarting the robot system.
- An interval of > 5 minutes between two restarts is recommended until the intermediate circuit is fully discharged. Avoid disassembling the power supply system in the control cabinet. High voltage can remain in the power supply system for several hours after the control cabinet has been switched off.
- ESD guidelines shall be followed when disassembling the robotic arm or control cabinet.

Precautions：

- Do not change any information in the software safety configuration (e.g. force limits). The safety configuration is described in the manual. If the safety parameters are changed, the entire robot system shall be considered a new system, this means that all safety audit processes, e.g. risk assessments, must be updated.
- Replace the faulty part with a new part with the same part number or an approved equivalent part.
- Reactivate all disabled safety measures as soon as the repair and maintenance is completed.
- Document all repair operations in writing and keep them in the technical documentation related to the entire robot system.

6.2 Maintenance

After completing the commissioning of the equipment, perform maintenance work in accordance with the specified maintenance period.

Table of maintenance period requirements

Maintenance activities	Regular	Every 1 month	Every 6 months	Every 12 months	Every 36 months	Note
Cleaning activities						
Clean explosion-proof control cabinet	X					
Cleaning of water accumulated in the filter pressure reducing valve	X					
Cleaning the robot	X					
Check activities						
Check positive pressure chamber pressure	X					Before each use
Check the robot	X					
Check information labels and nameplates				X		
Check cable harness			X			
Check plastic parts and sealing gaskets	X	X				
Check the signal lights				X		
Check the bolts at the connection points				X		

Regular:

This means that the relevant maintenance is to be performed at regular intervals, the actual intervals depend on the robot's operating cycle, working environment and motion pattern. In general, the shorter the operating cycle, the more contaminated the working environment and the more demanding the motion pattern, the shorter the interval between regular maintenance shall be.

In the state of cutting off the power supply, it shall regularly check the use of explosion-proof electrical cabinet: found abnormality shall be repaired in a timely manner, so that the electrical cabinet is in a normal working condition.

The following inspection and maintenance shall be done for the gas circuit system:

- Remove accumulated water from the filtering pressure reducing valve and adjust the pressure reducing valve outlet pressure to the appropriate position;
- Adjust the throttle valve outlet flow to the appropriate position;
- Check the sealing condition of electrical cabinet, and replace deteriorated rubber gaskets in a timely manner;
- Check the flame-proof surface of the flame-proof electrical box, rust shall be removed in a timely manner and rust-proof oil shall be applied;
- Check whether the safety devices and plug connections are solidly installed or not;
- Check whether labels and nameplates are clear and complete or not;
- Check whether the cable is damaged or not;
- Check whether all equipment parts have wear or damage or not.

6.3 Repair

Only users who have received appropriate training are allowed to perform repair work on the robot controller. Repair work within equipment components is only allowed to be carried out by personnel who have received professional training. Repairs must be carried out according to the latest service manual.

	● Repairs must be carried out by the authorized system integrator or robot manufacturer.

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