CONSTRUCTION
INDUSTRY COUNCIL
建造業議會

Reference Material

Technical Requirements for Construction Robots for Painting, Plastering and Welding

www.cic.hk

Apri 2023

First published, April 2023

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PREFACE

The Construction Industry Council (CIC) is committed to seeking continuous improvement in all aspects of the construction industry in Hong Kong. To achieve this aim, the CIC forms Committees, Task Forces and other forums to review specific areas of work with the intention of producing Alerts, Reference Materials, Guidelines and Codes of Conduct to assist participants in the industry to strive for excellence.

The CIC appreciates that some improvements and practices can be implemented immediately whilst others may take more time for implementation. It is for this reason that four separate categories of publication have been adopted, the purposes of which are given as follows:

Alerts	The Alerts are reminders in the form of brief leaflets produced quickly to draw the immediate attention of relevant stakeholders to the need to follow some good practices or to implement some preventive measures in relation to the construction industry.
Reference Materials	The Reference Materials provide standards or methodologies generally adopted and regarded by the industry as good practices. The CIC recommends the adoption of the standards or methodologies given in the Reference Materials by industry stakeholders where appropriate.
Guidelines	The Guidelines provide information and guidance on particular topics relevant to the construction industry. The CIC expects all industry stakeholders to adopt the recommendations set out in the Guidelines where applicable.
Codes of Conduct	The Codes of Conduct set out the principles that all relevant industry participants should follow. Under the Construction Industry Council (Cap 587), the CIC is tasked to formulate codes of conduct and enforce such codes. The CIC may take necessary actions to ensure compliance with the codes.

To allow us to further enhance this publication, we encourage you to share your feedback with us, after you have read this publication. Please take a moment to fill out the Feedback Form attached to this publication and send it back to us. With our joint efforts, we believe our construction industry will develop further and will continue to prosper in the years to come.

ABBREVIATIONS

HKAS	Hong Kong Accreditation Service
HOKLAS	Hong Kong Laboratory Accreditation Scheme
MRA	Mutual Recognition Arrangement

1. INTRODUCTION

The Hong Kong construction industry is facing a number of challenges, including ageing workforce, stagnant productivity growth, quality issues and unsatisfactory site safety performance. There is a need to adopt modern methods of construction to address these challenges. The use of robotics technology in construction sites is recognised as a strategic direction to advance the construction industry.

In June 2020, the CIC engaged SGS Hong Kong Limited (SGS) to carry out a study to establish the technical requirements, in terms of safety, quality performance and functional requirements, for construction robots for the following three trades: (i) painting; (ii) plastering; and (iii) welding. Definitions of the technical terms, assessment items, acceptance criteria and assessment methods used are given in the technical requirements. These three trades were given priority because of the rapidity and maturity of their development and a wider application of construction robots in those areas.

In this reference material, a brief description of the assessment of construction robots and the obligations of robot suppliers, robot owners and robot operators is given. The technical requirements established for the construction robots for the aforesaid three trades by SGS are included, which could be used as a basis for assessment of the acceptance of the construction robots in those trades in future.

2. ASSESSMENT OF CONSTRUCTION ROBOTS

There is a need to assess the construction robots before they are put to use and during their use to ensure that they are functioning in compliance with the technical requirements, in terms of safety, quality performance and functional requirements, given in Appendices A to C for painting, plastering and welding robots respectively. The assessment cycle should last for 3 years, consisting of an initial assessment, a surveillance assessment and a re-assessment.

In the initial assessment (i.e. before the construction robots are put to use), robot owners/robot operators should review and assess the items related to the safety, quality performance and functional requirements for the robots. They should witness the tests carried out on the robots. The testing should be carried out by a laboratory accredited by the Hong Kong Laboratory Accreditation Scheme (HOKLAS), or other laboratory accreditation bodies which have reached mutual recognition arrangement (MRA) with HOKLAS, for issue of HOKLAS or equivalent endorsed test certificates for the particular test concerned. The test results should be properly documented and endorsed by the laboratory.

During the use of construction robots, robot owners/robot operators should assess the construction robots on a yearly basis in the first two years (i.e. surveillance assessment) for robots maintained by robot suppliers, which are not yet sold or disposed. The purpose of the surveillance assessment is to check that the construction robots continue to function in accordance with the technical requirements. The surveillance assessment is not a full assessment and should be planned to cope with the actual work activities of the robots. In every surveillance assessment, robot owners/robot operators should conduct a simple desk-top review and an on-site visual inspection of the items given in the technical requirements (see Appendices A to C). Any non-conformity noted should be recorded and rectified within 6 months.

At the end of the 3-year assessment cycle, a re-assessment of the construction robots should be carried out. The purpose of the re-assessment is to confirm that the construction robots are continuing to function in compliance with the technical requirements.

Robot suppliers should retain all necessary quality and safety records of the projects completed by the construction robots for evaluation during the re-assessment.

3. OBLIGATIONS OF ROBOT SUPPLIERS, ROBOT OWNERS AND ROBOT OPERATORS

3.1 Robot Suppliers

Robot suppliers should:

(a) establish a risk assessment system with reference to ISO 10218-1: 2011 or other equivalent standards to identify potential safety hazards and risks to robot operators and to/or from the surrounding of its work areas during its set-up and operation, and to ensure its stability during operation, maintenance and disassembly;

(b) prepare a Set-up Manual, including a method statement of mounting the construction robot to secure its safety during initial and subsequent set-up;

(c) prepare Operation Manual, Maintenance Manual and Disassembly Manual and other necessary documents;

(d) establish a qualifying and authorisation system to ensure that robot operators are competent to operate the construction robot and to handle emergency issue;

(e) provide operation and safety training to the company representative and robot operators and to qualify them via evaluation before permitting to carry out their duties at construction sites; and provide refreshing training when the control system is upgraded;

(f) keep all training records and evaluation records for the company representative and robot operators for at least 3 years; and

(g) declare and disclose all relevant intellectual properties information about the ownership and the rights to use of the hardware and software related to the operation of the construction robot to robot owners and robot operators.

3.2 Robot Owners

Robot owners have the responsibility to ensure that robot operators follow the instructions from robot suppliers, provide support on operator training, employ competent personnel, and notify and coordinate with the main contractors and associated sub-contractors / tradesmen working in the same space when the construction robotics are in operation.

3.3 Robot Operators

Robot operators should be employed or hired by robot suppliers or robot owners. The duty of robot operators should be clearly defined in the Operation Manual.

4. TECHNICAL REQUIREMENTS FOR CONSTRUCTION ROBOTS FOR PAINTING, PLASTERING AND WELDING

The technical requirements for the construction robots for painting, plastering and welding are given in Appendices A to C.

APPENDIX A – TECHNICAL REQUIREMENTS FOR CONSTRUCTION PAINTING ROBOTS

The technical requirements for construction painting robots in terms of safety, quality performance and functional requirements should be in accordance with the following sections. Each Section covers "inspection" and / or "testing" activities.

1. Safety Requirements (for both Mobile and Non-mobile Robots)

This Section specifies the requirements for assessing the safety performance of a construction painting robot including the inherent design, protective measures, and information to be disclosed to users. It describes basic safety requirements associated with significant hazards incurred by construction painting robots and the need for preventive measures. Table 1 below tabulates the test items and their respective safety requirements, references (relevant standards and applicable regulatory requirements), assessment criteria and assessment methods. Non-fulfilment of any of the following assessment criteria should be considered as a Nonconformity.

Item No.	Safety Requirements	References	Assessment Criteria	Assessment Methods
1.1	**Power Transmission Guarding** Fixed or moveable guards should be installed to prevent exposure to hazards such as shafts, gears, drive belts, or linkages	ISO 10218-1 Clause 5.2.1 or equivalent standards	a. Protection guards must be available b. Location of guards should be appropriate c. Interlock of moveable guards should function properly d. Guard condition should be normal If the inspection results are 'Pass' for each of the above items, the Guard can give adequate protection	i) Document Review: robot's specifications and information, including technical data sheet, product catalogue, layout drawings, and other supplementary material to ensure that the protection guards are available, and their locations are appropriate ii) Visual inspection of availability of Protection Guards, and their condition and locations. (Note: The protection guards should be checked to re-confirm that they are installed in the correct locations and are functioning properly, in compliance with those shown in the documents.) iii) Check the Interlock function via demonstration during operation to ensure it functions properly.
1.2	**Loss or Change of Power** Loss of, or unstable, power should not result in a hazard, and any unprotected safety hazards should be identified / disclosed on the application form	ISO 10218-1 Clause 5.2.2 or equivalent standards IEC 60204-1:2018 Clause 5.4 or equivalent standards	When the power is off or unstable, speed is seen to be reduced, or no further hazardous movement is observed	i) Document Review: schematic circuit diagrams, design logic of software, to identify whether a robot is equipped with a protection feature ii) Shut down the power intentionally, then a visual inspection of any reduction in speed, or no further hazardous movement seen.

1.3	**Safety on Stored Energy** A means should be provided for the controlled release of stored hazardous energy. A label should be affixed to identify the stored energy hazard.	ISO 10218-1 Clause 5.2.5 or equivalent standards	A label should be affixed at the energised area to identify the stored energy hazard.	i) Document Review: technical data sheet, schematic circuit diagrams and product catalogue to identify whether the location of the affixed warning label is appropriate. ii) Visual inspection of the label affixed to indicate the energised area, and countercheck the position of the label.
1.4	**Electromagnetic Compatibility (EMC)** The design of the painting robot should meet electromagnetic compatibility requirements below and to ensure functional safety systems providing desired protection from possible interference and hazardous motion due to effects of electromagnetic interference (EMI), radio frequency interference (RFI) and electrostatic discharge (ESD). Two generic EMC requirements specifying the limits of interference for construction robots under different operation modes (working, battery charging and discharging) and different functions (movement, communication / networking, collaboration with human, sensory and identification / recognition) are: 1. Immunity requirements 2. Emission requirements	ISO 10218-1 Clause 5.2.6 or equivalent standards IEC 60204-1:2018 Clause 4.4.2 or equivalent standards BS EN IEC 61000-6-2:2019 Generic standards – Immunity standard for industrial environments BS EN IEC 61000-6-4:2019 Generic standards – Emission standard for industrial environments CR-1-08TS-02: 2021 Construction Robot – Electromagnetic compatibility – Generic standards – Immunity requirements and limits CR-1-08TS-03: 2021 Construction Robot – Electromagnetic compatibility – Generic standards – Emission requirements and limits	a. Acceptable if there is no occurrence of hazardous motion or situations such as frequent system restarts, unprogrammed and unexpected movement of the robot, and possible interference with functional-safety systems within the limits of interference*. b. Acceptable if the test results of Immunity test and Emission test of the painting robot are within the limits of interference* with respect to the Immunity and Emission requirements. Remarks (*) - the limits of interference under Immunity test and Emission test at relevant ports are specified in Appendix 7.	Document Review: specific schematic circuit diagrams, configuration design, EMC test reports to assure the required limits of Immunity and Emission requirements are complied.
Actuating Controls				
1.5	Status of the actuating controls should be clearly indicated	ISO 10218-1 Clause 5.3.2 – 5.3.4 or equivalent standards	Status of actuating controls (e.g. power on, fault detected, automatic mode) should be displayed.	Document Review: Technical data sheet, schematic circuit diagrams and product catalogue to identify the availability of actuating controls and the location of relevant labels.
1.6	Actuating controls should be labelled to clearly indicate their function.	ISO 10218-1 Clause 5.3.2 – 5.3.4 or equivalent standards	The labels of actuating controls must be available, and the functions of each control clearly shown	Visual inspection of the label of each actuating control, and use the “Lamp Test method” to countercheck that the function of each control matches the corresponding label.

1.7	**Safety-related Control System(SRCS) Performance** SRCS should comply with performance requirements. Performance requirements are stated by means of either: a. Performance Level (PL) and categories or b. Safety Integrity Levels (SIL) and hardware fault tolerance requirements Safety Performance requirements include: 1. A single fault in any of parts that does not lead to the loss of safety function; 2. A single fault should be detected at or before the next demand upon the safety function; 3. When a single fault occurs, the safety function is always performed, and a safe state should be maintained; 4. All foreseeable faults should be detected	ISO 10218-1 Clause 5.4.1 – 5.4.3 or equivalent standards	a. SRCS performance of the robot and any furnished equipment should be clearly stated in the information for use. Min. requirements of SRCS are: I. PL = d with structure category 3 or II. SIL = 2 and Hardware fault tolerance of 1 b. The data and criteria necessary to determine the SRCS performance should be included in the information for use.	Document Review: Robot's system specifications, schematic circuit diagrams and information related to the SRCS, to identify inclusion of SRCS performance of the robot and the data and criteria necessary to determine the conformity of SRCS performance.

Robot Stopping Functions				
1.8	**Emergency Stop (E-Stop)** Every robot should have a protective stop function and an independent emergency stop function. Each control station should have a manually initiated emergency stop function. The operator should be able to make a quick, unobstructed access to the E-Stop.	ISO 10218-1 clauses 5.5.1 and 5.5.2 or equivalent standards IEC 60204-1 clauses 9.2.3.4, 10.7 and Annex E or equivalent standards	a. A protective stop and an independent E-Stop should be available in each robot. b. Each E-Stop can function properly in the test. c. All E-Stops must function manually and should be free and easy to reach.	i) Visual inspection on the location and functions of the emergency stop and protective stop. ii) Test each stop at least once to check whether the stop functions work properly. iii) Test the reset mechanism of the E-stop
1.9	**Protective Stop** Information for use should include description of the stop category of every protective stop in the circuit.	ISO 10218-1 clauses 5.5.1 and 5.5.3 or equivalent standards	a. Protective devices should comply with specified safe distances. b. Connections of the stop functions with external protective devices should be available. c. Information for use should include description of the protection stop circuit.	Document Review: Robot's system specifications, product catalogue, technical data sheet, supplier's inhouse or external test reports and operation manual to identify any description of its E-Stop function, and braking system and quoted stopping performance
1.10	**Braking Functions** Every Mobile Robot should be equipped with brakes and a braking system. In case an obstacle, unbalancing motion or overspeed is detected, the braking system should function properly to slow down or where necessary, stop the robot for motion control and avoidance of hazard, and be capable of holding /restraining the robot	ISO 18646-1: 2016 Clause 6 or equivalent standards	a. Stopping performance of braking system and holding of stationary status can be demonstrated in three trials. b. The Mobile Robot can stop within the declared stopping distance and stopping time.	Demonstration of the stopping performance of the braking system and holding of stationary status in at least three trials.

Operation Mode				
1.11	**Selection of Operation Mode** Operational modes should be selectable with a mode selector which can be locked in each position. Each position of the selector should be clearly identifiable and should allow only one mode to be selected at any one time.	ISO 10218-1 Clauses 5.7.1 – 5.7.4 or equivalent standards	Acceptable if only one mode can be selected at any one time.	Visual inspection on the selector and test the selection of each working mode.
1.12	**Automatic Operation Mode** Safeguarding measures should be in place and functioning when the robot's task programme is executed in automatic mode. Automatic operation should be prevented if any stop condition is detected.	ISO 10218-1 Clauses 5.7.1 – 5.7.4 or equivalent standards	a. Acceptable if the safeguarding measures are functioning normally under the automatic mode, and the test result for each working mode is normal. b. Stop condition is detected when safeguarding measures function during automatic operation.	Test both the automatic mode and the manual mode. i) To set the robot to automatic mode and manually assign a possible stop condition to test whether the safeguarding measures are functioning, and the condition can be detected. ii) The manual mode of operation should be performed with all persons outside the safeguarded space. To check that clear instructions have been provided prior to selecting the automatic mode, any suspended safeguards should be returned to their full functionality. iii) Document Review: System specification, schematic circuit diagrams, design material and operation manual to confirm provision of an Automatic Operation Mode.
Safety Protection Features for Collaboration Operation				
1.13	**Visual Indication** Robots designed for collaborative operation should be provided with a visual indicator when the collaborative operation is activated.	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if there is an indication sign at a proper location.	i) Visual inspection on the indication sign. ii) Document Review: Robot's system specifications, technical data sheet, product catalogue and other supplementary material to identify whether any indication sign is available and the appropriateness of its location.

1.14	**Safety-rated Monitored Stop** The robot should stop when a human is in the collaborative workspace.	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	The time measured for each stop in a trail should be consistent, with limits of variation not more than 10% of the mean.	i) Test the safety related control system for collaborative operation by using an object with height similar to an adult to enter into the robot workplace and observe any stop signs. ii) Repeat the test at least 5 times and measure the time required to reach a stop condition in each trail iii) Document Review: Robot's system specifications, technical data sheet, product catalogue, supplier's inhouse test report and other supplementary material to identify whether a stop condition is available for collaborative work.
1.15	**Hand Guiding** Where provided, hand guiding equipment should be located close to the end-effector and should be equipped with an emergency stop and an enabling device.	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if the hand guiding is observed to be close to the end-effectors and is equipped with an emergency stop and an enabling device.	Visual inspection on the availability and location of the hand guiding equipment
1.16	**Speed and Separation Distance Monitoring** The robot should be able to maintain a determined speed and separation distance. Information for use should contain directions for implementing speed values and separation distances	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if the results of tests of safety speed and separation distance are within the range of the supplier's specification.	i) Test by setting the safety speed and separation distance as per the supplier's information and observe whether the outcomes are within the supplier's specification. ii) Document Review: System specifications, technical data sheet, product catalogue, supplier's inhouse test report and other supplementary material to identify whether the robot is equipped with features to monitor the speed andseparation distance.
1.17	**Movement without Drive Power** The robot should be designed so that the axes are capable of being moved without the use of drive power in an emergency or abnormal situation. Controls should be readily accessible but protected from unintended operation. Where practicable, warning notices should be posted near the activating controls.	ISO 10218-1 Clause 5.13 or equivalent standards	a. Acceptable if the axes of the robot can be moved freely by a single person without the use of drive power. b. Information for use should include a warning about a possible hazard created if the braking devices are released. Warning notices, when needed, should be posted near the controls. c. Controls must be protected from unintended operation.	i) Visual inspection of any movement of the robot if there is no drive power. ii) Visual inspection of the hazard warning notice iii) Visual inspection that the controls are protected.
1.18	**Electrical Protection** The robot should be designed and equipped with the following safety features: a. Isolation and Switching	IEC 60204-1:2018 or equivalent standards and	Acceptable if there is a proof to show that all protection measures have been taken to comply with IEC 60204-1:2018 or, BS EN 60204-1:2018 or other equivalent International	Document Review: Robot's system specifications, electrical circuit diagram /drawings, technical data sheet, product catalogue, external party's test reports, Product Safety Mark, and other supplementary material to identify whether the protection features have been equipped and tested.

	b. Overcurrent Protection c. Earth Leakage and Earth Fault Currents Protection d. Overloaded Protection e. Over-heat Protection f. Overspeed Protection	Relevant parts of Code of Practice for the Electricity (Wiring) Regulations, EMSD, HKSARG	Standards, and the Code of Practice for the Electricity (Wiring) Regulations, EMSD, HKSARG.	
1.19	**Batteries Protection** (applicable for Mobile Robots) **(applicable for Lead acid batteries using in Mobile Robot):** Overheat Protection Access for gas escape during charging **(applicable for Lithium based batteries using in Mobile Robot):** Overheat Protection Overcharging / Imbalanced charging Protection Short circuit Protection Mechanical Shock Protection Withstand Vibration	IEC 60896-21 (for lead acid batteries) IEC 62619: 2017 sections 7 and 8 (for lithium based batteries) UL 3100 clauses 7.2, 22.2, 22.5, 33 and 36 ANSI/RIA R15.08-1-2020 clause 5.1.16.5 or equivalent standards	a. Acceptable if the batteries had been certified by a nationally or international-wide recognized testing laboratory in compliance with IEC 60896 -21 or IEC 62619 : 2017 to show all protection features of batteries have been tested. b. No abnormal temperature rise is detected when touching the surface of a fully charged battery by hand.	i) Document Review: robot's batteries specifications, technical data sheet, product catalogue, test report and certificate of batteries issued by a national or international test laboratory to identify whether corresponding protection features have been equipped and tested. ii) Fully charge the battery and check the surface temperature of the battery by hand first. If the battery temperature feels abnormal, use a calibrated thermo-gun to detect the battery temperature.
1.20	**Stability** The robot in a whole should remain stable in all operating conditions and during all loading-handling and travelling movements, including an emergency stop. There are four key stability parameters (steering speed, traction speed, load handling, and uplifting of centre of gravity in the course of painting work) A tilting platform stability test should be carried out to ensure the stability of the robot is acceptable.	ISO 3691-4: 2020 ISO 22915-1 : 2016 or equivalent standards	The mobile is considered STABLE if it passes all the stability tests without tip-over.	i) The robot in a whole should be tested in the worst-case conditions, e.g. loaded, unloaded, loading height, max. slope gradient, bi-directional (fore & aft), emergency braking deceleration, controlled acceleration / deceleration. ii) The test should be performed with at least 110% of claimed capacity and either: a. At least 110% of predetermined speed at rated load; or b. At maximum reachable speed, in case 110% of predetermined speed cannot be reached. iii) Document Review: Technical data sheet, product catalogue and supplier's inhouse test report to identify the rated load and max. speed.
1.21	**IP Rating** Since the robot is intended to be used at construction sites, the robot in a whole should be protected from dust ingress and from water spray under IP rating from IP 55 to IP 68.	IEC 60529: 2013 + AMD1: 1999 + AMD2: 2013 + corrigenda (2003-2019) or equivalent standards	a. The sealing of entire painting robot should be effective. b. IP 55 to IP 68 (any rating)	Document Review: Technical data sheet, product catalogue, supplier's external test report showing IP rating achieved.

1.22	**Explosive Proof** (applicable for both non-Mobile and Mobile robots)	IECEx Scheme	a. Acceptable if there is a IECEx Certificate of Conformity available or b. Acceptable if the enclosure and electrical parts of the Robot are certified Flameproof	Document Review: either IECEx Certificate of Conformity for Explosive Atmospheres or Flameproof reports

Table 1 – Safety Requirements

2. Quality Performance Requirements

This Section specifies the requirements for assessing the quality performance of a construction painting robot. Its quality performance is assessed through an on-site painting test (spray painting or roller painting) with the use of multi-layer acrylic paint with texture coat as shown in a mock test paper in Appendix 1. Assessment methods include visual inspection, measurement of film thickness and adhesion strength test. Regarding quality performance, the construction painting robot should demonstrate a stable performance in path repeatability and high accuracy in positioning and orientation during painting process. A proof for claimed path accuracy and path repeatability of the construction painting robot with 30 cycles at 100% rated load should be presented during document assessment as pre-qualification for quality performance test.

The objectives of on-site painting tests are:

- ❖ to test the construction painting robot's ability to meet the requirements for general painting tasks in the construction industry, and
- ❖ to test the construction painting robot's path repeatability, stability, and productivity in the set up for finishing different wall surfaces.

The construction painting robot should complete and pass the "Painting Test" (Section 2.1) and the test consists of four test items (2.1.1 to 2.1.4), where a mark-deduction mechanism is adopted. Test items 2.1.1 to 2.1.3 carry different weighting of marks while test item 2.1.4 is used for deduction of marks due to incomplete work. In case the painting robot is able to complete part of the wall surfaces and ceiling surface due to its inherent design for particular application purpose such as for outdoor vertical wall only, part of the score will be adjusted to compensate the entire marking system. Details of the mark-deduction mechanism are described in Appendix 1. Full mark of the test is 100 and the overall passing mark is 60. Testing results will be stated on the evaluation report.

Before testing, the robot operator should be aware of the paint manufacturer's product data sheets which give detailed information on recommended limit of temperature and humidity during blending, application and storage of paint. The robot operator should identify the wet and dry film thickness per coat recommended by the paint manufacturer from the product data sheets.

In the "Painting Test", the painting robot is required to demonstrate its capability to complete painting on a composite plastered wall. The wall structure built for the test is made of concrete with 6 - 10 mm thick cement plaster. The wall structure consists of a vertical wall with two surfaces "A and B", and a ceiling with surface "C" (interior) and surface "D" (exterior). For indoor application, the painting robot is required to complete the painting on wall surfaces "A and B", and interior surface "C" of ceiling, while for outdoor application, the painting robot is required to complete the painting on wall surfaces "A and B", and exterior surface "D" of ceiling. Some surfaces are non-painted for control test purpose.

The wall surfaces prepared for painting test should be sound, smooth, straight, clean, free from laitance and contamination such as oil and grease, crack-free, and must be kept dry at the time of application and are in an orientation identified in the drawing P1 throughout the test.

Preparation work of wall surfaces suitable for test will be conducted by the testing laboratory. The robot operator is required to countercheck the dew point and relative humidity of the test environment to make sure that it is suitable for testing. The robot operator is required to seal the non-testable area in Drawing P1 with adhesive tape and polystyrene sheet, and to mix the paint with water in a ratio as per paint manufacturer's instruction.

The paint used is a set of water based low VOC multi-layer acrylic paint consisting of two / three kinds of coating, namely (a) a base primer / sealer (for all surfaces); (b) undercoat with texture (for wall surface A only), and (c) topcoat / finish coat with different colours (for all surfaces) and Table 2 below has shown its physical properties:

	Properties of Paint used	Specification
1.	Texture Coat	Min. 0.9 kg/m2 (Fine texture) ; Min. 1.3 kg/m2 (Medium texture)
2.	Adhesion strength (as per JIS A6909:2003)	At standard condition, strength >= 0.7 N/mm2
3.	Viscosity (as per ASTM D562-10)	Min. 75 KU, Max. 95 KU

Table 2 – Mechanical and physical properties of paints used for the Painting Test

Test item 2.1.1 Dimension control

The painting robot should complete the painting test with one layer of primer / sealer for all surfaces, one layer of undercoat with texture for wall surface A, and one layer of topcoat for all surfaces within 6 hours. Tolerance of main dimension covered by paints at each wall is less than 5 mm. The dimensions of wall surface shown in Appendix 2 indicate the outer sizes of final finished walls with paints. Tolerance of each main dimension is stated in Table 4 in following page. Marks will be deducted if the tolerance limit is exceeded.

The painting robot should cover different wall surfaces including the interior / exterior surface of the ceiling with various colour paints as required on the mock test paper. Table 3 below presents the dimension of and colour to be applied at each wall surface as shown in Drawing P1.

Test Items	Wall Surface Position	Dimension of Wall Surface (LxH) mm	Colour of primer / sealer	Colour of textured undercoat	Colour of topcoat
2.1.1	A	4000 x 3100	White colour	Any light colour other than white	Any light colour different from undercoat colour
	B	(4000 x 2950) + (270 x 3100) x 2	White colour	N/A	Any dark colour
	C	4000 x 1200	White colour	N/A	Same light colour as Wall Surface A
	D	4000 x 1200	White colour	N/A	Same light colour as Wall Surface A

Table 3 – A summary of the dimension of and colour to be applied at each wall surface as shown in drawing P1

Test item 2.1.2 Wet and Dry Film Thickness

The wet film thickness (WFT) of a freshly applied wet coating material is measured immediately after application and the dry film thickness (DFT) of a coating remaining on the surface is measured when the coating has hardened. Measurement of film thickness should be performed by a suitably qualified person. Such a person should be the Hong Kong Laboratory Accreditation Scheme (HOKLAS) qualified painting inspector, or a painting inspector with a recognised certified painting inspection qualification*.

Test item 2.1.3 Accuracy and Quality control

To validate the performance of a painting robot, a visual inspection should be performed by a suitably qualified person. Such a person should be a HOKLAS qualified painting inspector, or a painting inspector with a recognised certified painting inspection qualification* for examining the quality results of paint made by a painting robot. Assessment criteria under this test item are listed in Table 4 and a defect will be identified if there is a violation of any of assessment criteria. Marks will be deducted in proportion to the quantity of defects identified. Through visual inspection on each layer of coating with different colour, it can help identify the degree of repeatability and stability of the painting robot over repeated path.

(*Note: Recognised qualification of paint inspector in Hong Kong includes, but not limited to, BGAS-CSWIP painting Inspector Grade 2, AMPP-CIP painting inspector Level 2 and Level 3, or a trained skilled painter certified by the Trade Test Centre of CIC plus five years painting inspection experience. The qualified painting inspector should receive a CIC recognized training on Part Two clause 4.2 requirements prior to taking up the role as a qualified person under this Scheme.)

However, if the overall result is less than the passing score, the painting test will be considered as Fail and a Nonconformity will be raised.

If the Adhesion Strength Test result cannot meet the minimum strength requirement, the painting test will be considered as Fail and a Nonconformity will be raised.

Test item 2.1.4 Completion

This test item is to identify how fast the painting robot has worked. 40 marks will be deducted from the total score if less than 80% of total area has been completed.

During the test, a performance measurement will be conducted by the testing laboratory to measure the productivity of a construction painting robot. It will not induce any impact to the testing result. The methodology is to record the time spent in the painting work on Wall A of the drawing P1 in Appendix 1.

The testing laboratory should follow the general conditions of facility set-up and test environment for painting test as described in Appendix 2 and 3 for standardising the test results.

Item No.	Quality Performance Requirements	References	Assessment Criteria	Assessment Method
Section 2.1 Painting Test				
2.1.1	**Dimension control**	CIC Trade Test Centre's Painting Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.)	a. Referring to the drawing P1 in Appendix 1, the tolerance of each main dimension covered with paints is <5 mm (for any one end at each wall surface) Note: • Marks are deducted in proportion to the difference in length between the finish and the one in the drawing P1 per each dimension	By measurement
2.1.2	**Wet and Dry Film Thickness of topcoat**	ISO 2808: 2019 ASTM D4414: 1995 or equivalent standards	a. Referring to the drawing P1 in Appendix 1, the tolerance of either wet film thickness (WFT) or dry film thickness (DFT) of topcoat measured upon completion of painting work from the desired data given by the paint manufacturer should be less than 5%. Note: • Marks are deducted if the tolerance of excessive film thickness of topcoat identified at each wall is equal or larger than 5%.	By measurement with film thickness gauges at 5 spots at each wall when wet and dry.
2.1.3	**Accuracy and Quality control of painting**	CIC Trade Test Centre's Painter - Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.) Adhesion strength test / Pull out test – JIS A6909: 2003 cl. 7.10 or equivalent standards	Please refer to drawing P1 in Appendix 1. a. Insufficient paint film thickness is not allowed if its result has led to an appearance of undercoat / overlapping of paint film / uneven distribution b. Uneven distribution of paint colour is not allowed c. Irregular appearance on the paint surface like signs of crack, existence of gap, occurrence of runs, sagging, curtaining, lifting, blistering and creasing is not allowed d. Poor straightness of each stroke is not allowed e. Incomplete coverage with paint at all the edges and corners of the plastered wall surface is not allowed f. Adhesion strength (at standard condition) >=0.7 N/mm^2 Note: • A defect is identified if there is a violation of any of the above assessment criteria (a-e). • Marks are deducted in proportion to the quantity of defects identified.	Visual check of criteria "a – e" Adhesion strength test / Pull out test for criterion 'f '
2.1.4	**Completion (%)**	Nil	Please refer to drawing P1 in Appendix 1. Note: • If less than 80% of total area has been completed within 6 hours, 40 marks will be deducted from the total score.	By measurement

Table 4 – Quality Performance Requirements for Painting Test

3. Functional Requirements (for Mobile Robots only)

This Section specifies the requirements for assessing the functional performance of a mobile robot which forms part of a construction painting robot. Non-fulfilment of any of the following assessment criteria will be considered as a Nonconformity.

Item No.	Functional Requirements	References	Assessment Criteria	Assessment Methods
3.1	**Passing Over Sill**	Testing Facility and Testing Method of Rated Speed as per ISO 18646-1: 2016 Clauses 9.2 and 9.3 respectively, or equivalent standards	The Mobile Robot can pass over its specified maximum sill height (m) in at least three trials.	i) Document Review: robot's system specifications, product catalogue, technical data sheet, and supplier's inhouse or external test reports; and other supplementary material to identify any information about the maximum sill height. ii) Demonstration of how the Mobile Robot passes over the specified maximum sill height in at least three trials
3.2	**Navigation**	GB/T 38124-2019 clause 5.2 ISO 18646-2: 2019 clause 4, 5 and Annex A and ANSI/RIA R15.08-1-2020 clause 5.1.7 or equivalent standards Safety speed figure is based on MHEDA's recommendation. (MHEDA for Material Handling Equipment Distributors Association)	The Mobile Robot can follow the pre-set direction and reach the designated point with maximum allowable safety speed of 5 mph or 2.235 m/s in at least three trials	i) Document Review: robot's system specifications, product catalogue, technical data sheet, self-description letter, suppliers' inhouse or external test report, and other supplementary material to identify any information describing how the robot be navigated and ii) Demonstrate how the robot can be navigated to a designated point in at least three trials.
3.3	**Obstacle Detection and Obstacle Avoidance Functions**	GB/T 38124-2019 clause 5.2.3 UL 3100 clause 14 Obstacle Detection Test as per ISO 18646-2: 2019 Clause 6 Obstacle Avoidance Test as per ISO 18646-2: 2019 Clause 7 and ANSI/RIA R15.08-1-2020 Clause 7.4.4 or equivalent standards	a. The Mobile Robot can pass the static obstacle detection test with different shape, dimension and colour of objects in at least three trials. b. The Mobile Robot can pass a moving obstacle avoidance test in at least three trials.	i) Document Review: robot's system specifications, technical data sheet, product catalogue, self-description letter, supplier's inhouse or external test report, and other supplementary material to identify if the robot is equipped with any devices to detect and avoid obstacles. ii) Demonstrate how the robot detects static obstacles such as physical objects of different shape, dimension and colour, uneven floor sections, holes within a detection range, and iii) Demonstrate how to avoid collision with a moving object or falling into a hole in at least three trials.

Table 5 – Functional Requirements

4. Marking and labelling

Painting robot should be clearly marked with, but not limited to, the following information:

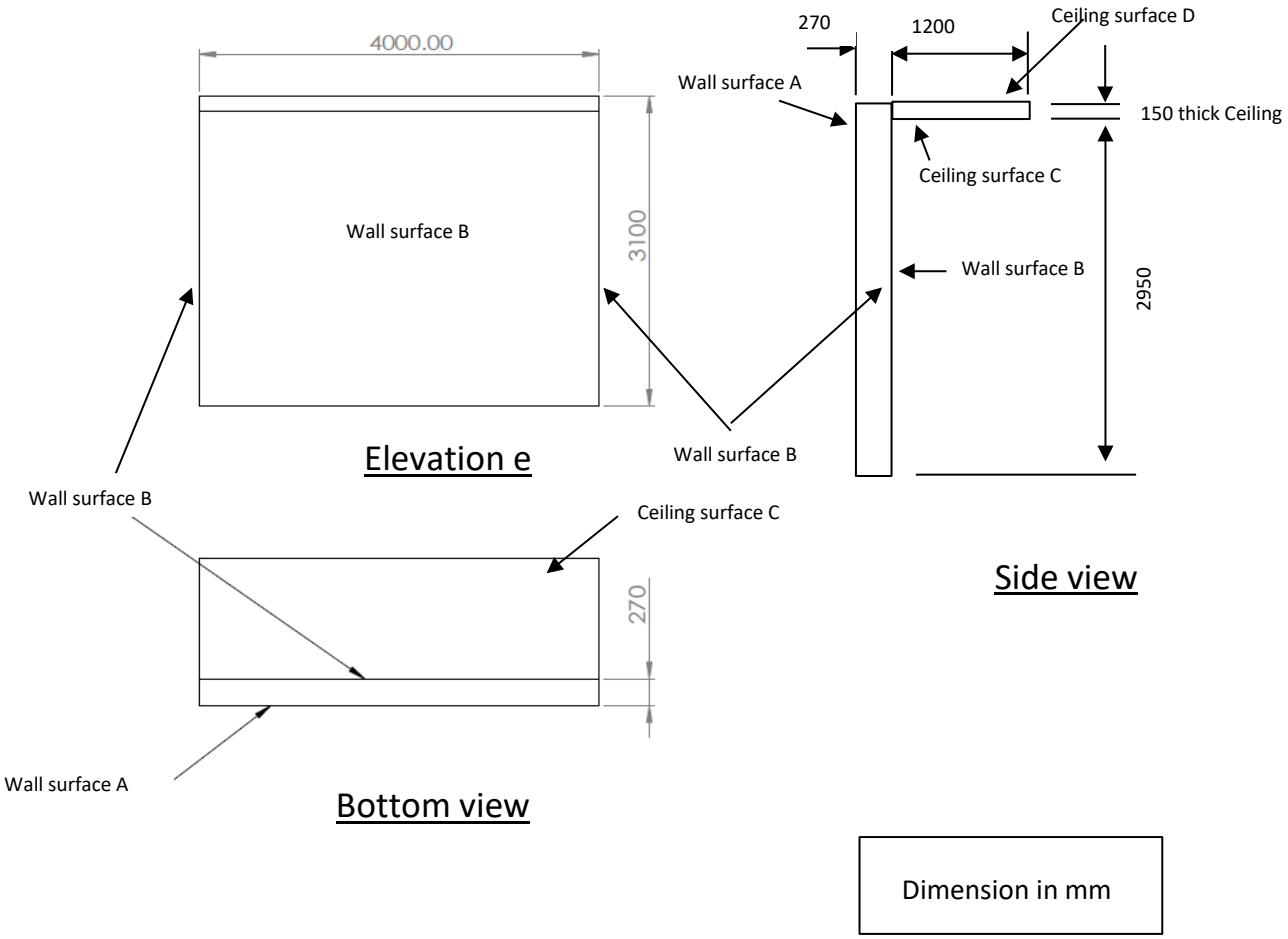
- Brand name of the robot
- Type, model, series, unique serial number / identity number of the robot
- Date or batch code of production/ integration of the robot
- Name and address of robot manufacturer
- Name and address of integrator (if applicable)
- Details of the certified robot supplier (name, address, phone contact, website, etc.)
- Any other information for use of robot recommended by the robot manufacturer/ integrator

Appendices

Appendix 1 – Mock Test Paper and Mark-deduction mechanism

Painting Test – Concrete Wall (Width 4m x High 3.1m) with a ceiling canopy (Length 4m x Width 1.2 m)

Drawing P1 Work Drawing for Painting Test



Note:

1. The preparation work of wall surface is to be done by others.
2. The wall surface should be smooth, straight, dry, clean, and crack-free.

Instruction:

1. Seal the non-testable area with adhesive tape and polystyrene sheet by robot operator
2. Complete painting the surface at Wall surface A with a layer of white primer / sealer, a layer of light colour undercoat with texture coat, and a topcoat with different light colour in order by painting robot,
3. Complete Wall surface B (one front wall surface and two side wall surfaces) with a layer of white primer / sealer, and a topcoat of different colours in order by painting robot
4. Complete ceiling surface either C or D with a layer of white primer / sealer, and a topcoat of different colours in order by painting robot, subject to the application of construction robot.

Duration: 6 hours (Include set up time)

This mark-deduction mechanism describes how many marks to be assigned for test items (2.1.1 to 2.1.4) and maximum mark will be deducted for each defect item against corresponding assessment criteria. Test items 2.1.1, 2.1.2 and 2.1.3 carry 6 marks, 10 marks and 84 marks respectively while test item 2.1.4 will deduct 40 marks if the finished area is measured less than 80% of overall total area.

Full mark of the test is 100 and the overall passing mark is 60. Marks are progressively deducted according to the number of defects identified against each assessment criteria in test items 2.1.1 and 2.1.3. The mark carried by each defect item is different. More defects are identified more marks will be deducted.

In test item 2.1.2, both wet film thickness (WFT) is measured immediately after application and dry film thickness (DFT) are measured. Marks are deducted when the measured value of either WFT or DFT has excessed than the desired values given by the paint manufacturer by 5%.

Following table (Table 6) tabulates the maximum marks to be deducted and it is for reference only.

Test Items	Wall Surface Position	Dimension of Wall Surface (LxH) mm	Tolerance of each main dimension covered with paints at each wall surface	Colour of primer / undercoat / topcoat	Max. marks to be deducted against main dimension at each wall in drawing P1
2.1.1 (Dimension control)	A	4000 x 3100	<5mm	White colour / any light colour / any other light colour	2
	B	(4000 x 2950) + (270 x 3100) x 2	<5mm	White colour / no undercoat / any dark colour	2
	*C or D	4000 x 1200	<5mm	White colour / no undercoat / same colour as wall surface A	2
Test Items	Wall Surface Position	Wet film / Dry film thickness desired (µm) (WFT/ DFT desired)	Wet film / Dry film thickness measured (WFT / DFT measured)	Max. tolerance of thickness between the measured and desired values of either WFT or DFT	Max. marks to be deducted against the difference of the measured values and the desired values of either WFT or DFT
2.1.2 (Film Thickness)	A	As per technical data provided by Paint Manufacturer	Mean of 3 measured results	<5%	2
	B	As per technical data provided by Paint Manufacturer	Mean of 3 measured results	<5%	2
	*C or D	As per technical data provided by Paint Manufacturer	Mean of 3 measured results	<5%	6
Remarks (*): Test items 2.1.1 and 2.1.2 are applicable to the ceiling surface either C or D, subject to the application of the construction robot (i.e. for indoor or outdoor application).					
Test Items	Wall Surface Position	Defect item no. (For details, refer to Table 4)	Defects (For details, refer to Table 4)	Max. defects allowed	Max. marks to be deducted against each defective item

2.1.3 (Accuracy and Quality Control)	A, B, C, D	2.1.3 a	Insufficient paint film thickness	4	8
		2.1.3 b	Uneven distribution of paint colour	4	8
		2.1.3 c	Irregular appearance	8	48
		2.1.3 d	Poor straightness	2	10
		2.1.3 e	Incomplete coverage with paint at all the edges and corners of the wall	2	10
Test Items	Wall Surface Position	Total area of Wall Surface (m2)	Definition of Completion (%)	Overall Completion % within 6 hours	Mark to be deducted if minimum completion (%) is not reached
2.1.4 (Completion %)	A	12.40 m2	Completed areas / Total area (Note: Completion areas include full height of each painted wall surface completed by the painting robot)	min. 80% of overall area	40
	B	13.47 m2			
	C	4.80 m2			
	D	4.80 m2			
Remarks (*): Test items 2.1.3 and 2.1.4 are applicable to the ceiling surface either C or D, subject to the application of the construction robot (i.e. for indoor or outdoor application).					

Table 6 – Mark-deduction mechanism

Appendix 2 – Facility Set-up

Item	Facility Item	Criteria / Requirements for Painting Processes	Remarks / Technical Reference.
1.	Workplace	The test laboratory should be operated under a Quality, Health and Safety System. Where appropriate, the test laboratory should provide suitable Personnel Protection Equipment (PPE). The workplace should be fitted for testing and be equipped with adequate and stable supply of electrical power and adequate Illumination. The workplace should be ventilated with adequate supply of fresh air and proper discharge of contaminated vapour particles during painting work. The test laboratory should be spacious to accommodate the concrete walls for practical test and equipped with sufficient works areas for the painting robot to rotate or move to different directions. If a mechanical paint mixer is required, relevant safety precaution measures should be taken. The workplace should be structurally fitted to prevent damage from any detrimental effects of weather or other issues which may affect the quality performance test and safety of personnel.	Layout plan with emergency escape route should be provided and displayed. The supply of electrical power sources should be stable and adequate. Single phase – 220V 50 Hz and Three phase – 380V 50 Hz Maximum allowable lighting power density (LPD) should be maintained at 13.5 W/m^2 as per Table 5.4 of EMSD's Building Energy Code (BEC) 2021. Appropriate mechanical ventilation measures and exhaust facilities should be equipped to provide fresh air for dilution of contaminants accumulated in the testing laboratory and to help removing the contaminants out from the workplace. Appropriate Fire Extinguishers should be available in the testing laboratory. Protection of motorized paint mixer should comply with the latest edition of HKSAR Ordinances, corresponding Regulations and Code of Practice including the followings: 1. Cap 406, the Electricity (Wiring) Regulations and its Code of Practice, 2. Cap 59, the Factories and Industrial Undertakings Ordinance (FIUO) and its Regulations under FIUO 3. Cap 95, the Fire Services Ordinance and its Code of Practice 4. Guidance Notes on Paint Spraying and Related Coating Processes issued by Labour Department Smoking or the presence of any naked flame or other means likely to ignite vapour from a flammable liquid are strictly prohibited inside the spraying room or areas including spray booth or within 6 meters of any spraying areas. If the pressure of the compressed air vessel for spray painting exceeds the min. requirement of the FIUO, regular inspection should be carried out by an authority person. Fence-off the working areas.

2.	Equipment, tools, and devices	All painting handling tools such as spray guns and paint containers and mixers are maintained in proper condition and kept apart from flame. All equipment and devices for measurement and testing should be maintained in good condition. Valid calibration status of measurement and testing devices used must be maintained when the test is performed.	Special care should be taken to prevent spray guns from pointing towards robot operator and other personnel in the vicinity. When pressurized equipment such as compressed air spraying is used, the correct balance of air and liquid should be adjusted to minimise the formation of fine droplets that are not deposited on the paint. Measurement device such as measuring tape should be calibrated, and the calibration certificate is available, and the calibration status remains valid when the test is performed. Preferably the certificate was issued by a HKAS accredited test laboratory.
3.	Painting Processes	During painting, vibration, noise, mist and smell could be generated or emitted to affect the operator's health and safety.	A spray room with proper ventilation and electrostatic dust collection equipment should be installed to improve the air quality inside the test laboratory. Robot operator and the inspection personnel must wear suitable PPE before start of painting work, in particular ear, eye and mouth protection equipment if the noise limit is exceeded and paint mist and smell are continuously emitted.
4.	Storage and Handling of painting material	Dry and clean condition with seals should be maintained on container of paint	The spray room must be kept dry and temperature should be set as per paint manufacturer's specification.
5.	Information on test report and drawings	Instruction for inspection and testing should be clearly documented	The type and accuracy of the measurement system, if use, e.g., 3D camera system or GPS equipment suitable for measuring the pose characteristics of construction robot should be included in the test report.
6.	Set-up for inspection	Jigs, fixtures and temporary structure, if necessary, should be used.	The jigs, fixtures and temporary structure should be rigid and convenient to use
7.	Inspection and documentation	Inspection and test reports should be documented and sent for compilation of the Evaluation Report within one week after completion of the Adhesion Strength Test / Pull-out test.	N/A

Appendix 3 – Testing Environment

Item	Testing Environment Condition	Criteria / requirements	Remarks / Technical Reference
1.	Robot mounting	Mounting should be in accordance with the robot supplier's recommendations	With reference to robot supplier's specifications or other publicly available information
2.	Conditions prior to testing	The robot should be completed assembled and fully operational. All necessary levelling measurement, alignment procedures and functional test instructions must be available and followed.	Appropriate robot supplier's procedures, instruction and testing methods
		The plastered walls prepared for testing should be kept clean before test.	Keep monitoring the RH (%) and dew point of the test area.
		If cables are used for lifting the painting robots, the cable and its hoisting system must be examined by authorized person (AP) before use.	Under F&IU Cap 59, all hoisting cables must be checked periodically, and a mandatory form is signed by AP.
3.	Operating conditions	The normal operating conditions should be stipulated by the robot supplier. Particular safety precautions to operation should be specified by the robot supplier prior to testing. For functional performance test, the Travel surface conditions for Indoor usage are (source: ISO 18646-2: 2019 cl. 4.3): 1. Type of surface required – Hard, even and horizontal ; 2. Coefficient of friction of surface: 1.0	Normal operation conditions include requirements for electrical, hydraulic, and pneumatic power, power fluctuations and disturbances, maximum safe operating limits.
4.	Environmental conditions for normal operation conditions	During functional performance test, typical Indoor Environmental conditions (Ref.: ISO 18646-2: 2019 cl. 4.2) should be maintained at: 1. Range of RH: 0% - 80% ; 2. Range of illumination: 100 lux – 1000 lux. For outdoor application, the Outdoor Environmental conditions should be kept under normal outdoor usage or according to the robot supplier's specifications or recommendations	Environmental conditions include temperature, relative humidity (RH), electromagnetic and electrostatic fields, radio frequency interference, atmospheric contaminants, and altitude limits should be declared in the test report. (Ref. ISO 18646-2 cl. 4.2 and Annex A cl A.3 and ISO 9946)

5.	Temperature and Relative humidity of testing environment	During functional performance test, typical Indoor Environmental conditions (Ref.: ISO 18646-2: 2019 cl. 4.2): 1. Range of ambient temperature (Θ): 10°C - 30°C In average, the ambient temperature (Θ) should be 20°C. 2. The test temperature should be maintained at (Θ ± 2) °C Relative humidity (RH) of spray test room must be kept between 0% - 80%, optimized RH is 40% - 50 %. For outdoor application, the Outdoor Environmental conditions (Ref: ISO 18646-2: 2019 Annex A) should be kept under normal outdoor usage or according to the robot supplier's specifications or recommendations	If situation is allowed, the robot and the measuring instruments should have been kept in the test environment long enough (preferably overnight) so that they are in a thermally stable condition before testing. They should be protected from draughts and external thermal radiation like sunlight, heaters.

Appendix 4 – Document Quality Control

Documents should be kept by Robot Operator	
1.	Business Registry or other legal documents as a proof of registry as a legal entity
2.	Safety-related Risk Assessment and Safety Precaution measures
3.	Manual / Procedure for Set-up including Mounting of Construction Robot and relevant Records
4.	Manual / Procedure for Disassembly of Construction Robot and relevant Records
5.	Manual / Procedure/ Handbook for Operation with Emergency Control measures
6.	Manual / Procedure/ Handbook and Schedule for Maintenance and relevant Records
7.	Authorization Documents / Records
8.	Key Production Procedures and Records
9.	Internal Quality Assurance Procedures and Quality Control Records
10.	Pre-work Risk Assessment Record (on-site)
11.	Product Quality and Safety Inspection Record (on-site)
12.	Product Catalogue (latest version)
13.	Technical Specification Data Sheet (latest version)
14.	Drawings / Electrical Circuit Diagram (where applicable)
15.	Test Reports (Internal / External)
16.	Test Certificates
17.	Training Records of Robot Operator, Robot Users and Company Representative
18.	Safety-related Incident or Accident Occurrence Reports and follow-up
19.	Quality performance related nonconforming issues
20.	Post-delivery Complaint received
21.	Warning Letter or Summit received regarding offence of local statutory or regulatory regulations, and violence of contractual requirements

Following document quality control activities, not limited to, should be followed:

1. Before each piece of documented information is created and updated, appropriate identification and description (e.g. title, date, author or reference number), and format (e.g. language, software version, graphics) and media (e.g. paper, electronic) have been established, reviewed and approval for suitability and adequacy.
2. The documents and records, not limited to the above table, should be adequately protected (e.g. from loss of confidentiality, improper use, or loss of integrity or unintended alternations) ; stored and preserved (e.g. software licences, permits to use, electronic / digital information).
3. The documents and records, not limited to the above table, when distributed, access, retrieval and use should be properly controlled (e.g. distributed to whom, grant of access right and right of use).
4. The documents and records, not limited to the above table, should be kept in a defined retention period, typically not less than 3 years.
5. Any changes, including version number, of the documents and records, not limited to the above table, should be clearly identified and traceable.

Appendix 5 – Audit Planning Matrix for a 3-year Cycle

Areas / Documents to be available for audit	Initial Audit	First SV	Second SV	Re-audit
Business Registry or other legal documents as a proof of registry as a legal entity	✓			✓
Safety-related risk assessment and safety precaution measures	✓	✓	✓	✓
Set-up and Mounting Manual / Procedure to describe safety hazards, risk, and precaution measures to be taken during initial set-up and subsequent set-up in case of re-location at site.	✓	✓	✓	✓
Disassembly Manual / Procedure to describe safety hazards, risk, and precaution measures to be taken during disassembly and re-location at site.	✓	✓	✓	✓
Operation Manual	✓	✓	✓	✓
Maintenance Manual	✓	✓	✓	✓
Maintenance Schedule and Records		✓	✓	✓
Authorization Documents / Records	✓	✓	✓	✓
Key Production Procedures and Records	✓	✓	✓	✓
Internal Quality Assurance Procedures and Quality Control Records	✓	✓	✓	✓
Pre-work Risk Assessment Record (on-site)	✓	✓	✓	✓
Product Quality and Safety Inspection Record (on-site)	✓	✓	✓	✓
Product catalogue	✓			✓
Technical Specification Sheet (where applicable)	✓			✓
Drawings (where applicable)	✓			✓
Test Reports (Internal / external)	✓			✓
Test Certificates	✓			✓
Training Records of Robot Operator	✓	✓	✓	✓
Safety related incident or accident occurrence reports and follow-up		✓	✓	✓
Quality performance related nonconforming issues		✓	✓	✓
Post-delivery complaint received		✓	✓	✓
Warning letter or summit received regarding offence of local statutory or regulatory regulations, and violence of contractual requirements	✓	✓	✓	✓
Technical Aspects*	✓	✓	✓	✓

*Remark: Technical aspects, not limited to, battery protection, stability, distance monitoring, where applicable, are required to be covered in audits, and each SV.

Appendix 6 – Key Contents of Set-up Manual, Operation Manual and Maintenance Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot operator and close stakeholders who are involved for the set-up of robot.	Relevant stakeholders must be communicated about their role and responsibility.
2.	Required conditions, facility, environment, and resources for the set-up of robot at site.	Conditions may include licenses issued from various government departments, isolated works area and power supply. Environment should include situation of adverse weather and critical site conditions. Resources here include legal employment of qualified / authorized personnel and authorized vehicles.
3.	A robot set-up methodology should include the followings: - Description of the set-up and mounting methods at different situations in details. - Risk assessment and precaution measures should be included.	If the set-up methodology is required to be examined by AP, the robot operator has to assist the AP for processing the examination. The robot operator should conduct a pre-work risk assessment prior to the set-up and mounting of the certified construction robot at site. Where possible, the methodology should be illustrated or accompanied with self-explanatory sketches, diagrams, or drawings.
4.	The person / party who approves / endorses the structural safety of the set-up / mounting for robot using at site.	If the set-up is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer), or Site-in-charge, approval / endorsement results has to be obtained prior to the use of the robot, documented and retained.
5.	Emergency Contacts should be included in the set-up manual.	The emergency contacts should be accessible 24 hours per day.

A. Operation Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot supplier and robot operator	Robot supplier has responsibility to update the robot operator of any issue related to the operation of robot without delay. The Certified Robot Supplier should delegate the company representative to carry out a random inspection on the Product Quality and Operational Safety in relation to the Certified Construction Robot at site on regular time-basis and/ or batch/ log-basis of product. A sampling plan to define sampling frequency and sampling rate should be incorporated in the Operation Manual Typical sampling rate should be at least 10% of accountable figures of outputs.
2.	Required conditions, facility, environment, and resources for the operation of robot at site	Conditions may include power supply, works area, access, use approval issued by relevant authority. Environment should include situation of adverse weather and critical site conditions. Resources here include trained and authorized robot operators.
3.	Operation of a robot should include the followings: - Intended uses of the robot and its controls - Function of the robot and each control mode - Scheduled safety and function checks of the robot (e.g. e-stop) - Warning of risk to personnel during robot operation - Instruction to prevent unauthorized use - Description of the operation of the robot in details. - Risk assessment and precaution measures should be included.	Where possible, the operation should be illustrated or accompanied with self-explanatory sketches or diagrams. The robot operator should conduct pre-work risk assessment before start of daily work at site, and prior to significant changes (e.g., re-location of construction robot work area) at site.

4.	The person / party who approves / endorses the operation of robot at site.	If operation is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer) or Site-in-charge, such approval or endorsement result has to be obtained prior to the fully operation of the robot, documented and retained.
5.	Emergency Control measures including emergency contacts should be specified in the operation manual.	Emergency Control measures should include all possible mobile control means for the construction robot from causing further adverse impact to personnel, environment, property, and assets. The emergency contacts should be accessible 24 hours per day.

B. Maintenance Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot supplier and robot operator.	Robot supplier has responsibility to update the robot operator of any issue related to the maintenance of robot without delay.
2.	Required conditions, facility, environment, and resources for the maintenance of robot at site.	Conditions may include power supply, access, maintenance area and spare parts needed. Facilities and tooling required for maintenance should be listed out in the maintenance manual. Environment should include situation of adverse weather and critical site conditions. Resources here include trained and authorized robot operators.
3.	Maintenance of a robot should include the followings: - Methodology for identifying or detecting defects - Type and frequency of maintenance of the robot - Information necessary for maintenance - Warning of risk to personnel and safety precaution measures to be taken before and during robot maintenance - Description of routine preventive maintenance of the robot in details. - Instruction for changing critical parts. - A sample template of preventive maintenance and corrective maintenance records - Risk assessment and precaution measures should be included.	Where possible, the maintenance procedures should be illustrated or accompanied with self-explanatory sketches or diagrams. Type of maintenance can be preventive maintenance, corrective maintenance, and predictive maintenance. Maintenance Schedule/ Plan should be established before 1st SV audit. Template of maintenance reports/ checklist should be ready before 1st SV audit.
4.	The person / party who approves / endorses the maintenance result for the robot at site	If maintenance result is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer) or Site-in-charge, such approval or endorsement result has to be obtained prior to resuming the robot to duty, documented and retained.
5.	Emergency Contacts should be included in the maintenance manual.	The emergency contacts should be accessible 24 hours per day.

C. Disassembly Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot operator and close stakeholders who are involved in the disassembly of the robot.	Relevant stakeholders must be communicated about their role and responsibility.
2.	Required conditions, facility, environment, and resources for the disassembly of robot at site	Conditions may include licenses issued from various government departments and power supply. Resources here include legal employment of qualified / authorized personnel and authorized vehicles
3.	A robot disassembly methodology should include the followings: - Description of the disassembly or dis-mounting method of the robot at different situations in details, - Risk assessment and precaution measures should be included.	If the disassembly methodology is required to be examined by AP, the robot operator has to assist the AP for processing the examination. Where possible, the methodology should be illustrated or accompanied with self-explanatory sketches, diagrams, or drawings.
4.	The person / party who approves / endorses the disassembly methodology for the robot	If the disassembly of the robot is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer), or Site-in-charge, approval or endorsement result has to be obtained prior to the disassembly of the robot, documented and retained.
5.	Emergency Contacts should be included in the disassembly manual	The emergency contacts should be accessible 24 hours per day

Appendix 7 – Immunity and Emission test requirements and limits according to CR-1-08TS-02: 2021 and CR-1-08TS-03: 2021 technical specifications and made reference to IEC 61000-4-3 ; IEC 61000-4-4; IEC 61000-4-5 ; IEC 61000-4-8

Table Im1 – Immunity test requirement at Enclosure Port

Item no.	Type of Immunity Test	Limits
Im1.1	Electrostatic discharge	±1 kV (contact discharge) ±8 kV (air discharge)
Im1.2	Radiated, radio-frequency electromagnetic field	80 ~ 1000 MHz 10 Volt/m 80 % AM @ 1kHz
Im1.3	Radiated, radio-frequency electromagnetic field	1.4 ~ 6.0 GHz 3 Volt/m 80 % AM @ 1kHz
Im1.4	Power frequency magnetic field	50 Hz 30 A/m

Table Im 2 - Immunity test requirement at Telecommunications Port

Item no.	Type of Immunity Test	Limits
Im2.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im2.2	Electrical Fast Transient Immunity Test	±1 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im2.3	Surge Immunity Test line to earth	1.2/50 (8/20) T_r/ T_h ns ±1 kV (open circuit test voltage)

Table Im 3 - Immunity test requirement at Low voltage DC mains Port

Item no.	Type of Immunity Test	Limits
Im3.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im3.2	Electrical Fast Transient Immunity Test	±1 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im3.3	Surge Immunity Test line to earth line to line	1.2/50 (8/20) T_r/ T_h ns ±1 kV (open circuit test voltage) ±0.5 kV (open circuit test voltage)

Table Im 4 - Immunity test requirement at Low voltage AC mains Port

Item no.	Type of Immunity Test	Limits
Im4.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im4.2	Electrical Fast Transient Pulse Immunity Test	±2 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im4.3	Surge Immunity Test line to earth line to line	1.2/50 (8/20) T_r/ T_h ns ±2 kV (open circuit test voltage) ±1 kV (open circuit test voltage)
Im4.4	Voltage Dip	0 % residual voltage after 1 cycle
		40 % residual voltage after 10 cycles
		70 % residual voltage after 25 cycles
Im4.5	Voltage Terminated	0 % residual voltage after 1 cycle

Table Em1 - Emission requirement at Low voltage AC mains Port - Limit of Conducted Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em1	Low voltage AC Mains	0.15 MHz to 0.5 MHz	79 dB (μV) quasi-peak 66 dB (μV) average	
		0.5 MHz to 30 MHz	73 dB (μV) quasi-peak 60 dB (μV) average	

Table Em2 - Emission requirement at Telecommunications / Network Port – Voltage Disturbance Limit at Asymmetric / Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em2	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	97 ~ 87 dB (μV) quasi-peak 84 ~ 74 dB (μV) average	
		0.5 MHz to 30 MHz	87 dB (μV) quasi-peak 74 dB (μV) average	

Table Em3 - Emission requirement at Telecommunications / Network Port – Current Disturbance Limit at Asymmetric / Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em3	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	53 ~ 43 dB (μV) quasi-peak 40 ~ 30 dB (μV) average	
		0.5 MHz to 30 MHz	43 dB (μV) quasi-peak 30 dB (μV) average	

Table Em4 - Emission requirement at Telecommunications / Network Port – Current Limit of (Asymmetric) Transmission Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em4	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	53 ~ 43 dB (μV) quasi-peak 40 ~ 30 dB (μV) average	
		0.5 MHz to 30 MHz	43 dB (μV) quasi-peak 30 dB (μV) average	

Glossary

ORDINANCES, REGULATIONS and CODES OF PRACTICE in HKSAR

Cap 59 Factories & Industrial Undertakings Ordinance (F&IU)

Cap 59I F&IU (Construction Sites (Safety)) Regulations

Cap 59N F&IU (Spraying of Flammable Liquids) Regulations

Cap 59Q F&IU (Guarding and Operation of Machinery) Regulations

Cap 59T F&IU (Noise at Work) Regulations

Cap 59W F&IU (Electricity) Regulations

Cap 59AC F&IU (Suspended Working Platform) Regulations

Cap 59AI F&IU (Gas Welding and Flame Cutting) Regulations

Cap 400 Noise Control Ordinance and Regulations

Cap 509 Occupational Safety and Health Ordinance

Cap 406 Electricity Ordinance and Electricity (Wiring) Regulations

Cap 51 Gas Safety Ordinance

Cap 295 Dangerous Goods ordinance

Cap 311 Air Pollution Ordinance - Air Pollution Control (Volatile Organic Compounds) Regulation

Guidelines Notes on the Trials of autonomous vehicles

Code of Practice for the Electricity (Wiring) Regulations, Electrical and Mechanical Services Department

Code of Practice for the Structural Use of Steel, Building Department

Code of Practice for Safety and Health at Work for Gas Welding and Flame Cutting, Labour Department

Code of Practice for Safe Use and Operation of Suspended Working Platforms, Labour Department

Guidance Notes on Paint Spraying and Related Coating Processes, Labour Department

General Specification for Building Maintenance Works in Residential Buildings, BS Div., The Hong Kong Institute of Surveyors

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CIC Trade Test Centre's General Welder Trade Test pack

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CIC Trade Test Centre's Plasterer Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.)

Link: https://www.elegislation.gov.hk/

STANDARDS & REFERENCES

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ISO/ IEC 2382 : 2015 Information Technology – Vocabulary

ISO 2808 : 2019 Paints and varnishes – Determination of film thickness

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*ISO 10218-1 : 2011 Robots and robotic devices – Safety requirements for industrial robots –

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*ISO 10218-2 : 2011 Robots and robotic devices – Safety requirements for industrial robots –

Part 2: Robot systems and integration - Equivalent standards : (GB 11291.2-2013), (ANSI RIA R15.06)

(UL1740)

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ISO 13849-1 : 2015 Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design

ISO 14732: 2013 Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials

ISO 15614-1:2017 + corrigenda July 2017 and May 2018 Specification and qualification of welding procedures for metallic materials – Welding procedure test Equivalent standard : (BS EN ISO 15614-1:2017)

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ISO 18646-2:2019 Robotics — Performance criteria and related test methods for service robots — Part 2: Navigation

ISO 22915-1: 2016 Industrial trucks – Verification of stability – Part 1: General

*IEC 60204-1: 2016 Safety of machinery – electrical equipment of machines Part 1 : General requirements - Equivalent standards : (EN 60204-1:2018), (GB/T 5226.1- 2019), (UL 508A) (NFPA 79)

IEC 60529: 1989+AMD 1:1999 + AMD2: 2013 +five corrigenda from Jan 2003 to Jan. 2019 – Degrees of Protection provided by enclosures (International Protection (IP) Code)

IEC 60896-21:2004 Stationary lead-acid batteries

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IEC 61000-4-5:2017 Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test

IEC 61000-4-8:2009 Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test

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* EN 60204-1: 2018 Safety of machinery – electrical equipment of machines Part 1 : General requirements - Equivalent standards : (GB/T 5226.1- 2019) (UL 508A) (NFPA 79) (IEC 60204-1: 2016)

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BS EN 1015-12: 2016 Methods of test for mortar for masonry – Part 12 : Determination of adhesive strength of hardened rendering and plastering mortars on substrates. Equivalent standard : (ASTM C1860-20)

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BS EN IEC 61000-6-2:2019 Generic standards – Immunity standard for industrial environments

BS EN IEC 61000-6-4:2019 Generic standards – Emission standard for industrial environments

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CR-1-08TS-02: 2021 建筑机器人 电磁兼容 通用标准 抗扰度要求和限值 (Construction robot – Electromagnetic compatibility – Generic standards – Immunity requirements and limits)

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JIS A6909-2003 Coating materials for textured finishes of buildings

NFPA 79 -2012 Electrical standard for industrial machinery

UL 3100 Outline of Investigation for Automated Guides Vehicles

APPENDIX B – TECHNICAL REQUIREMENTS FOR CONSTRUCTION PLASTERING ROBOTS

The requirements for construction plastering robots in terms of safety, quality performance and functional requirements should be in accordance with Sections 1.1 – 1.3, as follows. Each Section has covered "inspection" and / or "testing" activities.

1. Safety Requirements (for both Mobile and Non-mobile Robots)

This Section specifies the requirements for assessing the safety performance of a construction plastering robot including the inherent design, protective measures, and information to be disclosed to users. It describes basic safety requirements associated with significant hazards incurred by construction plastering robots and the need for preventive measures. Table 1 below tabulates the test items and their respective safety requirements, references (relevant standards and applicable regulatory requirements), acceptable criteria and assessment methods. Non-fulfilment of any of the following Acceptance Criteria will be considered as a Nonconformity.

Item No.	Safety Requirements	References	Acceptance Criteria	Assessment Methods
1.1	**Power Transmission Guarding** Fixed or moveable guards should be installed to prevent exposure to hazards such as shafts, gears, drive belts, or linkages	ISO 10218-1 Clause 5.2.1 or equivalent standards	a. Protection guards must be available b. Location of guards should be appropriate c. Interlock of moveable guards should function properly d. Guard condition should be normal If the inspection results are 'Pass' for each of the above items, the Guard can give adequate protection	i) Document Review: robot's specifications and information, including technical data sheet, product catalogue, layout drawings, and other supplementary material to ensure that the protection guards are available, and their locations are appropriate ii) Visual inspection of availability of Protection Guards, and their condition and locations. (Note: The protection guards should be checked to re-confirm that they are installed in the correct locations and are functioning properly, in compliance with those shown in the documents.) iii) Check the Interlock function via demonstration during operation to ensure it functions properly
1.2	**Loss or Change of Power** Loss of, or unstable, power should not result in a hazard, and any unprotected safety hazards should be identified / disclosed on the application form	ISO 10218-1 Clause 5.2.2 or equivalent standards IEC 60204-1:2018 Clause 5.4 or equivalent standards	When the power is off or unstable, speed is seen to be reduced, or no further hazardous movement is observed	i) Document Review: schematic circuit diagrams, design logic of software, to identify whether a robot is equipped with a protection feature ii) Shut down the power intentionally, then a visual inspection of any reduction in speed, or no further hazardous movement seen.

1.3	**Safety on Stored Energy** A means should be provided for the controlled release of stored hazardous energy. A label should be affixed to identify the stored energy hazard	ISO 10218-1 Clause 5.2.5 or equivalent standards	A label should be affixed at the energised area to identify the stored energy hazard.	i) Document Review: technical data sheet, schematic circuit diagrams and product catalogue to identify whether the location of the affixed warning label is appropriate. ii) Visual inspection of the label affixed to indicate the energised area, and countercheck the position of the label
1.4	**Electromagnetic Compatibility (EMC)** The design of the plastering robot should meet electromagnetic compatibility requirements below and to ensure functional safety systems providing desired protection from possible interference and hazardous motion due to effects of electromagnetic interference (EMI), radio frequency interference (RFI) and electrostatic discharge (ESD). Two generic EMC requirements specifying the limits of interference for construction robots under different operation modes (working, battery charging and discharging) and different functions (movement, communication / networking, collaboration with human, sensory and identification / recognition) are: 1. Immunity requirements 2. Emission requirements	ISO 10218-1 Clause 5.2.6 or equivalent standards IEC 60204-1:2018 Clause 4.4.2 or equivalent standards BS EN IEC 61000-6-2:2019 Generic standards – Immunity standard for industrial environments BS EN IEC 61000-6-4:2019 Generic standards – Emission standard for industrial environments CR-1-08TS-02: 2021 Construction Robot – Electromagnetic compatibility – Generic standards – Immunity requirements and limits CR-1-08TS-03: 2021 Construction Robot – Electromagnetic compatibility – Generic standards – Emission requirements and limits	a. Acceptable if there is no occurrence of hazardous motion or situations such as frequent system restarts, unprogrammed and unexpected movement of the robot, and possible interference with functional-safety systems within the limits of interference*. b. Acceptable if the test results of Immunity test and Emission test of the plastering robot are within the limits of interference* with respect to the Immunity and Emission requirements. Remarks (*) - the limits of interference under Immunity test and Emission test at relevant ports are specified in Appendix 8.	Document Review: specific schematic circuit diagrams, configuration design, EMC test reports to assure the required limits of Immunity and Emission requirements are complied.
Actuating Controls				
1.5	Status of the actuating controls should be clearly indicated	ISO 10218-1 Clauses 5.3.2 – 5.3.4 or equivalent standards	Status of actuating controls (e.g. power on, fault detected, automatic mode) should be displayed	Document Review: Technical data sheet, schematic circuit diagrams and product catalogue to identify the availability of actuating controls and the location of relevant labels.

1.6	Actuating controls should be labelled to clearly indicate their function	ISO 10218-1 Clauses 5.3.2 – 5.3.4 or equivalent standards	The labels of actuating controls must be available, and the functions of each control clearly shown	Visual inspection of the label of each actuating control, and use the "Lamp Test method" to countercheck that the function of each control matches the corresponding label
1.7	**Safety-related Control System(SRCS) Performance** SRCS should comply with performance requirements. Performance requirements are stated by means of either": a. Performance Level (PL) and categories or b. Safety Integrity Levels (SIL) and hardware fault tolerance requirements Safety Performance requirements include: 1. A single fault in any of parts that does not lead to the loss of safety function; 2. A single fault should be detected at or before the next demand upon the safety function; 3. When a single fault occurs, the safety function is always performed, and a safe state should be maintained; 4. All foreseeable faults should be detected.	ISO 10218-1 Clauses 5.4.1 – 5.4.3 or equivalent standards	a. SRCS performance of the robot and any furnished equipment should be clearly stated in the information for use. Min. requirements of SRCS are: I. PL= d with structure category 3; or II. SIL = 2 and Hardware fault tolerance of 1 b. The data and criteria necessary to determine the SRCS performance should be included in the information for use.	Document Review: Robot's system specifications, schematic circuit diagrams and information related to the SRCS, to identify inclusion of SRCS performance of the robot and the data and criteria necessary to determine the conformity of SRCS performance.
Robot Stopping Functions				
1.8	**Emergency Stop (E-Stop)** Every robot should have a protective stop function and an independent emergency stop function Each control station should have a manually initiated emergency stop function The operator should be able to make a quick, unobstructed access to the E-Stop	ISO 10218-1 clauses 5.5.1 and 5.5.2 or equivalent standards IEC 60204-1 clauses 9.2.3.4, 10.7 and Annex E or equivalent standards	a. A protective stop and an independent E-Stop should be available in each robot. b. Each E-Stop can function properly in the test. c. All E-Stops must function manually and should be free and easy to reach.	i) Visual inspection on the location and functions of the emergency stop and protective stop. ii) Test each stop at least once to check whether the stop functions work properly. iii) Test the reset mechanism of the E-stop

1.9	**Protective Stop** Information for use should include description of the stop category of every protective stop in the circuit.	ISO 10218-1 clauses 5.5.1 and 5.5.3 or equivalent standards	a. Protective devices should comply with specified safe distances. b. Connections of the stop functions with external protective devices should be available. c. Information for use should include description of the protection stop circuit.	Document Review: Robot's system specifications, product catalogue, technical data sheet, supplier's inhouse or external test reports and operation manual to identify any description of its E-Stop function, and braking system and quoted stopping performance.
1.10	**Braking Functions** Every Mobile Robot should be equipped with brakes and a braking system. In case an obstacle, unbalancing motion or overspeed is detected, the braking system should function properly to slow down or where necessary, stop the robot for motion control and avoidance of hazard, and be capable of holding /restraining the robot	ISO 18646-1: 2016 Clause 6 or equivalent standards	a. Stopping performance of braking system and holding of stationary status can be demonstrated in three trials. b. The Mobile Robot can stop within the declared stopping distance and stopping time.	Demonstration of the stopping performance of the braking system and holding of stationary status in at least three trials.
Operation Mode				
1.11	**Selection of Operation Mode** Operational modes should be selectable with a mode selector which can be locked in each position. Each position of the selector should be clearly identifiable and should allow only one mode to be selected at any one time.	ISO 10218-1 Clauses 5.7.1 – 5.7.4 or equivalent standards	Acceptable if only one mode can be selected at any one time.	Visual inspection on the selector and test the selection of each working mode.
1.12	**Automatic Operation Mode** Safeguarding measures should be in place and functioning when the robot's task programme is executed in automatic mode. Automatic operation should be prevented if any stop condition is detected.	ISO 10218-1 Clauses 5.7.1 – 5.7.4 or equivalent standards	a. Acceptable if the safeguarding measures are functioning normally under the automatic mode, and the test result for each working mode is normal. b. Stop condition is detected when safeguarding measures function during automatic operation.	Test both the automatic mode and the manual mode. i) To set the robot to automatic mode and manually assign a possible stop condition to test whether the safeguarding measures are functioning, and the condition can be detected. ii) The manual mode of operation should be performed with all persons outside the safeguarded space. To check that clear instructions have been provided prior to selecting the automatic mode, any suspended safeguards should be returned to their full functionality. iii) Document Review: System specification, schematic circuit diagrams, design material and operation manual to confirm provision of an Automatic Operation Mode

Safety Protection Features for Collaborative Operation					
1.13	**Visual Indication** Robots designed for collaborative operation should be provided with a visual indicator when the collaborative operation is activated	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if there is an indication sign at a proper location.	i) ii)	Visual inspection on the indication sign. Document Review: Robot's system specifications, technical data sheet, product catalogue and other supplementary material to identify whether any indication sign is available and the appropriateness of its location.
1.14	**Safety-rated Monitored Stop** The robot should stop when a human is in the collaborative workspace.	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	The time measured for each stop in a trail should be consistent, with limits of variation not more than 10% of the mean.	i) ii) iii)	Test the safety related control system for collaborative operation by using an object with height similar to an adult to enter into the robot workplace and observe any stop signs. Repeat the test at least 5 times and measure the time required to reach a stop condition in each trail Document Review: Robot's system specifications, technical data sheet, product catalogue, supplier's inhouse test report and other supplementary material to identify whether a stop condition is available for collaborative work.
1.15	**Hand Guiding** Where provided, hand guiding equipment should be located close to the end-effector and should be equipped with an emergency stop and an enabling device.	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if the hand guiding is observed to be close to the end-effectors and is equipped with an emergency stop and an enabling device.	Visual inspection on the availability and location of the hand guiding equipment	
1.16	**Speed and Separation Distance Monitoring** The robot should be able to maintain a determined speed and separation distance. Information for use should contain directions for implementing speed values and separation distances	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if the results of tests of safety speed and separation distance are within the range of the supplier's specification.	i) ii)	Test by setting the safety speed and separation distance as per the supplier's information and observe whether the outcomes are within the supplier's specification. Document Review: System specifications, technical data sheet, product catalogue, supplier's inhouse test report and other supplementary material to identify whether the robot is equipped with features to monitor the speed and separation distance.

1.17	**Movement without Drive Power** The robot should be designed so that the axes are capable of being moved without the use of drive power in an emergency or abnormal situation. Controls should be readily accessible but protected from unintended operation. Where practicable, warning notices should be posted near the activating controls.	ISO 10218-1 Clause 5.13 or equivalent standards	a. Acceptable if the axes of the robot can be moved freely by a single person without the use of drive power. b. Information for use should include a warning about a possible hazard created if the braking devices are released. Warning notices, when needed, should be posted near the controls. c. Controls must be protected from unintended operation.	i) Visual inspection of any movement of the robot if there is no drive power. ii) Visual inspection of the hazard warning notice iii) Visual inspection that the controls are protected.
1.18	**Electrical Protection** The robot should be designed and equipped with the following safety features: a. Isolation and Switching b. Overcurrent Protection c. Earth Leakage and Earth Fault Currents Protection d. Overloaded Protection e. Over-heat Protection f. Overspeed Protection	IEC 60204-1:2018 or equivalent standards and Relevant parts of Code of Practice for the Electricity (Wiring) Regulations, EMSD, HKSARG	Acceptable if there is a proof to show that all protection measures have been taken to comply with IEC 60204-1:2018 or, BS EN 60204-1:2018 or other equivalent International Standards; and the Code of Practice for the Electricity (Wiring) Regulations, EMSD, HKSARG.	Document Review: Robot's system specifications, electrical circuit diagram /drawings, technical data sheet, product catalogue, external party's test reports, Product Safety Mark, and other supplementary material to identify whether the protection features have been equipped and tested.
1.19	**Batteries Protection** (applicable for Mobile Robots) **(applicable for Lead acid batteries using in Mobile Robot):** Overheat Protection Access for gas escape during charging **(applicable for Lithium based batteries using in Mobile Robot):** Overheat Protection Overcharging / Imbalanced charging Short circuit Protection Mechanical Shock Protection Withstand Vibration	IEC 60896-21 (for Lead Acid batteries) IEC 62619: 2017 sections 7 and 8 (for lithium based batteries) UL 3100 clauses 7.2, 22.2, 22.5, 33 and 36 ANSI/RIA R15.08-1-2020 clause 5.1.16.5 or equivalent standards	a. Acceptable if the batteries had been certified by a nationally or international-wide recognized testing laboratory in compliance with IEC 60896-21 or IEC 62619 : 2017 to show all protection features of batteries have been tested. b. No abnormal temperature rise is detected when touching the surface of a fully charged battery by hand.	i) Document Review: robot's batteries specifications, technical data sheet, product catalogue, test report and certificate of batteries issued by a national or international test laboratory to identify whether corresponding protection features have been equipped and tested. ii) Fully charge the battery and check the surface temperature of the battery by hand first. If the battery temperature feels abnormal, use a calibrated thermo-gun to detect the battery temperature.
1.20	**Stability** The robot in a whole should remain stable in all operating conditions and during all loading-handling	ISO 3691-4: 2020 ISO 22915-1 : 2016 or equivalent standards	The mobile is considered STABLE if it passes all the stability tests without tip-over.	i) The robot in a whole should be tested in the worst-case conditions, e.g. loaded, unloaded, loading height, max. slope gradient, bi-direction (fore & aft), emergency braking deceleration, controlled acceleration / deceleration.

	and travelling movements, including an emergency stop. There are four key stability parameters (steering speed, traction speed, load handling, and uplifting of centre of gravity in the course of plastering work) A tilting platform stability test should be carried out to ensure the stability of the robot is acceptable.			ii) The test should be performed with at least 110% of claimed capacity and either: a. At least 110% of predetermined speed at rated load; or b. At maximum reachable speed, in case 110% of predetermined speed cannot be reached. iii) Document Review: Technical data sheet, product catalogue, supplier's inhouse test report to identify the rated load and max. speed.
1.21	**IP Rating** Since the robot is intended to be used at construction sites, the robot in a whole should be protected from dust ingress and from water spray under IP rating from IP 55 to IP 68.	IEC 60529 : 2013 + AMD1: 1999 + AMD2: 2013 + corrigenda (2003-2019) or equivalent standards	a. The sealing of entire plastering robot should be effective. b. IP 55 to IP 68 (any rating)	Document Review: Technical data sheet, product catalogue, supplier's external test report showing IP rating achieved.

Table 1 – Safety Requirements

2. Quality Performance Requirements

This Section specifies the requirements for assessing the quality performance of a construction plastering robot. Its quality performance is assessed through an on-site plastering test as shown in a mock test paper in Appendix 1. Assessment methods include visual inspection, hammer tapping test, adhesion strength test and compressive strength test. Regarding quality performance, the construction plastering robot should demonstrate a stable performance in path repeatability and high accuracy in positioning and orientation during plastering process. A proof for claimed path accuracy and path repeatability of the construction plastering robot with 30 cycles at 100% rated load should be presented to the audit team during document assessment as pre-qualification for quality performance test.

The Testing objectives are:

- ❖ to test the construction plastering robot's ability to meet the requirements for general plastering tasks in the construction industry, and
- ❖ to test the construction plastering robot's path repeatability, stability, and productivity in the set up for producing different wall finishes.

The construction plastering robot should complete and pass the "Plastering Test" (Section 2.1) and the test consists of three test items of no. 2.1.1 to 2.1.3, where a mark-deduction mechanism is adopted. Test items 2.1.1 and 2.1.2 carry different weighting of marks while test item 2.1.3 is used for deduction of marks due to incomplete work. Details of the mark-deduction mechanism are described in Appendix 1. Full mark of the test is 100 and the overall passing mark is 60. Testing results will be stated on the evaluation report.

In the "Plastering Test", the construction plastering robot is required to demonstrate the capability to produce different type of finishes on a composite concrete wall (substrate). The wall structures built for the test are made of 30/20 concrete, and the wall surfaces should be sound, even, clean, and free of loose particles, grease, and unwanted contaminants. The preparation work such as cleaning and moistening of wall surface and mixing of cement with water and sand will be carried out by the testing laboratory. The robot operator is required to operate the construction plastering robot to perform all the test items, to cover the non-testable area like the door frame and the floor with adhesive tape or polystyrene sheet and to do sand rendering. In addition, the robot operator has to tidy-up the testing venue after test. The maximum height that the construction plastering robot can reach is up-to the ceiling height. The composite wall must be kept in an orientation identified in the drawing P1 throughout the test. Drying time of typical 30 - 60 minutes should be allowed for each layer of coat in accordance with manufacturer's recommendations.

The plaster used is either a pre-mixed mortar for plastering or is mixed in a typical ratio of 1:4:1 (cement: fine sand: water) by volume. Water for plastering work should be clean fresh water taken from the public supply. Minimum amount of water should be applied to avoid an increasing risk in drying shrinkage of plaster. Sand for mixes for plasterwork should be clean, hard, and durable. The cement used should conform to BS EN 197-1:2011 or latest version for Portland Cement CEM I or equivalent. It is recommended to use CEM I cement with strength class 32.5N, 42.5N or 52.5N or equivalent.

Test item 2.1.1 Dimension control

The composite wall has three major types of wall surface at positions A, B and C. Each wall surface will be plastered with different finishes of different thickness of coating. The plastering robot should complete the plastering test with one single coat of finished thickness of 10 mm with tolerance 1 mm at wall surface A and with two layers of coat at wall surfaces B and C, where render used should have finished thickness exceeding 10mm but not more than 20 mm and should be applied in two layers of equal thickness. The dimension control test can help identify the stability of the construction plastering robot over repeated path.

The construction plastering robot should produce two kinds of finish "Grind finish and Glossy surface" at different wall surfaces as shown on the mock test paper.

Dimension of each wall surface as shown in Appendix 1 indicates the outer sizes of final plastered composite wall. Tolerance of each main dimension with finished plaster is stated in Table 2 in the following page. Marks will be deducted if the tolerance limit is exceeded.

Test item 2.1.2 Accuracy and Quality control

To validate the quality performance of a plastering robot, a visual inspection on the appearance of final finish should be performed by a suitably qualified person. Such a person should be the Hong Kong Laboratory Accreditation Scheme (HOKLAS) qualified plastering inspector, or a skilled plasterer certified by the Trade Test Centre of CIC plus five years plastering inspection experience.

Acceptance criteria under this test item are listed in Table 2 and a defect will be identified if there is a violation of any of acceptance criteria. Marks will be deducted in proportion to the quantity of defects identified. Parts of the accuracy and quality control test for two layers of coating can help identify the repeatability and stability of the plastering robot over repeated path.

However, if the overall result is less than the passing mark, the plastering test will be considered as Fail and a Nonconformity will be raised.

If there is any hollow area found during the Hammer Tapping Test, or the test result of Adhesion Strength Test or the Compressive Strength Test cannot meet the minimum strength requirement, the plastering test will be considered as Fail and a Nonconformity will be raised.

Test item 2.1.3 Completion

This test item is to identify how fast the plastering robot has worked. 40 marks will be deducted from the total score if less than 80% of total area has been completed. The completed area should include the full height of each wall surface. During the test, a performance measurement will be conducted by the testing laboratory to measure the productivity of the construction plastering robot. It will not induce any impact to the testing result. The methodology is to record the time spent in the plastering work on Wall A and Wall B in the drawing P1 in Appendix 1. The testing laboratory should follow the general conditions of facility set-up and test environment for plastering test as described in Appendix 3 and 4 standardising the test results.

Item No.	Quality Performance Requirements	References	Acceptance Criteria	Assessment Methods
Section 2.1 Plastering Test				
2.1.1	**Dimension control**	CIC Trade Test Centre's Plasterer Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.)	a. Refer to drawing P1 in Appendix 1 (Dim. Code 1.1-1.4), the tolerance of each main dimension with finished plaster is ≤3 mm (for any one end) Note: • Marks are deducted in proportion to the difference in length between the finish and the one in the drawing P1 per each dimension	By measurement
2.1.2	**Accuracy and Quality control of following finish:** **1. Grind finish** **2. Glossy surface**	CIC Trade Test Centre's Plasterer Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.) GS for Building Maintenance Works in Residential Buildings (Dec 2009 ed.) Hong Kong Housing Authority Specification Library (Feb. 2019 ed.) Hammer tapping test (industrial normal practice) Adhesion strength test / Pull-out test / Pull -off test - BS EN 1015-12: 2016; ASTM C1860-20 or equivalent standards Compressive strength test – BS EN 1015-11:2019 or equivalent standards	<u>Grind finish (also named as Float Finish)</u> a. The tolerance of the verticality of grind finish at the corner of the wall is <3mm b. The tolerance of the evenness / straightness of grind finish on the wall is <3mm* c. Incomplete grind finish at more than two corners of the wall is not allowed d. Poor grind finishes with vertical texture is not allowed e. Any hidden hollow area is not permitted f. Adhesion strength (28 days) – min. 0.5 N / mm^2 (for individual) and min. 0.7 N/mm^2 (for average) g. Compressive strength (28 days) – min. 6 N / mm^2 <u>Glossy surface (also named as C/S rendering)</u> h. The tolerance of the verticality of glossy surface at the corner of the wall is <3mm i. The tolerance of the evenness / straightness of glossy surface on the wall is <3mm j. Poor unsharpened glossy surface is not allowed k. Incomplete glossy surface at the skirting is not allowed l. Incomplete glossy surface at more than two corners of the walls is not allowed m. Poor smoothness of glossy surface with trachoma is not allowed n. Any hidden hollow areas are not permitted o. Adhesion strength (28 days) – min. 0.5 N / mm^2 (for individual) and min. 0.7 N/mm^2 (for average) p. Compressive strength (28 days) – min. 6 N / mm^2 Note: • A defect is identified if there is a violation of any of the above acceptance criteria (a-d and h-m) • Marks are deducted in proportion to the quantity of defects identified • The tolerance of evenness / straightness is measured in any direction with 1.2 m straight edge	Direct measurement for criteria 'a -b' and 'h – i " Visual check for criteria 'c –d' and 'j – m' Hammer tapping Test for criterion "e" and "n" Adhesion strength test for criterion "f" and "o" Compressive strength test for criterion "g" and "p"
2.1.3	**Completion (%)**	Nil	Please refer to drawing P1 in Appendix 1. Note: • If less than 80% of total area has been completed within 6 hours, 40 marks will be deducted from the total score.	By measurement

<u>Table 2 – Quality Performance Requirements for Plastering Test</u>

3. Functional Requirements (for Mobile Robots only)

This Section specifies the requirements for assessing the functional performance of a mobile robot which forms part of a construction plastering robot. Non-fulfilment of any of the following acceptance criteria will be considered as a Nonconformity.

Item No.	Functional Requirements	References	Acceptance Criteria	Assessment Methods
3.1	**Passing Over Sill**	Testing Facility and Testing Method of Rated Speed as per ISO 18646-1: 2016 Clauses 9.2 and 9.3 respectively, or equivalent standards	The Mobile Robot can pass over its specified maximum sill height (m) in at least three trials.	a. Document Review: robot's system specifications, product catalogue, technical data sheet, and supplier's inhouse or external test reports; and other supplementary material to identify any information about the maximum sill height. b. Demonstration of how the Mobile Robot passes over the specified maximum sill height in at least three trials.
3.2	**Navigation**	GB/T 38124-2019 clause 5.2 ISO 18646-2: 2019 clause 4, 5 and Annex A and ANSI/RIA R15.08-1-2020 clause 5.1.7 or equivalent standards Safety speed figure is based on MHEDA's recommendation. (MHEDA for Material Handling Equipment Distributors Association)	The Mobile Robot can follow the pre-set direction and reach the designated point with maximum allowable safety speed of 5 mph or 2.235 m/s in at least three trials	i) Document Review: robot's system specifications, product catalogue, technical data sheet, self-description letter, suppliers' inhouse or external test report, and other supplementary material to identify any information describing how the robot be navigated and ii) Demonstrate how the robot can be navigated to a designated point in at least three trials.
3.3	**Obstacle Detection and Obstacle Avoidance Functions**	GB/T 38124-2019 clause 5.2.3 UL 3100 clause 14 Obstacle Detection Test as per ISO 18646-2: 2019 clause 6 Obstacle Avoidance Test as per ISO 18646-2: 2019 clause 7 and ANSI/RIA R15.08-1-2020 clause 7.4.4 or equivalent standards	a. The Mobile Robot can pass the static obstacle detection test with different shape, dimension and colour of objects in at least three trials. b. The Mobile Robot can pass a moving obstacle avoidance test in at least three trials.	i) Document Review: robot's system specifications, technical data sheet, product catalogue, self-description letter, supplier's inhouse or external test report, and other supplementary material to identify if the robot is equipped with any devices to detect and avoid obstacles. ii) Demonstrate how the robot detects static obstacles such as physical objects of different shape, dimension and colour, uneven floor sections, holes within a detection range in at least three trials; and iii) Demonstrate how to avoid collision with a moving object or falling into a hole in at least three trials.

Table 3 – Functional Requirements

4. Marking and labelling

Plastering robot should be clearly marked with, but not limited to, the following information:

- Brand name of the robot
- Type, model, series, unique serial number / identity number of the robot
- Date or batch code of production/ integration of the robot
- Name and address of robot manufacturer
- Name and address of integrator (if applicable)
- Details of the certified robot supplier (name, address, phone contact, website, etc.)
- Any other information for use of robot recommended by the robot manufacturer/ integrator

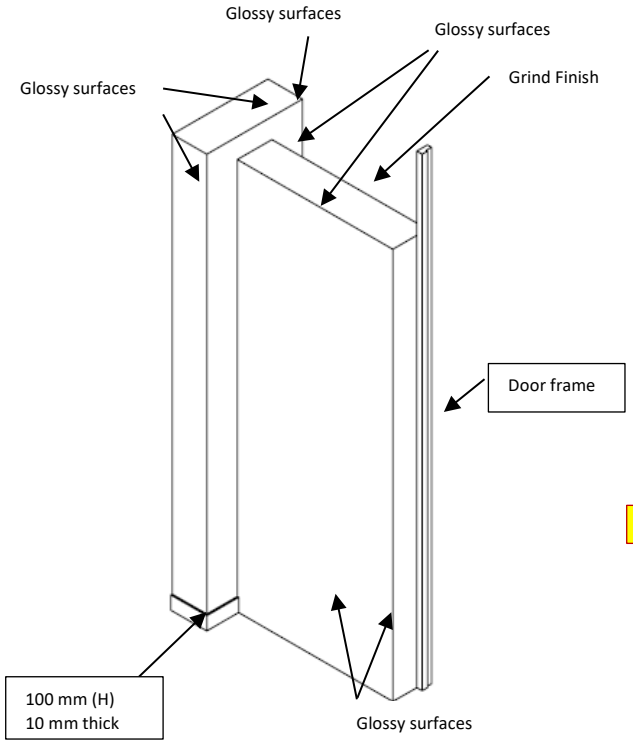
Appendices

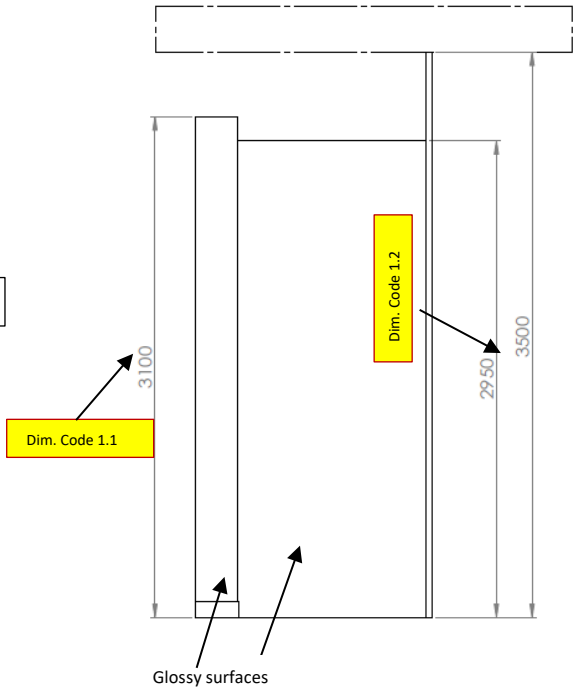
Appendix 1 – Mock Test Paper and Mark-deduction mechanism

Plastering Test – Composite Concrete Wall

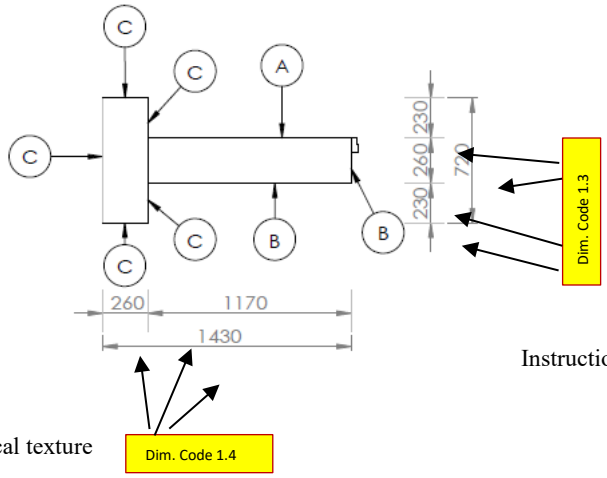
Drawing P1 Work Drawing for Plastering Test

Dimension in mm





A	Grind Finish
B	Glossy surfaces
C	Glossy surfaces & 100 mm (H) 10 mm thick skirting



Note:

1. The preparation work of wall surface is to be done by others.
2. The wall surface shall be even, clean, and free from loose particles, grease, and unwanted contaminants

Instruction:

Instruction:

1. Complete the position “A” with grind finishes with vertical texture
2. Complete the position “B” with glossy rendering coat
3. Complete the position “C” with glossy rendering coat, including formation of skirting of size 10mm thick x 100mm high.

Duration: 6 hours (Including set up time)

This mark-deduction mechanism describes how many marks to be assigned for test items (2.1.1 to 2.1.3) and maximum mark will be deducted for each defect item against corresponding acceptance criteria. Test items 2.1.1 and 2.1.2 carry 28 marks and 72 marks respectively while test item 2.1.3 will deduct 40 marks if the finished area is measured less than 80% of overall total area.

Full mark of the test is 100 and the overall passing mark is 60. Marks are progressively deducted according to the number of defects identified against each acceptance criteria in test items 2.1.1 and 2.1.2. The mark carried by each defect item is different. More defects are identified more marks will be deducted.

Following table (Table 5) tabulates the maximum marks to be deducted and it is for reference only.

Test Items	Wall Surface Position	Dimension of Wall Surface (L x H) mm	Type of Finish	Dim. Code	Max. marks to be deducted against each dim code in drawing P1
2.1.1 (Dimension control) (tolerance of each main dimension: ≤ 2 mm (for any one end); (tolerance of thickness at wall surface A = 1mm)	A	(1170 x 2950)	Grind Finish	1.4	8
	B	(260 x 2950) + (260 x 1170) +	Glossy surfaces	1.2	4
		(1170 x 2950)		1.4	4
	C	(720 x 3100) +	Glossy surfaces and 100mm (H) 10 mm thick skirting	1.1	4
		(260 x 3100) x 2 + (260 x 150) +		1.4	4
		(230 x 3100) x 2		1.3	4
Test Items	**Wall Surface Position**	**Defect item no.** (For details, refer to Table 4)	**Defects** (For details, refer to Table 4)	**Max. defects allowed**	**Max. marks to be deducted against each defective item**
2.1.2 (Accuracy and Quality Control)	A, B, C	2.1.2 a	Grind finish not vertical at wall corner	3	12
		2.1.2 b	Grind finish not straight / even on the wall	3	12
		2.1.2 c	Incomplete grind finish at the corner of wall	2	4
		2.1.2 d	Poor grind finish	1	4
		2.1.2 e	Hidden hollow area in grind finish	not permitted	N/A
		2.1.2 f	Less than min. Adhesion Strength in grind finish	not permitted	N/A
		2.1.2 g	Less than min. Compressive Strength in grind finish	not permitted	N/A
		2.1.2 h	Glossy surface not vertical at wall corner	3	12
		2.1.2 i	Glossy surface not straight / even on the wall	3	12
		2.1.2 j	Poor glossy surface	1	4
		2.1.2 k	Incomplete glossy surface at the skirting	1	4
		2.1.2 l	Incomplete glossy surface at the corner of wall	2	4

		2.1.2 m	Poor smoothness of glossy surface with trachoma	2	4
		2.1.2 n	Hidden hollow area in glossy surface	not permitted	N/A
		2.1.2 o	Less than min. Adhesion Strength in glossy surface	not permitted	N/A
		2.1.2 p	Less than min. Compressive Strength in glossy surface	not permitted	N/A
Test Items	Wall Surface Position	Total area of Wall Surface (m2)	Definition of Completion (%)	Overall Completion % within 6 hours	Mark to be deducted if minimum completion (%) is not reached
2.1.3 (Completion %)	A	3.452 m2	*Completed areas / Total area (Note: Completion areas include full height of each plastered wall surface completed by the plastering robot)	min. 80% of overall total area	40
	B	4.523 m2			
	C	5.309 m2			

Table 5 – Mark-deduction mechanism

Appendix 2 – Inspection and Testing Procedure of Render / Plaster and acceptance criteria

(Source: BS EN 1015-12: 2016 ; ASTM C1860-20)

Inspection on plaster finish and assessment criteria:

Item	Assessment areas	Assessment Criteria
1.	Dimension Control on locations for dim. codes 1.1 to 1.4	Tolerance of each main dimension ≤ 2 mm (for any one end) Tolerance of thickness at wall surface A ≤1mm
2.	Quality control on Grind Finish and Glossy Surface at following locations: 1. The corner of the wall, 2. Wall surface, 3. Skirt, 4. Chamfer.	Tolerance of Evenness / Straightness or Verticality is measured in any direction with 1.2 m straight edge: < 3mm
3.	Completion (%)	Complete not less than 80% of total area within 6 hours including full height of each plastered wall surface completed by the plastering robot

Tests for Plaster Surfaces

Test Items	Test objective	Acceptance criteria	Test Method
Hammer Tapping Test	To identify any hidden hollow areas	No hollow areas are allowed	Tap all wall surfaces with a metal stick slightly after final coat is dry. Hollow areas can be identified by listening to the 'void' sound.
Adhesion strength Test / Pull-out Test / Pull-off Test	To test the adhesion strength of the plaster	1. Average tensile pull out strength of the five specimen ≥ 0.70 N/mm^2, and 2. Individual pull-out strength of each specimen ≥ 0.50 N/mm^2	Curing the plaster for 28 days Then conduct a pull-out test on the plaster by applying tensile force on the plaster surfaces on the 28th day. Taking 5 specimen randomly as test sample. Size of each test sample – 75 mm x 75 mm. Reference standard: EN 1015-12: 2016 – tensile adhesion strength subject to the design load rate and self-declared by manufacturer.
Compressive strength Test	To test the compressive strength of the plaster	1. Average compressive strength of the six half specimens ≥ 6 N/mm^2	Curing the plaster for 28 days Then take three specimens, each of which is 160 mm x 40mm x 40 mm and break each specimen into two halves to provide six half specimens for compressive strength test. Carry out the test as per EN 1015-11:2019 Reference standard:

			EN 1015-11: 2019 – Methods of test for mortar for masonry. The compressive strength subject to the max. load carried by the specimen and self-declared by manufacturer but typical compressive strength is min. 6 N/mm^2

Appendix 3 – Facility Set-up

Item	Facility Item	Criteria / Requirements for Plastering Processes	Remarks / Technical Reference.
1.	Workplace	The test laboratory should be operated under a Quality, Health and Safety System. Where appropriate, the test laboratory should provide suitable Personnel protection Equipment (PPE). The workplace should be fitted for testing and be equipped with adequate and stable supply of electrical power and adequate Illumination. The workplace should be ventilated with adequate supply of fresh air and proper discharge of contaminated air particles during plastering work. The test laboratory should be spacious to accommodate the concrete walls for practical test and equipped with sufficient works areas for the plastering robot to rotate to different directions. If a mechanical plaster mixer is required, relevant safety precaution measures should be taken. The workplace should be structurally fitted to prevent damage from any detrimental effects of weather or other issues which may affect the quality performance test and safety of personnel. The testing zone should be fenced off and slippage signage labels should be displayed. All power cables, electrical plugs and sockets used within the testing zone should be of water-proof type.	Layout plan with emergency escape route should be provided and displayed. The supply of electrical power sources should be stable and adequate. Single phase – 220V 50 Hz and Three phase – 380V 50 Hz Maximum allowable lighting power density (LPD) should be maintained at 13.5 W/m^2 as per Table 5.4 of EMSD's Building Energy Code (BEC) 2021. Appropriate mechanical ventilation measures and exhaust facilities should be equipped to provide fresh air for dilution of contaminants accumulated in the testing laboratory and to help removing the contaminants out from the workplace. Protection of motorized plaster mixer should comply with the latest edition of HKSAR Ordinances, corresponding Regulations and Code of Practice including the followings: 5. Cap 406, the Electricity (Wiring) Regulations and its Code of Practice, 6. Cap 59, the Factories and Industrial Undertakings Ordinance (FIUO) and its Regulations under FIUO 7. Cap 95, the Fire Services Ordinance and its Code of Practice
2.	Equipment, tools, and devices	All plastering handling tools and mixers should be available and are maintained in proper condition. All equipment and devices for testing and measurement should be maintained in good condition, in particular those pressurized equipment and facilities. Valid calibration status of measurement and testing devices used must be maintained when the test is performed. .	Different mixers are available for plasters doing different tasks, i.e. plaster for glossy surfaces do not mix with the one for grind finish. Special safety precaution to avoid spillage of cement and other hazard should be taken if pressurized hose and cement pump are used. Measurement device such as steel rule, level gauge and measurement tape should be calibrated and the calibration certificate is available, and the calibration status remains valid when the test is performed.

			Preferably the certificate was issued by a HKAS or its MRA accredited test laboratory.
3.	Plastering Processes	During plastering, vibration, noise, dust and cement paste could be generated or emitted to affect the operator's health and the cement paste may cause slipping risk.	Ventilation / Extraction Fans should be installed to improve the air quality inside the test laboratory. The wet testing zone should be fenced off. Slipping signage label should be displayed. Anti-slip safety shoes to be wear by the operator.
4.	Storage and Handling of plastering material	Dry and clean condition should be maintained on the packaging of cement material.	Typical condition of the package bag should be dry and no dew found on the surface of package bag.
5.	Information on test report and drawings	Instruction for inspection and testing should be clearly documented	Nil
6.	Set-up for inspection and pull out test	Jigs, fixtures and temporary structure, if necessary, should be available and ready for use.	The jigs, fixtures and temporary structure should be rigid and convenient to use
7.	Inspection and documentation	Inspection and test reports should be documented and sent to the Audit Team for compilation of the Evaluation Report within one week after completion of the Adhesion Strength Test / Pull-out test.	N/A

Appendix 4 – Testing Environment

Item	Testing Environment Condition	Criteria / requirements	Remarks / Technical Reference
1.	Robot mounting	Mounting should be in accordance with the robot supplier's recommendations	With reference to robot supplier's specifications or other publicly available information
2.	Conditions prior to testing	The robot should be completed assembled and fully operational. All necessary levelling measurement, alignment procedures and functional test instructions must be available and followed.	Appropriate robot supplier's procedures, instruction and testing methods
		If cleaning of the base wall, and keeping the wall surface moist are needed, water spraying facilities should be available near to the test area.	The ventilated air flow should be taken into consideration. It can be too strong, otherwise, the wall surface may be easily dried.
		The concrete walls prepared for testing should be kept moisten before test.	Keep monitoring the RH (%) of the test area.
		If cables are used for lifting the plastering robots, the cable and its hoisting system must be examined by authorized person (AP) before use.	Under F&IU Cap 59, all hoisting cables must be checked periodically, and a mandatory form is signed by AP.
3.	Operating conditions	The normal operating conditions should be stipulated by the robot supplier. Particular safety precautions to operation should be specified by the robot supplier prior to testing. For functional performance test, the Travel surface conditions for Indoor usage (source: ISO 18646-2: 2019 cl. 4.3): 1. Type of surface required – Hard, even and horizontal 2. Coefficient of friction of surface: 1 .0	Normal operation conditions include requirements for electrical, hydraulic and pneumatic power, power fluctuations and disturbances, maximum safe operating limits.
4.	Environmental conditions for normal operation	During functional performance test, typical Indoor Environmental conditions (source: ISO 18646-2 : 2019 cl. 4.2) should be maintained at: 1. Range of RH: 0% - 80% ; 2. Range of illumination:	Environmental conditions include temperature, relative humidity (RH), electromagnetic and electrostatic fields, radio frequency interference, atmospheric contaminants, and altitude limits should be declared in the test report (Ref. ISO 18646-

		100 lux – 1000 lux For outdoor application, the Outdoor Environmental conditions should be kept under normal outdoor usage or according to the robot supplier's specifications or recommendations	2 cl. 4.2 and Annex A cl A.3 and ISO 9946)
5.	Temperature of testing environment	During functional performance test, typical Indoor Environmental conditions (source: ISO 18646-2 : 2019 cl. 4.2): 3. Range of ambient temperature (Θ): 10°C - 30°C 4. The test temperature should be maintained at (Θ ± 2) °C For outdoor application, the Outdoor Environmental conditions (Ref: ISO 18646-2: 2019 Annex A) should be kept under normal outdoor usage or according to the robot supplier's specifications or recommendations	If situation is allowed, the robot and the measuring instruments should have been kept under the test environment long enough (preferably overnight) so that they are in a thermally stable condition before testing. They should be protected from draughts and external thermal radiation like sunlight, heaters.

Appendix 5 – Document Quality Control

Documents should be kept by Robot Operator	
1.	Business Registry or other legal documents as a proof of registry as a legal entity
2.	Safety-related Risk Assessment and Safety Precaution measures
3.	Manual / Procedure for Set-up including Mounting of Construction Robot and relevant Records
4.	Manual / Procedure for Disassembly of Construction Robot and relevant Records
5.	Manual / Procedure/ Handbook for Operation with Emergency Control measures
6.	Manual / Procedure/ Handbook and Schedule for Maintenance and relevant Records
7.	Authorization Documents / Records
8.	Key Production Procedures and Records
9.	Internal Quality Assurance Procedures and Quality Control Records
10.	Pre-work Risk Assessment Record (on-site)
11.	Product Quality and Safety Inspection Record (on-site)
12.	Product Catalogue (latest version)
13.	Technical Specification Data Sheet (latest version)
14.	Drawings / Electrical Circuit Diagram (where applicable)
15.	Test Reports (Internal / External)
16.	Test Certificates
17.	Training Records of Robot Operator, Robot Users and Company Representative
18.	Safety-related Incident or Accident Occurrence Reports and follow-up
19.	Quality performance related nonconforming issues
20.	Post-delivery Complaint received
21.	Warning Letter or Summit received regarding offence of local statutory or regulatory regulations, and violence of contractual requirements

Following document quality control activities, not limited to, should be followed:

4. Before each piece of documented information is created and updated, appropriate identification and description (e.g. title, date, author or reference number), and format (e.g. language, software version, graphics) and media (e.g. paper, electronic) have been established, reviewed and approval for suitability and adequacy.
5. The documents and records, not limited to the above table, should be adequately protected (e.g. from loss of confidentiality, improper use, or loss of integrity or unintended alternations) ; stored and preserved (e.g. software licences, permits to use, electronic / digital information).
6. The documents and records, not limited to the above table, when distributed, access, retrieval and use should be properly controlled (e.g. distributed to whom, grant of access right and right of use).
7. The documents and records, not limited to the above table, should be kept in a defined retention period, typically not less than 3 years.
8. Any changes, including version number, of the documents and records, not limited to the above table, should be clearly identified and traceable.

Appendix 6 – Audit Planning Matrix for a 3-year Cycle

Areas / Documents to be available for audit	Initial Audit	First SV	Second SV	Re-Audit
Business Registry or other legal documents as a proof of registry as a legal entity	✓			✓
Safety-related risk assessment and safety precaution measures	✓	✓	✓	✓
Set-up and Mounting Manual / Procedure to describe safety hazards, risk, and precaution measures to be taken during initial set-up and subsequent set-up in case of re-location at site.	✓	✓	✓	✓
Disassembly Manual / Procedure to describe safety hazards, risk, and precaution measures to be taken during disassembly and re-location at site.	✓	✓	✓	✓
Operation Manual	✓	✓	✓	✓
Maintenance Manual	✓	✓	✓	✓
Maintenance Schedule and Records		✓	✓	✓
Authorization Documents / Records	✓	✓	✓	✓
Key Production Procedures and Records	✓	✓	✓	✓
Internal Quality Assurance Procedures and Quality Control Records	✓	✓	✓	✓
Pre-work Risk Assessment Record (on-site)	✓	✓	✓	✓
Product Quality and Safety Inspection Record (on-site)	✓	✓	✓	✓
Product catalogue	✓			✓
Technical Specification Sheet (where applicable)	✓			✓
Drawings (where applicable)	✓			✓
Test Reports (Internal / external)	✓			✓
Test Certificates	✓			✓
Training Records of Robot Operator	✓	✓	✓	✓
Safety related incident or accident occurrence reports and follow-up		✓	✓	✓
Quality performance related nonconforming issues		✓	✓	✓
Post-delivery complaint received		✓	✓	✓
Warning letter or summit received regarding offence of local statutory or regulatory regulations, and violence of contractual requirements	✓	✓	✓	✓
Technical Aspects*	✓	✓	✓	✓

*Remark: Technical aspects, not limited to, battery protection, stability, distance monitoring, where applicable, are required to be covered in the audits, and each SV.

Appendix 7 – Key Contents of Set-up Manual, Operation Manual and Maintenance Manual

Set-up Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot operator and close stakeholders who are involved for the set-up of robot.	Relevant stakeholders must be communicated about their role and responsibility.
2.	Required conditions, facility, environment, and resources for the set-up of robot at site.	Conditions may include licenses issued from various government departments, isolated works area and power supply. Environment should include situation of adverse weather and critical site conditions. Resources here include legal employment of qualified / authorised personnel and authorised vehicles.
3.	A robot set-up methodology should include the followings: - Description of the set-up and mounting methods at different situations in details. - Risk assessment and precaution measures should be included.	If the set-up methodology is required to be examined by AP, the robot operator has to assist the AP for processing the examination. The robot operator should conduct a pre-work risk assessment prior to the set-up and mounting of the certified construction robot at site. Where possible, the methodology should be illustrated or accompanied with self-explanatory sketches, diagrams, or drawings.
4.	The person / party who approves / endorses the structural safety of the set-up / mounting for robot using at site.	If the set-up is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer), or Site-in-charge, approval / endorsement results has to be obtained prior to the use of the robot, documented and retained.
5.	Emergency Contacts should be included in the set-up manual.	The emergency contacts should be accessible 24 hours per day.

Operation Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot supplier and robot operator	Robot supplier has responsibility to update the robot operator of any issue related to the operation of robot without delay. The Certified Robot Supplier should delegate the company representative to carry out a random inspection on the Product Quality and Operational Safety in relation to the Certified Construction Robot at site on regular time-basis and/ or batch/ log-basis of product. A sampling plan to define the sampling frequency and sampling rate should be incorporated in the Operation Manual. Typical sampling rate should be at least 10% of accountable figures of outputs.
2.	Required conditions, facility, environment, and resources for the operation of robot at site	Conditions may include power supply, works area, access, use approval issued by relevant authority. Environment should include situation of adverse weather and critical site conditions. Resources here include trained and authorised robot operators.
3.	Operation of a robot should include the followings: - Intended uses of the robot and its controls - Function of the robot and each control mode - Scheduled safety and function checks of the robot (e.g. e-stop) - Warning of risk to personnel during robot operation - Instruction to prevent unauthorised use - Description of the operation of the robot in details. - Risk assessment and precaution measures should be included.	Where possible, the operation should be illustrated or accompanied with self-explanatory sketches or diagrams. The robot operator should conduct pre-work risk assessment before start of daily work at site, and prior to significant changes (e.g., re-location of construction robot work area) at site.

4.	The person / party who approves / endorses the operation of robot at site.	If operation is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer) or Site-in-charge, such approval or endorsement result has to be obtained prior to the fully operation of the robot, documented and retained.
5.	Emergency Control measures including emergency contacts should be specified in the operation manual.	Emergency Control measures should include all possible mobile control means for the construction robot from causing further adverse impact to personnel, environment, property, and assets. The emergency contacts should be accessible 24 hours per day.

Maintenance Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot supplier and robot operator.	Robot supplier has responsibility to update the robot operator of any issue related to the maintenance of robot without delay.
2.	Required conditions, facility, environment, and resources for the maintenance of robot at site.	Conditions may include power supply, access, maintenance area and spare parts needed. Facilities and tooling required for maintenance should be listed out in the maintenance manual. Environment should include situation of adverse weather and critical site conditions. Resources here include trained and authorised robot operators.
3.	Maintenance of a robot should include the followings: - Methodology for identifying or detecting defects - Type and frequency of maintenance of the robot - Information necessary for maintenance - Warning of risk to personnel and safety precaution measures to be taken before and during robot maintenance - Description of routine preventive maintenance of the robot in details. - Instruction for changing critical parts. - A sample template of preventive maintenance and corrective maintenance records - Risk assessment and precaution measures should be included.	Where possible, the maintenance procedures should be illustrated or accompanied with self-explanatory sketches or diagrams. Type of maintenance can be preventive maintenance, corrective maintenance, and predictive maintenance.
4.	The person / party who approves / endorses the maintenance result for the robot at site	If maintenance result is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer) or Site-in-charge, such approval or endorsement result has to be obtained prior to resuming the robot to duty, documented and retained.
5.	Emergency Contacts should be included in the maintenance manual.	The emergency contacts should be accessible 24 hours per day.

Disassembly Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot operator and close stakeholders who are involved in the disassembly of the robot.	Relevant stakeholders must be communicated about their role and responsibility.
2.	Required conditions, facility, environment, and resources for the disassembly of robot at site	Conditions may include licenses issued from various government departments and power supply. Resources here include legal employment of qualified / authorised personnel and authorised vehicles
3.	A robot disassembly methodology should include the followings: - Description of the disassembly or dis-mounting method of the robot at different situations in details, - Risk assessment and precaution measures should be included.	If the disassembly methodology is required to be examined by AP, the robot operator has to assist the AP for processing the examination. Where possible, the methodology should be illustrated or accompanied with self-explanatory sketches, diagrams, or drawings.
4.	The person / party who approves / endorses the disassembly methodology for the robot	If the disassembly of the robot is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer), or Site-in-charge, approval or endorsement result has to be obtained prior to the disassembly of the robot, documented and retained.
5.	Emergency Contacts should be included in the disassembly manual	The emergency contacts should be accessible 24 hours per day

Appendix 8 – Immunity and Emission test requirements and limits according to CR-1-08TS-02: 2021 and CR-1-08TS-03: 2021 technical specifications and made reference to IEC 61000-4-3 ; IEC 61000-4-4; IEC 61000-4-5 ; IEC 61000-4-8

Table Im1 – Immunity test requirement at Enclosure Port

Item no.	Type of Immunity Test	Limits
Im1.1	Electrostatic discharge	±1 kV (contact discharge) ±8 kV (air discharge)
Im1.2	Radiated, radio-frequency electromagnetic field	80 ~ 1000 MHz 10 Volt/m 80 % AM @ 1kHz
Im1.3	Radiated, radio-frequency electromagnetic field	1.4 ~ 6.0 GHz 3 Volt/m 80 % AM @ 1kHz
Im1.4	Power frequency magnetic field	50 Hz 30 A/m

Table Im 2 - Immunity test requirement at Telecommunications Port

Item no.	Type of Immunity Test	Limits
Im2.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im2.2	Electrical Fast Transient Immunity Test	±1 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im2.3	Surge Immunity Test line to earth	1.2/50 (8/20) T_r/ T_h ns ±1 kV (open circuit test voltage)

Table Im 3 - Immunity test requirement at Low voltage DC mains Port

Item no.	Type of Immunity Test	Limits
Im3.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im3.2	Electrical Fast Transient Immunity Test	±1 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im3.3	Surge Immunity Test line to earth line to line	1.2/50 (8/20) T_r/ T_h ns ±1 kV (open circuit test voltage) ±0.5 kV (open circuit test voltage)

Table Im 4 - Immunity test requirement at Low voltage AC mains Port

Item no.	Type of Immunity Test	Limits
Im4.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz

Im4.2	Electrical Fast Transient Pulse Immunity Test	±2 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im4.3	Surge Immunity Test line to earth line to line	1.2/50 (8/20) T_r/ T_h ns ±2 kV (open circuit test voltage) ±1 kV (open circuit test voltage)
Im4.4	Voltage Dip	0 % residual voltage after 1 cycle
		40 % residual voltage after 10 cycles
		70 % residual voltage after 25 cycles
Im4.5	Voltage Terminated	0 % residual voltage after 1 cycle

Table Em1 - Emission requirement at Low voltage AC mains Port - Limit of Conducted Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em1	Low voltage AC Mains	0.15 MHz to 0.5 MHz	79 dB (μV) quasi-peak 66 dB (μV) average	
		0.5 MHz to 30 MHz	73 dB (μV) quasi-peak 60 dB (μV) average	

Table Em2 - Emission requirement at Telecommunications / Network Port – Voltage Disturbance Limit at Asymmetric / Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em2	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	97 ~ 87 dB (μV) quasi-peak 84 ~ 74 dB (μV) average	
		0.5 MHz to 30 MHz	87 dB (μV) quasi-peak 74 dB (μV) average	

Table Em3 - Emission requirement at Telecommunications / Network Port – Current Disturbance Limit at Asymmetric / Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em3	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	53 ~ 43 dB (μV) quasi-peak 40 ~ 30 dB (μV) average	
		0.5 MHz to 30 MHz	43 dB (μV) quasi-peak 30 dB (μV) average	

Table Em4 - Emission requirement at Telecommunications / Network Port – Current Limit of (Asymmetric) Transmission Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em4	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	53 ~ 43 dB (μV) quasi-peak 40 ~ 30 dB (μV) average	
		0.5 MHz to 30 MHz	43 dB (μV) quasi-peak 30 dB (μV) average	

Glossary

ORDINANCES, REGULATIONS and CODES OF PRACTICE in HKSAR

Cap 59 Factories & Industrial Undertakings Ordinance (F&IU)

Cap 59I F&IU (Construction Sites (safety)) Regulations

Cap 59N F&IU (Spraying of Flammable Liquids) Regulations

Cap 59Q F&IU (Guarding and Operation of Machinery) Regulations

Cap 59T F&IU (Noise at Work) Regulations

Cap 59W F&IU (Electricity) Regulations

Cap 59AI F&IU (Gas Welding and Flame Cutting) Regulations

Cap 400 Noise Control Ordinance and Regulations

Cap 509 Occupational Safety and Health Ordinance

Cap 406 Electricity Ordinance and Electricity (Wiring) Regulations

Cap 59AC F&IU (Suspended Working Platform) Regulations

Cap 51 Gas Safety Ordinance

Cap 295 Dangerous Goods ordinance

Cap 311 Air Pollution Ordinance - Air Pollution Control (Volatile Organic Compounds) Regulation

Guidelines Notes on the Trials of autonomous vehicles

Code of Practice for the Electricity (Wiring) Regulations, Electrical and Mechanical Services Department

Code of Practice for the Structural Use of Steel, Building Department

Code of Practice for Safety and Health at Work for Gas Welding and Flame Cutting, Labour Department

Code of Practice for Safe Use and Operation of Suspended Working Platforms, Labour Department

Guidance Notes on Paint Spraying and Related Coating Processes, Labour Department

General Specification for Building Maintenance Works in Residential Buildings, BS Div., The Hong Kong Institute of Surveyors

Hong Kong Housing Authority Specification Library (Feb. 2019 ed.)

CIC Trade Test Centre's General Welder Trade Test pack

CIC Trade Test Centre's Painting Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.)

CIC Trade Test Centre's Plasterer Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.)

Link: https://www.elegislation.gov.hk/

STANDARDS & REFERENCES

EC Directive 2006/42/EC on Machinery (17 May 2006)

ISO / IEC Standards:

ISO 1513: 2010 – Paints and varnishes – Examination and preparation of test samples

ISO/ IEC 2382 : 2015 Information Technology – Vocabulary

ISO 2808 : 2019 Paints and varnishes – Determination of film thickness

ISO 3691-4 : 2020 Industrial trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems

*ISO 8373: 2012 Robots and Robotic devices – Vocabulary

ISO 9283:1998 Manipulating industrial robots – Performance criteria and related test, Equivalent standards (GB/T12642 -2013)

ISO 9946: 1999 – Manipulating industrial robots – Presentation of characteristics

*ISO 10218-1 : 2011 Robots and robotic devices – Safety requirements for industrial robots –

Part 1: Robots - Equivalent standards: (GB 11291.1-2011) (ANSI RIA R15.06) (UL1740)

*ISO 10218-2 : 2011 Robots and robotic devices – Safety requirements for industrial robots –

Part 2: Robot systems and integration - Equivalent standards: (GB 11291.2-2013), (ANSI RIA R15.06)

(UL1740)

*ISO 12100: 2010 Safety of machinery – General principles for design- Risk assignment and risk reduction - Equivalent standards : (GB/T15706 -2010)

ISO 13849-1 : 2015 Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design

ISO 14732: 2013 Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials

ISO 15614-1:2017 + corrigenda July 2017 and May 2018 Specification and qualification of welding procedures for metallic materials – Welding procedure test Equivalent standard : (BS EN ISO 15614-1:2017)

ISO /IEC 17065: 2012 Conformity assessment – Requirements for bodies certifying products, processes and services

ISO 18646-1:2016 Robotics — Performance criteria and related test methods for service robots — Part 1: Locomotion for wheeled robots

ISO 18646-2:2019 Robotics — Performance criteria and related test methods for service robots — Part 2: Navigation

ISO 22915-1: 2016 Industrial trucks – Verification of stability – Part 1: General

*IEC 60204-1: 2016 Safety of machinery – electrical equipment of machines Part 1 : General requirements - Equivalent standards : (EN 60204-1:2018), (GB/T 5226.1- 2019), (UL 508A) (NFPA 79)

IEC 60529: 1989+AMD 1:1999 + AMD2: 2013 +five corrigenda from Jan 2003 to Jan. 2019 – Degrees of Protection provided by enclosures (International Protection (IP) Code)

IEC 60896-21:2004 Stationary lead-acid batteries

IEC 61000-4-3:2020 Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency electromagnetic field immunity test

IEC 61000-4-4:2012 Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/ burst immunity test

IEC 61000-4-5:2017 Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test

IEC 61000-4-8:2009 Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test

IEC 62619:2017 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications

EN / BS EN / BS Standards:

* EN 60204-1: 2018 Safety of machinery – electrical equipment of machines Part 1 : General requirements - Equivalent standards : (GB/T 5226.1- 2019) (UL 508A) (NFPA 79) (IEC 60204-1: 2016)

BS EN 197-1: 2011 Composition, specifications, and conformity criteria for common cements

BS EN 1011-1: 2009 Welding – Recommendations for welding of metallic materials Part 1: General guidance for arc welding

BS EN 1015-11: 2019 Methods of test for mortar for masonry. Part 11 : Determination of flexural and compressive strength of hardened mortar.

BS EN 1015-12: 2016 Methods of test for mortar for masonry – Part 12 : Determination of adhesive strength of hardened rendering and plastering mortars on substrates. Equivalent standard : (ASTM C1860-20)

BS EN 16985: 2018 Spray booths for organic coating material – Safety requirements

BS EN 60529:1992 + A2:2013 Degrees of protection provided by enclosures (IP Code)

BS 6150: 2019 Painting of buildings – Code of Practice

GB Standards and relevant Specifications and Regulations:

*GB 11291.1-2011 工业环境用机器人 安全要求 第 1 部分：机器人 (Robots for industrial environments-Safety requirements- Part 1: Robot). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

*GB 11291.2-2013 机器人与机器人装备 工业机器人的安全要求 第 2 部分：机器人系统与集成 (Robots and robotic devices. Safety requirements for industrial robots. Part 2: Robot systems and integration). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

GB 15579.1-2013 弧焊设备 第 1 部分焊接电源 (Arc welding equipment-part 1: Welding power sources). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

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GB 50300-2001 建筑工程施工质量验收统一标准(含条文说明) (Unified standard for constructional quality acceptance of building engineering). 中华人民共和国国家质量监督检验检疫总局、中华人民共和国住房和城乡建设部.

*GB/T 5226.1-2019 机械电气安全机械电气设备 第 1 部分通用技术条件 (Electrical safety of machinery—Electrical equipment of machines—Part 1: General requirements). 国家市场监督管理总局、中国国家标准化管理委员会.

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GB/T 34136-2017 机械电气安全 GB 28526 和 GB/T 16855.1 用于机械安全相关控制系统设计的应用指南 (Electrical safety of machinery—Guidance on the application of GB 28526 and GB/T 16855.1 in the design of safety-related control systems for machinery). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

GB/T 35080-2018 机械安全 B 类标准和 C 类标准与 GB/T 15706 的关系 (Safety of machinery—Relationship of type-B and type-C standards to GB/T 15706). 国家市场监督管理总局、中国国家标准化管理委员会.

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NFPA 79 -2012 Electrical standard for industrial machinery

UL 3100 Outline of Investigation for Automated Guides Vehicles

APPENDIX C – TECHNICAL REQUIREMENTS FOR CONSTRUCTION WELDING ROBOTS

The requirements for construction welding robots in terms of safety, quality performance and functional requirements should be in accordance with sections as follows. Each Section has covered "inspection" and / or "testing" activities.

1. Safety Requirements (for both Mobile and Non-mobile Robots)

This Section specifies the requirements for assessing the safety performance of a construction welding robot, including the inherent design, protective measures, and information to be disclosed to users. It describes basic safety requirements associated with significant hazards incurred by construction welding robots and the need for preventive measures. Table 1 below tabulates the test items and their respective safety requirements, references (relevant standards and applicable regulatory requirements), acceptable criteria and assessment methods. Non-fulfilment of any of the following Acceptance Criteria will be considered as a Nonconformity.

Item No.	Safety Requirements	References	Acceptance Criteria	Assessment Methods
1.1	**Power Transmission Guarding** Fixed or moveable guards should be installed to prevent exposure to hazards such as shafts, gears, drive belts, or linkages	ISO 10218-1 Clause 5.2.1 or equivalent standards	a. Protection guards must be available b. Location of guards should be appropriate c. Interlock of moveable guards should function properly d. Guard condition should be normal If the inspection results are 'Pass' for each of the above items, the Guard can give adequate protection.	i) Document Review: robot's specifications and information, including technical data sheet, product catalogue, layout drawings, and other supplementary material to ensure that the protection guards are available, and their locations are appropriate ii) Visual inspection of availability of Protection Guards, and their condition and locations. (Note: The protection guards should be checked to re-confirm that they are installed in the correct locations and are functioning properly, in compliance with those shown in the documents.) iii) Check the Interlock function via demonstration during operation to ensure it functions properly.
1.2	**Loss or Change of Power** Loss of, or unstable, power should not result in a hazard, and any unprotected safety hazards should be identified / disclosed on the application form	ISO 10218-1 Clause 5.2.2 or equivalent standards IEC 60204-1:2018 Clause 5.4 or equivalent standards	When the power is off or unstable, speed is seen to be reduced, or no further hazardous movement is observed	i) Document Review: schematic circuit diagrams, design logic of software, to identify whether a robot is equipped with a protection feature ii) Shut down the power intentionally, then a visual inspection of any reduction in speed, or no further hazardous movement seen.
1.3	**Safety on Stored Energy** A means should be provided for the controlled release of stored hazardous energy. A label should be affixed to identify the stored energy hazard	ISO 10218-1 Clause 5.2.5 or equivalent standards	A label should be affixed at the energised area to identify the stored energy hazard.	Document Review: technical data sheet, schematic circuit diagrams and product catalogue to identify whether the location of the affixed warning label is appropriate. Visual inspection of the label affixed to indicate the energised area, and countercheck the position of the label

1.4	**Electromagnetic Compatibility (EMC)** The design of the welding robot should meet electromagnetic compatibility requirements below and to ensure functional safety systems providing desired protection from possible interference and hazardous motion due to effects of electromagnetic interference (EMI), radio frequency interference (RFI) and electrostatic discharge (ESD). Two generic EMC requirements specifying the limits of interference for construction robots under different operation modes (working, battery charging and discharging) and different functions (movement, communication / networking, collaboration with human, sensory and identification / recognition) are: 1. Immunity requirements 2. Emission requirements	ISO 10218-1 Clause 5.2.6 or equivalent standards IEC 60204-1:2018 Clause 4.4.2 or equivalent standards BS EN IEC 61000-6-2:2019 Generic standards – Immunity standard for industrial environments BS EN IEC 61000-6-4:2019 Generic standards – Emission standard for industrial environments CR-1-08TS-02: 2021 Construction Robot – Electromagnetic compatibility – Generic standards – Immunity requirements and limits CR-1-08TS-03: 2021 Construction Robot – Electromagnetic compatibility – Generic standards – Emission requirements and limits	a. Acceptable if there is no occurrence of hazardous motion or situations such as frequent system restarts, unprogrammed and unexpected movement of the robot, and possible interference with functional-safety systems within the limits of interference*. b. Acceptable if the test results of Immunity test and Emission test of the welding robot are within the limits of interference* with respect to the Immunity and Emission requirements. Remarks (*) - the limits of interference under Immunity test and Emission test at relevant ports are specified in Appendix 10.	Document Review: specific schematic circuit diagrams, configuration design, EMC test reports to assure the required limits of Immunity and Emission requirements are complied.

Actuating Controls				
1.5.	Status of the actuating controls should be clearly indicated	ISO 10218-1 Clauses 5.3.2 – 5.3.4 or equivalent standards	Status of actuating controls (e.g. power on, fault detected, automatic mode) should be displayed	Document Review: Technical data sheet, schematic circuit diagrams and product catalogue to identify the availability of actuating controls and the location of relevant labels.
1.6	Actuating controls should be labelled to clearly indicate their function	ISO 10218-1 Clauses 5.3.2 – 5.3.4 or equivalent standards	The labels of actuating controls must be available, and the functions of each control clearly shown	Visual inspection of the label of each actuating control, and use the "Lamp Test method" to countercheck that the function of each control matches the corresponding label
1.7	Safety-related Control System Performance (SRCS) SRCS should comply with performance requirements. Performance requirements are stated by means of either: a. Performance Level (PL) and categories or b. Safety Integrity Levels (SIL) and hardware fault tolerance requirements Safety Performance requirements include: 1. A single fault in any of parts that does not lead to the loss of safety function; 2. A single fault should be detected at or before the next demand upon the safety function; 3. When a Single fault occurs, the safety function is always performed and a safe state should be maintained; 4. All foreseeable faults should be detected.	ISO 10218-1 Clauses 5.4.1 – 5.4.3 or equivalent standards	a. SRCS performance of the robot and any furnished equipment should be clearly stated in the information for use. Min. requirements of SRCS are: I. PL = d with structure category 3; or II. SIL = 2 and Hardware fault tolerance of 1 b. The data and criteria necessary to determine the SRCS performance should be included in the information for use.	Document Review: Robot's system specifications, schematic circuit diagrams and information related to the SRCS, to identify inclusion of SRCS performance of the robot and the data and criteria necessary to determine the conformity of SRCS performance.

Robot Stopping Functions				
1.8	**Emergency Stop (E-Stop)** Every robot should have a protective stop function and an independent emergency stop function Each control station should have a manually initiated emergency stop function The operator should be able to make a quick, unobstructed access to the E-Stop	ISO 10218-1 clauses 5.5.1 and 5.5.2 or equivalent standards IEC 60204-1 clauses 9.2.3.4, 10.7 and Annex E or equivalent standards	a. A protective stop and an independent E-Stop should be available in each robot. b. Each E-Stop can function properly in the test. c. All E-Stops must function manually and should be free and easy to reach.	i) Visual inspection on the location and functions of the emergency stop and protective stop. ii) Test each stop at least once to check whether the stop functions work properly. iii) Test the reset mechanism of the E-stop
1.9	**Protective Stop** Information for use should include description of the stop category of every protective stop in the circuit.	ISO 10218-1 clauses 5.5.1 and 5.5.3 or equivalent standards	a. Protective devices should comply with specified safe distances. b. Connections of the stop functions with external protective devices should be available. c. Information for use should include description of the protection stop circuit.	Document Review: Robot's system specifications, product catalogue, technical data sheet, supplier's inhouse or external test reports and operation manual to identify any description of its E-Stop function, and braking system and quoted stopping performance.
1.10	**Braking Functions** Every Mobile Robot should be equipped with brakes and a braking system. In case an obstacle, unbalancing motion or overspeed is detected, the braking system should function properly to slow down or where necessary, stop the robot for motion control and avoidance of hazard, and be capable of holding /restraining the robot	ISO 18646-1: 2016 Clause 6 or equivalent standards	a. Stopping performance of braking system and holding of stationary status can be demonstrated in three trials. b. The Mobile Robot can stop within the declared stopping distance and stopping time.	Demonstration of the stopping performance of the braking system and holding of stationary status in at least three trials.

Operation Mode				
1.11	**Selection of Operation Mode** Operational modes should be selectable with a mode selector which can be locked in each position. Each position of the selector should be clearly identifiable and should allow only one mode to be selected at any one time.	ISO 10218-1 Clauses 5.7.1 – 5.7.4 or equivalent standards	Acceptable if only one mode can be selected at any one time.	Visual inspection on the selector and test the selection of each working mode.
1.12	**Automatic Operation Mode** Safeguarding measures should be in place and functioning when the robot's task programme is executed in automatic mode. Automatic operation should be prevented if any stop condition is detected.	ISO 10218-1 Clauses 5.7.1 – 5.7.4 or equivalent standards	Acceptable if the safeguarding measures are functioning normally under the automatic mode, and the test result for each working mode is normal. Stop condition is detected when safeguarding measures function during automatic operation.	Test both the automatic mode and the manual mode. i) To set the robot to automatic mode and manually assign a possible stop condition to test whether the safeguarding measures are functioning, and the condition can be detected. ii) The manual mode of operation should be performed with all persons outside the safeguarded space. To check that clear instructions have been provided prior to selecting the automatic mode, any suspended safeguards should be returned to their full functionality. iii) Document Review: System specification, schematic circuit diagrams, design material and operation manual to confirm provision of an Automatic Operation Mode
Safety Protection Features for Collaborative Operation				
1.13	**Visual Indication** Robots designed for collaborative operation should be provided with a visual indicator when the collaborative operation is activated	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if there is an indication sign at a proper location.	i) Visual inspection on the indication sign. ii) Document Review: Robot's system specifications, technical data sheet, product catalogue and other supplementary material to identify whether any indication sign is available and the appropriateness of its location.

1.14	**Safety-rated Monitored Stop** The robot should stop when a human is in the collaborative workspace.	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	The time measured for each stop in a trail should be consistent, with limits of variation not more than 10% of the mean.	i) Test the safety related control system for collaborative operation by using an object with height similar to an adult to enter into the robot workplace and observe any stop signs. ii) Repeat the test at least 5 times and measure the time required to reach a stop condition in each trail iii) Document Review: Robot's system specifications, technical data sheet, product catalogue, supplier's inhouse test report and other supplementary material to identify whether a stop condition is available for collaborative work.
1.15	**Hand Guiding** Where provided, hand guiding equipment should be located close to the end-effector and should be equipped with an emergency stop and an enabling device.	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if the hand guiding is observed to be close to the end-effectors and is equipped with an emergency stop and an enabling device.	Visual inspection on the availability and location of the hand guiding equipment
1.16	**Speed and Separation Distance Monitoring** The robot should be able to maintain a determined speed and separation distance. Information for use should contain directions for implementing speed values and separation distances	ISO 10218-1 Clauses 5.10.1 – 5.10.5 or equivalent standards	Acceptable if the results of tests of safety speed and separation distance are within the range of the supplier's specification.	i) Test by setting the safety speed and separation distance as per the supplier's information and observe whether the outcomes are within the supplier's specification. ii) Document Review: System specifications, technical data sheet, product catalogue, supplier's inhouse test report and other supplementary material to identify whether the robot is equipped with features to monitor the speed and separation distance.
1.17	**Movement without Drive Power** The robot should be designed so that the axes are capable of being moved without the use of drive power in an emergency or abnormal situation. Controls should be readily accessible but protected from unintended operation. Where practicable, warning notices should be posted near the activating controls.	ISO 10218-1 Clause 5.13 or equivalent standards	a. Acceptable if the axes of the robot can be moved freely by a single person without the use of drive power. b. Information for use should include a warning about a possible hazard created if the braking devices are released. Warning notices, when needed, should be posted near the controls. c. Controls must be protected from unintended operation.	i) Visual inspection of any movement of the robot if there is no drive power. ii) Visual inspection of the hazard warning notice iii) Visual inspection that the controls are protected.

1.18	**Electrical Protection** The robot should be designed and equipped with the following safety features: a. Isolation and Switching b. Overcurrent Protection c. Earth Leakage and Earth Fault Currents Protection d. Overloaded Protection e. Over-heat Protection f. Overspeed Protection	IEC 60204-1:2018 or equivalent standards and Relevant parts of Code of Practice for the Electricity (Wiring) Regulations, EMSD, HKSARG	Acceptable if there is a proof to show that all protection measures have been taken to comply with IEC 60204-1:2018 or, BS EN 60204-1:2018 or other equivalent International Standards; and the Code of Practice for the Electricity (Wiring) Regulations, EMSD, HKSARG	Document Review: Robot's system specifications, electrical circuit diagram /drawings, technical data sheet, product catalogue, external party's test reports, Product Safety Mark, and other supplementary material to identify whether the protection features have been equipped and tested.
1.19	**Batteries Protection** **(applicable for Mobile Robots)** **(applicable for Lead acid batteries using in Mobile Robot):** Overheat Protection Access for gas escape during charging **(applicable for Lithium based batteries using in Mobile Robot):** Overheat Protection Overcharging / Imbalanced charging Short circuit Protection Mechanical Shock Protection Withstand Vibration	IEC 60896-21 (for Lead Acid batteries) IEC 62619: 2017 sections 7 and 8 (for lithium based batteries) UL 3100 clauses 7.2, 22.2, 22.5, 33 and 36 ANSI/RIA R15.08-1-2020 clause 5.1.16.5 or equivalent standards	a. Acceptable if the batteries had been certified by a nationally or international-wide recognized testing laboratory in compliance with IEC 60896 -21 or IEC 62619 : 2017 to show all protection features of batteries have been tested. b. No abnormal temperature rise is detected when touching the surface of a fully charged battery by hand.	i) Document Review: robot's batteries specifications, technical data sheet, product catalogue, test report and certificate of batteries issued by a national or international test laboratory to identify whether corresponding protection features have been equipped and tested. ii) Fully charge the battery and check the surface temperature of the battery by hand first. If the battery temperature feels abnormal, use a calibrated thermo-gun to detect the battery temperature.
1.20	**Stability** The robot in a whole should remain stable in all operating conditions and during all loading-handling and travelling movements, including an emergency stop. There are four key stability parameters (steering speed, traction speed, load handling, and uplifting of centre of gravity in the course of welding work) A tilting platform stability test should be carried out to ensure the stability of the robot is acceptable.	ISO 3691-4: 2020 ISO 22915-1 : 2016 or equivalent standards	The mobile is considered **STABLE** if it passes all the stability tests without tip-over.	i) The robot in a whole should be tested in the worst-case conditions, e.g. loaded, unloaded, loading height, max. slope gradient, bi-directional (fore & aft), emergency braking deceleration, controlled acceleration / deceleration. ii) The test should be performed with at least 110% of claimed capacity and either: a. At least 110% of predetermined speed at rated load; or b. At maximum reachable speed, in case 110% of predetermined speed cannot be reached. iii) Document Review: Technical data sheet, product catalogue, supplier's inhouse test report to identify the rated load and max. speed.

1.21	**IP Rating** Since the robot is intended to be used at construction sites, the robot in a whole should be protected from dust ingress and from water spray under IP rating from IP 55 to IP 68.	IEC 60529 : 2013 + AMD1: 1999 + AMD2: 2013 + corrigenda (2003-2019) or equivalent standards	a. The sealing of entire welding robot should be effective. b. IP 55 to IP 68 (any rating)	Document Review: Technical data sheet, product catalogue, supplier's external test report showing IP rating achieved.

Table 1 – Safety Requirements

2. Quality Performance Requirements

This Section specifies the requirements for assessing the quality performance of a construction welding robot. Its quality performance is assessed through an on-site welding test as shown in a mock test paper in Appendix 1. Assessment methods include visual inspection and non-destructive tests (NDTs). Regarding quality performance, the construction welding robot should demonstrate a stable performance in pose repeatability and high accuracy in positioning and orientation during welding process. According to ISO 9283: 1998 and GB/T 12642-2013 standards, proof for claimed pose accuracy and pose repeatability of the construction welding robot with 30 cycles at 100% rated load should be presented to the audit team as pre-qualification for quality performance test.

The objectives of on-site welding tests are:

- ❖ to test the construction welding robot's ability to meet the requirements for general welding tasks in the construction industry, and
- ❖ to test the construction welding robot's pose repeatability and accuracy, flexibility, and stability in the set up for producing different complex workpieces.

Robot operators can opt for either an "Individual Welding Test" (Section 2.1) or a "Comprehensive Welding Test" (Section 2.2), and the testing results will be stated in the evaluation report accordingly.

When an "Individual Welding Test" is selected, the robot operator may choose any one of the welding test items 2.1.1 to 2.1.5 in Section 2.1. In each welding test from items 2.1.1 to 2.1.3, and 2.1.5, the robot operator will be given a Test Paper with a drawing identifying the configuration of a workpiece and type of weld required, and the welding robot must complete that selected test within a specific period of time. The workpieces, made of Mild Steel Grade either S355 or S275, must be kept in an orientation identified in the drawing throughout the test. The quality performance test carried out on the workpiece of selected steel grade does not imply that it also qualifies the construction welding robot on workpiece material of higher-grade steel or other metal.

The Table 2 below illustrates the configuration of workpiece, type of weld / flame-cut required, position of welds, thickness of workpiece and corresponding drawing for test items 2.1.1 to 2.1.5. Test items 2.1.1 to 2.1.3 are using mild steel workpieces of thickness ranged from 6mm to 20mm. For test item 1.4, the welding robot is required to use an oxy-acetylene gas flame torch to cut a mild steel plate of 9 mm thick as per drawing W4. Test item 2.1.5 is using a thicker workpiece of thickness 40mm.

Test item	Configuration of Workpiece	Weld type / Flame-cut	Position	Thickness of Workpiece	Corresponding Drawing
2.1.1	Multi-Layer & T-joint	Butt Weld Joint Fillet Weld	Horizontal Horizontal	20mm, 20mm 15mm, 20mm	W1
2.1.2	T-joint	Fillet Weld Fillet Weld	Vertical Overhead	15mm, 15mm 10mm, 15mm	W2
2.1.3	Pipe-shape	Fillet Weld	Horizontal Curve path	6mm, 15mm	W3
2.1.4	Flat shape	Flame-cut	Horizontal	9mm	W4

Table 2 – A summary of thickness of workpiece against each configuration of the workplace for individual welding test

2.1.5	Multi-Layer	Butt Weld Joint	Horizontal	40mm, 40mm	W5

Alternatively, robot operator can choose a "Comprehensive Welding Test" (Section 2.2). This test is an integrated test, comprising a combination of four individual tests. In the Comprehensive Welding Test, the welding robot is required to weld the test workpieces of thickness ranged from 6mm to 20mm in horizontal, vertical and overhead positions with butt weld / fillet welds according to the drawings "W1 + W2 + W3" and to use an oxy-acetylene gas flame torch to cut a flat mild steel plate and a circular plate as per drawing W4 within a defined period of time. Table 3 below illustrates the requirements for test item 2.2.1.

Test item	**Configuration of Workpiece**	**Weld type / Flame-cut**	**Position**	**Thickness of Workpiece**	**Corresponding Drawing**
2.2.1	Multi-Layer & T-joint	Butt Weld Joint Fillet Weld	Horizontal Horizontal	20mm, 20mm 15mm, 20mm	W1
	T-joint	Fillet Weld Fillet Weld	Vertical Overhead	15mm, 15mm 10mm, 15mm	W2
	Pipe-shape	Fillet Weld	Horizontal Curve path	6mm, 15mm	W3
	Flat shape	Flame-cut	Horizontal	9mm	W4

Table 3 – A summary of thickness of workpiece against each configuration of the workplace for comprehensive welding test

To validate the quality performance of a welding robot, a visual inspection followed by an non-destructive testing (NDT) should be performed over the full length of all welds by a suitably qualified person with reference to a welding procedural specification (WPS) approved by HKAS or its MRA partners accredited testing laboratory, and the testing procedures listed in Appendix 2. Such a person should be a Hong Kong Laboratory Accreditation Scheme (HOKLAS) qualified NDT Operator, or a NDT Operator with a recognised certified welding inspection qualification* for examining the quality results of welds made by a welding robot.

(*Note: Recognised qualification of NDT operator in Hong Kong includes, but not limited to, PCN-NDT Level 2 and Level 3; CSWIP-NDT Level 2 and Level 3, ASTM-NDT Level 3 and AWS-NDT level 3. The qualified NDT operator should receive a CIC recognised training on Part Two clause 4.2 requirements prior to taking up the role as a qualified person under this Scheme.)

Unless otherwise specified, the acceptance criteria for welds for general application should meet the minimum acceptance levels for imperfections given in Table 4 of the ISO 15614-1: 2017 requirements (Appendix 3), and the minimum requirements as contained in Table 14.3b of the Building Department's Code of Practice for the Structural Use of Steel (2011) for welds on structural steel (Appendix 4).

Various non-destructive testing of welds, including Penetrant Testing, Magnetic Particle Testing, Ultrasonic Testing and Radiographic examination can be applied, subject to actual work requirements. Where necessary to facilitate a particular test, post-weld treatment should be carried out prior to non-destructive testing.

The testing laboratory should follow the general conditions of facility set-up for welding tests as described in Appendix 5 and 6 for standardising the test results.

Non-fulfilment of any of the following Acceptance Criteria will be considered as a Nonconformity.

Item No.	Quality Performance Requirements	References	Acceptance Criteria	Assessment Methods and Work Instructions (WI)
Section 2.1 Individual Welding Test				
2.1.1	**Multi-layer & T- joint:** **Horizontal butt weld and fillet weld**	ISO 15614-1: 2017 Section 7 Cl. 7.1 and Table 2, and its and corrigenda July 2017 and May 2018 or equivalent standards BS EN 1011-1:2009 General guidance for Arc Welding or equivalent standards CIC Trade Test Centre's General Welder Trade Test pack Code of Practice for the Structural Use of Steel, 2011, issued by the Building Department of the HKSARG	a. Fillet weld size must comply with the drawing b. Fillet leg length* must be within acceptable limits c. Any obvious cracks are not permitted d. Lack of fusion (incomplete fusion) is not permitted e. Incomplete root penetration is not permitted f. Excess weld metal (butt weld)* must be within acceptable limits g. Excess convexity (fillet weld)* must be within acceptable limits h. Linear misalignment* must be within acceptable limits i. Incomplete groove or concave root* must be within acceptable limits j. Undercut* must be within acceptable limits k. Porosity at surface* must be within acceptable limits l. Slag inclusion at surface* must be within acceptable limits m. Any hidden cracks are not permitted n. Any hidden porosities are not permitted o. Any hidden slag inclusion is not permitted Remark (*) – for acceptable limits, refer to Table 14.3b of the Code of Practice for the Structural Use of Steel, 2011 Complete the test within 1 hour (including set-up time).	Visual check of criteria "a – l" NDT, i.e. penetrant or other testing, of criteria "m – o" WI: The welding robot is required to weld work pieces with a horizontal butt weld and two horizontal fillet welds according to Drawing W1. The orientation of workpieces should be maintained as indicated in Drawing W1 throughout the test. Cosmetic welding is not allowed Slag at the surface and spatter must be removed after welding
2.1.2	**T-joint :** **Vertical, and overhead fillet weld**	ISO 15614-1: 2017 Section 7 Cl. 7.1 and Table 2, and its and corrigenda July 2017 and May 2018 or equivalent standards BS EN 1011-1:2009 General guidance for Arc Welding or equivalent standards CIC Trade Test Centre's General Welder Skilled Trade Test pack Code of Practice for the Structural use of Steel, 2011, issued by the Building Department of the HKSARG	a. Fillet weld size must comply with the drawing b. Fillet leg length* must be within acceptable limits c. Any obvious cracks are not permitted d. Lack of fusion (incomplete fusion) is not permitted e. Incomplete root penetration is not permitted f. Excess convexity (fillet weld) * must be within acceptable limits g. Linear misalignment* must be within acceptable limits h. Incomplete groove or concave root* must be within acceptable limits i. Undercut* must be within acceptable limits j. Porosity at surface* must be within acceptable limits k. Slag inclusion at surface* must be within acceptable limits l. Any hidden cracks are not permitted m. Any hidden porosities are not permitted	Visual check of criteria "a – k" NDT, i.e. penetrant or other testing, for criteria "l – n" WI: The welding robot is required to weld work pieces vertically, and with an overhead fillet weld according to Drawing W2.

			n. Any hidden slag inclusion is not permitted Remark (*) – for acceptable limits, refer to Table 14.3b of the Code of Practice for the Structural Use of Steel, 2011 Complete the test within 1 hour (including set up time).	The orientation of workpieces should be maintained as indicated in Drawing W2 throughout the test. Cosmetic welding is not allowed Slag at the surface and spatter must be removed after welding
2.1.3	**Curve Path Weld**	ISO 15614-1: 2017 Section 7 Cl. 7.1 and Table 2, and its corrigenda July 2017 and May 2018 or equivalent standards BS EN 1011-1:2009 General guidance for Arc Welding or equivalent standards CIC Trade Test Centre's General Welder Trade Test pack Code of Practice for the Structural Use of Steel, 2011, issued by the Building Department of the HKSARG	a. Fillet weld size must comply with the drawing b. Fillet leg length* must be within acceptable limits c. Any obvious cracks are not permitted d. Lack of fusion (incomplete fusion) is not permitted e. Incomplete root penetration is not permitted f. Excess convexity (fillet weld)* must be within acceptable limits g. Linear misalignment* must be within acceptable limits h. Incomplete groove or concave root* must be within acceptable limits i. Undercut* must be within acceptable limits j. Porosity at surface* must be within acceptable limits k. Slag inclusion at surface* must be within acceptable limits l. Any hidden cracks are not permitted m. Any hidden porosities are not permitted n. Any hidden slag inclusion is not permitted Remark (*) – for acceptable limits, refer to Table 14.3b of the Code of Practice for the Structural Use of Steel, 2011 Complete the test within 1 hour (including set-up time).	Visual check of criteria "a – k" NDT, i.e. penetrant or other testing, for criteria "l – n" WI: The welding robot is required to weld work pieces in a horizontal curve path weld according to Drawing W3. The orientation of workpieces should be maintained as indicated in Drawing W3 throughout the test. Cosmetic welding is not allowed Slag at the surface and spatter must be removed after welding
2.1.4	**Flame Cutting**	CIC Trade Test Centre's General Welder Trade Test Kit	a. Width of the kerf should not exceed 3 mm b. Tolerance of the kerf should not exceed 3 mm c. Roughness of the kerf should not exceed 3 mm d. Straightness perpendicular to the kerf should not exceed 1 mm e. Any slag attached at the bottom of the kerf can be easily removed. Complete the test within 1 hour (including set-up time).	Visual check of criteria "a – e WI: The welding robot is required to use an oxy-acetylene torch to cut straight lines and a circular plate pre-marked on a mild steel plate according to Drawing W4.

2.1.5	**Multi-layer:** **Horizontal butt weld**	ISO 15614-1: 2017 Section 7 Cl. 7.1 and Table 2, and its and corrigenda July 2017 and May 2018 or equivalent standards BS EN 1011-1:2009 General guidance for Arc Welding or equivalent standards CIC Trade Test Centre's General Welder Trade Test pack Code of Practice for the Structural Use of Steel, 2011, issued by the Building Department of the HKSARG	a. Any obvious cracks are not permitted b. Lack of fusion (incomplete fusion) is not permitted c. Incomplete root penetration is not permitted d. Excess weld metal (butt weld)* must be within acceptable limits e. Linear misalignment* must be within acceptable limits f. Incomplete groove or concave root* must be within acceptable limits g. Undercut* must be within acceptable limits h. Porosity at surface* must be within acceptable limits i. Slag inclusion at surface* must be within acceptable limits j. Any hidden cracks are not permitted k. Any hidden porosities are not permitted l. Any hidden slag inclusion is not permitted Remark (*) – for acceptable limits, refer to Table 14.3b of the Code of Practice for the Structural Use of Steel, 2011 Complete the test within 1 hour (including set-up time).	Visual check of criteria "a – f" NDT, i.e. penetrant or other testing, of criteria "g – l" WI: The welding robot is required to weld work pieces with a horizontal butt weld according to Drawing W5. The orientation of workpieces should be maintained as indicated in Drawing W5 throughout the test. Cosmetic welding is not allowed Slag at the surface and spatter must be removed after welding

Table 4 – Quality Performance Requirements for Individual Welding Test

Item No.	Quality Performance Requirements	References	Acceptance Criteria	Assessment Methods and Work Instructions (WI)
Section 2.2 Comprehensive Welding Test				
2.2.1	**Integration of following tests:** 1. Multi-layer & T- joint: Horizontal butt weld and fillet weld 2. T-joint : Vertical, and overhead fillet weld 3. Curve Path Weld 4. Flame Cutting	ISO 15614-1: 2017 Section 7 Cl. 7.1 and Table 2, and its and corrigenda July 2017 and May 2018 or equivalent standards BS EN 1011-1:2009 General guidance for Arc Welding or equivalent standards CIC Trade Test Centre's General Welder Trade Test pack Code of Practice for the Structural use of Steel 2011 issued by the Building Department of the HKSAR Government	a. Fillet weld size must comply with the drawing b. Fillet leg length* must be within acceptable limits c. Any obvious cracks are not permitted d. Lack of fusion (incomplete fusion) is not permitted e. Incomplete root penetration is not permitted f. Excess weld metal (butt weld)* must be within acceptable limits g. Excess convexity (fillet weld)* must be within acceptable limits h. Linear misalignment* must be within acceptable limits i. Incomplete groove or concave root* must be within acceptable limits j. Undercut* must be within acceptable limits k. Porosity at surface* must be within acceptable limits l. Slag inclusion at surface* must be within acceptable limits m. Any hidden cracks are not permitted n. Any hidden porosities are not permitted o. Any hidden slag inclusion is not permitted Remark (*) – for acceptable limits, refer to Table 14.3b of the Code of Practice for the Structural Use of Steel, 2011 Complete the test within 4 hours (including set up time).	Visual check of criteria "a – l" NDT, i.e. penetrant or other testing, of criteria "m – o" WI: The welding robot is required to weld work pieces in horizontal, vertical, flat and overhead positions according to Drawings W1, W2 & W3. The orientation of workpieces should be kept as indicated in Drawings W1, W2 & W3 throughout the test. The welding robot is required to use an oxy-acetylene torch to cut straight lines and a circular plate pre-marked on a mild steel plate according to Drawing W4. It is required to do an individual set-up in each test.

Table 5 – Quality Performance Requirements for Comprehensive Welding Test

3. Functional Requirements (for Mobile Robots only)

This Section specifies the requirements for assessing the functional performance of a mobile robot which forms part of a construction welding robot. Non-fulfilment of any of the following acceptance criteria will be considered as a Nonconformity.

Item No.	Functional Requirements	References	Acceptance Criteria	Assessment Methods
3.1	**Passing Over Sill**	Testing Facility and Testing Method of Rated Speed as per ISO 18646-1: 2016 Clauses 9.2 and 9.3 respectively or equivalent standards	The Mobile Robot can pass over its specified maximum sill height (m) in at least three trials.	i) Document Review: robot's system specifications, product catalogue, technical data sheet, and supplier's inhouse or external test reports; and other supplementary material to identify any information about the maximum sill height. ii) Demonstration of how the Mobile Robot passes over the specified maximum sill height in at least three trials.
3.2	**Navigation**	GB/T 38124-2019 clause 5.2 ISO 18646-2: 2019 clause 4, 5 and Annex A and ANSI/RIA R15.08-1-2020 clause 5.1.7 or equivalent standards Safety speed figure is based on MHEDA's recommendation. (MHEDA for Material Handling Equipment Distributors Association)	The Mobile Robot can follow the pre-set direction and reach the designated point with maximum allowable safety speed of 5 mph or 2.235 m/s in at least three trials	i) Document Review: robot's system specifications, product catalogue, technical data sheet, self-description letter, suppliers' inhouse or external test report, and other supplementary material to identify any information describing how the robot be navigated and ii) Demonstrate how the robot can be navigated to a designated point in at least three trials.
3.3	**Obstacle Detection and Obstacle Avoidance Functions**	GB/T 38124-2019 clause 5.2.3 UL 3100 clause 14 Obstacle Detection Test as per ISO 18646-2: 2019 clause 6 Obstacle Avoidance Test as per ISO 18646-2: 2019 clause 7 and ANSI/RIA R15.08-1-2020 clause 7.4.4 or equivalent standards	a. The Mobile Robot can pass the static obstacle detection test with different shape, dimension and colour of objects in at least three trials. b. The Mobile Robot can pass a moving obstacle avoidance test in at least three trials.	i) Document Review: robot's system specifications, technical data sheet, product catalogue, self-description letter, supplier's inhouse or external test report, and other supplementary material to identify if the robot is equipped with any devices to detect and avoid obstacles. ii) Demonstrate how the robot detects static obstacles such as physical objects of different shape, dimension and colour, uneven floor sections, holes within a detection range in at least three trials; and iii) Demonstrate how to avoid collision with a moving object or falling into a hole in at least three trials.

Table 6 – Functional Requirements

4. Marking and labelling

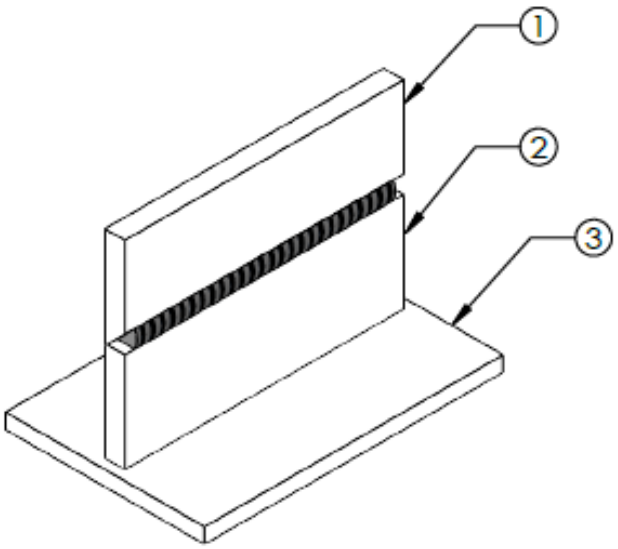
Welding Robot should be clearly marked with, but not limited to, the following information:

- Brand name of the robot
- Type, model, series, unique identification number of the robot
- Date or batch code of production/ integration of the robot
- Name and address of robot manufacturer
- Name and address of integrator (if applicable)
- Details of the certified robot supplier (name, address, phone contact, website, etc.)
- Any other information for use of robot recommended by the robot manufacturer/ integrator

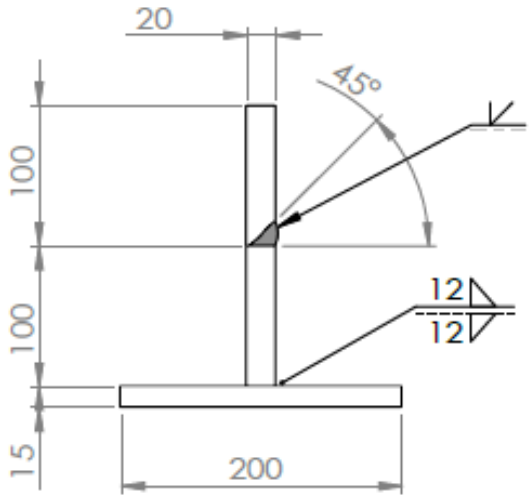
Appendices

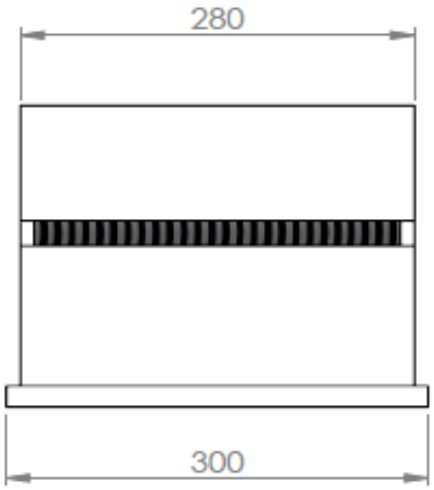
Appendix 1 – Mock Test Paper

Drawing W1
Multi-layer – Horizontal Butt Weld and Fillet Weld



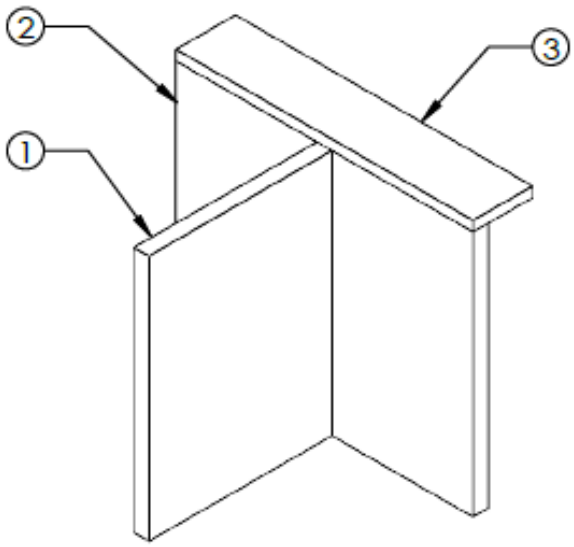
MATERIAL (MILD STEEL)	SIZE (mm)
1	280 x 100 x 20, 18x45 degree chamfer
2	280 x 100 x 20
3	300 x 200 x 15

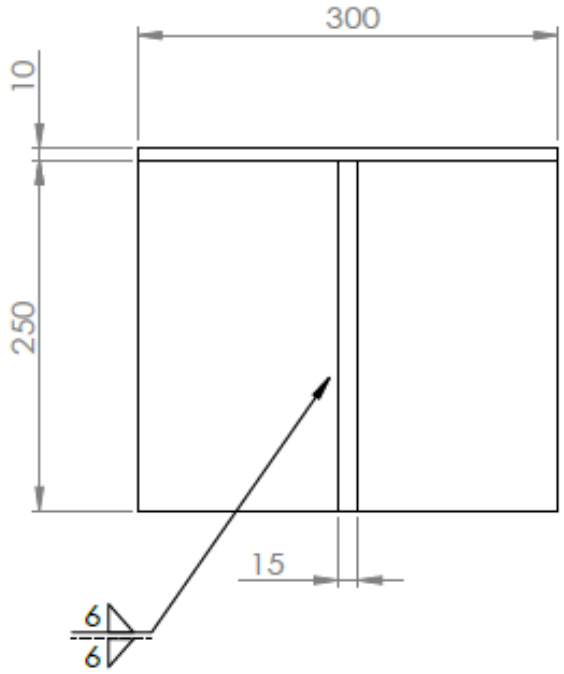


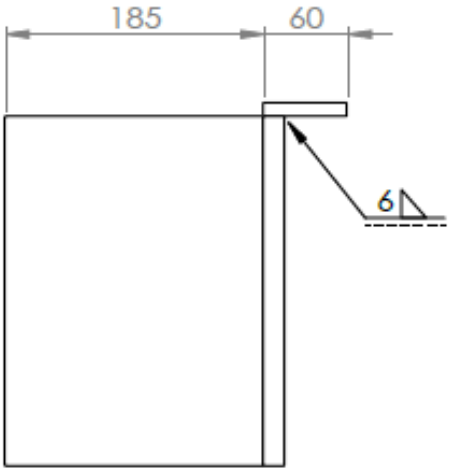


Drawing W2
Vertical and Overhead Fillet Welding

MATERIAL (MILD STEEL)	SIZE (mm)
1	250 x 185 x 15
2	300 x 250 x 15
3	300 x 60 x 10

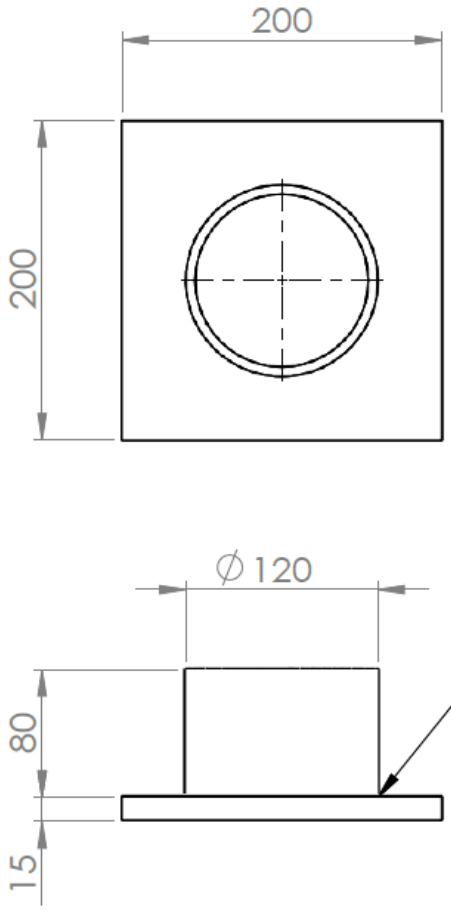




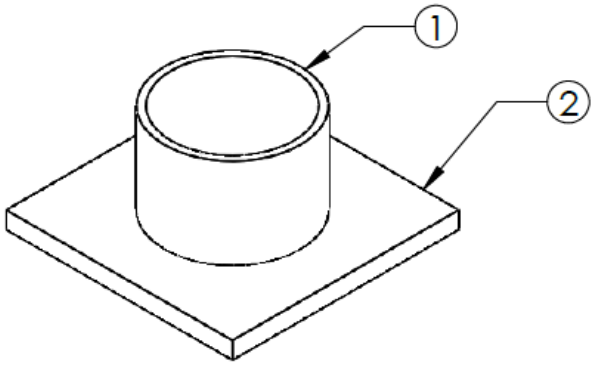


Drawing W3

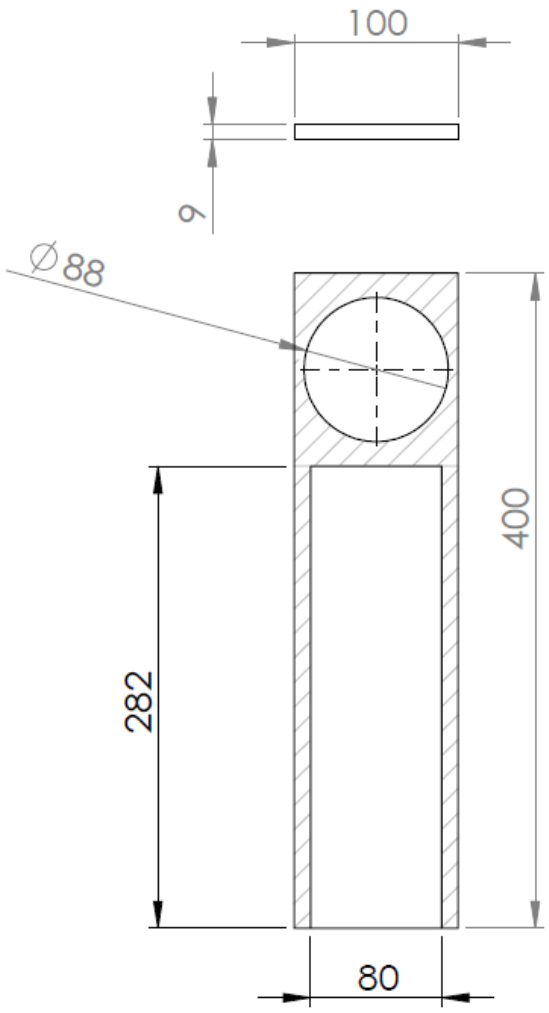
Curve Path Welding



MATERIAL (MILD STEEL)	SIZE (mm)
1	D120 x 80 x 6
2	200 x 200 x 15

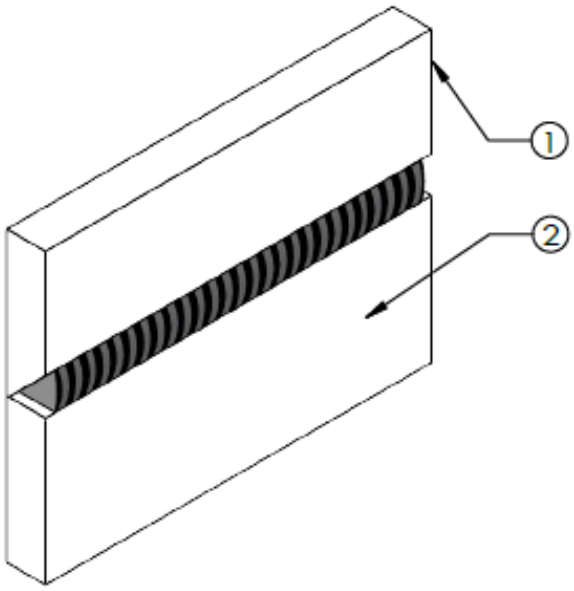


Drawing W4
Flame Cutting Application

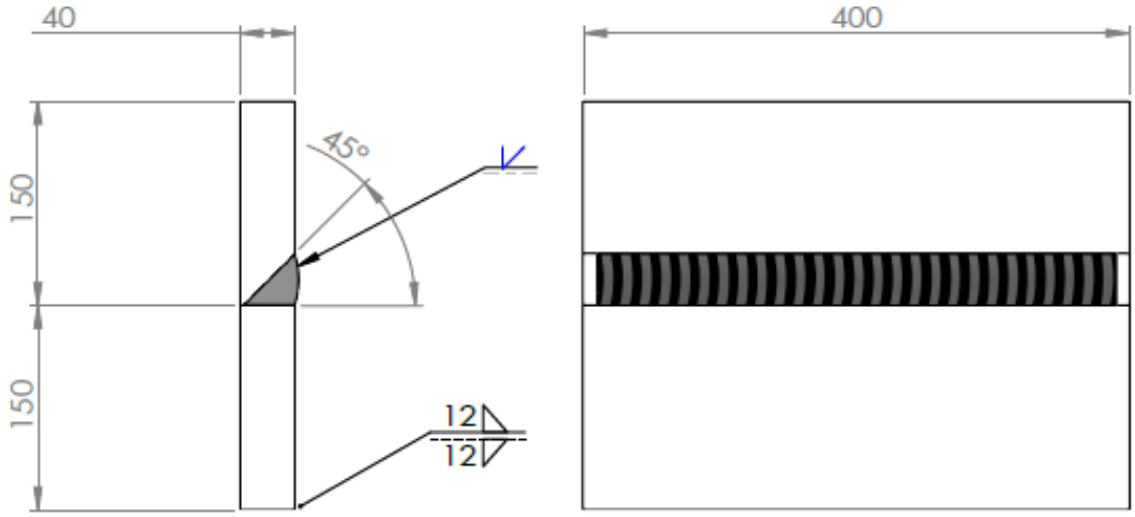


MATERIAL (MILD STEEL)	SIZE (mm)
1	400 x 100 x 9

Drawing W5
Multi-layer – Horizontal Butt Weld on thick workpiece



MATERIAL (MILD STEEL)	SIZE (mm)
1	400 x 150 x 40, 18x45 degree chamfer
2	400 x 150 x 40



Appendix 2 – List of Testing Procedure References

For the details of welding procedures, please refer to ISO 15614-1:2017 Section 7.1.

EN ISO 15614-1:2017-06	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2017, Corrected version 2017-10-01)
EN ISO 15614-1/A1:2019-0	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys - Amendment 1 (ISO 15614-1:2017/Amd 1:2019)

For different Non-Destructive Test Methods, please refer to the following testing standards. All welds are required to have Visual Testing, as referred to in ISO 17637: 2016

BS EN ISO 17637:2016	Non-destructive Testing of welds. Visual Testing of Fusion Welded Joints
BS EN ISO 17640: 2010	Non-destructive Testing of welds. Ultrasonic Testing, Techniques, Testing Levels and Assessment
BS EN 571-1:1997	Non-destructive testing. Penetrant Testing Part 1: General Principles
BS EN ISO 17638:2009	Non-destructive Testing of welds. Magnetic Particle testing
BS EN ISO 9934-1:2001	Non-destructive Testing. Magnetic Particle testing. Part 1: General Principles
BS EN 1435:1997	Non-destructive examination of welds. Radiographic examination of welded joints

For different Destructive Test Methods, please refer to the following testing standards.

BS EN ISO 9016: 2011	Destructive tests on welds in metallic materials – Impact Tests. Test specimen location, notch orientation and examination
BS EN ISO 5178:2011	Destructive tests on welds in metallic materials – Longitudinal Tensile Tests on weld metal in fusion welded joints
BS EN ISO 4136:2011	Destructive tests on welds in metallic materials – Transverse Tensile Test
BS EN ISO 5173:2010	Destructive tests on welds in metallic materials – Bend Tests
BS EN ISO 9015:2011	Destructive tests on welds in metallic materials – Hardness Testing Hardness Test on Arc Welded Joints
BS EN 1320:1997	Destructive tests on welds in metallic materials – Fracture Tests
BS EN 1321:1997	Destructive tests on welds in metallic materials – Macroscopic and microscopic examination of welds

Appendix 3 – Testing Procedure of Welds

(Source: ISO 15614-1: 2017)

7 Examination and testing

7.1 Type and extent of testing

For level 1: Type and the extent of testing shall be in accordance with the requirements of Table 1. If impact testing, hardness testing or non-destructive testing (NDT) is required by an application standard or specification, they shall be carried out and assessed in accordance with the requirements of level 2, unless otherwise specified by the application standard or specification.

For level 2: Type and the extent of testing shall be in accordance with the requirements of Table 2.

An application standard may specify additional tests, e.g.:

— longitudinal weld tensile test;

— all weld metal bend test;

— corrosion test;

— chemical analysis;

— microscopic examination;

— delta ferrite examination;

— hardness test;

— cruciform test;

— impact test;

— non-destructive testing (NDT).

NOTE Specific service, material or manufacturing conditions may require more comprehensive testing than is specified by this document in order to gain more information and to avoid repeating the welding procedure test at a later date just to obtain additional test data.

Table 1 — For level 1: Examination and testing of the test pieces

Test piece	Type of test	Extent of testing	Footnote
Butt joint with full penetration — Figure 1 and Figure 2	Visual testing Transverse tensile test Transverse bend test	100 % 2 specimens 4 specimens	a
Fillet welds — Figure 3	Visual testing Macroscopic examination	100 % 2 specimens	b

a For bend tests, see 7.4.2.

b Where mechanical properties are required by an application standard, it shall be tested accordingly. If an additional test piece is needed, the dimensions should be sufficient enough to allow testing of the mechanical properties. For this additional test piece, the welding parameter range, parent material group, filler metal and heat treatment are required to be the same.

Table 2 — For level 2: Examination and testing of the test pieces

Test piece	Type of test	Extent of testing	Footnote
Butt joint with full penetration — Figure 1 and Figure 2	Visual testing	100 %	—
	Radiographic or ultrasonic testing	100 %	a
	Surface crack detection	100 %	b
	Transverse tensile test	2 specimens	—
	Transverse bend test	4 specimens	c
	Impact test	2 sets	d
	Hardness test	required	e
	Macroscopic examination	1 specimen	—
T- joint with full penetration — Figure 3 Branch connection with full penetration — Figure 4 f	Visual testing	100 %	
	Surface crack detection	100 %	b
	Ultrasonic or radiographic testing	100 %	a, g
	Hardness test	required	e
	Macroscopic examination	2 specimens	
Fillet weld — Figure 3 and Figure 4 f	Visual testing	100 %	
	Surface crack detection	100 %	b
	Hardness test	required	e
	Macroscopic examination	2 specimens	

a Ultrasonic testing shall not be used for $t < 8$ mm and not for material groups 8, 10, 41 to 48.

b Accessible weld surfaces: penetrant testing or magnetic particle testing. For non-magnetic materials, penetrant testing.

c For bend tests, see 7.4.2.

d One set in the weld metal and one set in the HAZ for materials ≥12 mm thick and having specified impact properties required by technical delivery conditions and/or if appropriate according to the service conditions. Application standards may require impact testing below 12 mm thick. The testing temperature shall be chosen by the manufacturer with regard to the application or application standards. For additional tests, see 7.4.4.

e Not required for parent metals: sub-group 1.1, groups 8 and 41 to 48 and dissimilar joints between these groups, except for dissimilar joints between sub-group 1.1 and group 8.

f Where mechanical properties are required by an application standard, it shall be tested accordingly. If an additional test piece is needed, the dimensions should be sufficient enough to allow testing of the mechanical properties. For this additional test piece, the welding parameter range, parent material group, filler metal and heat treatment are required to be the same.

g For outside diameter ≤50 mm, no ultrasonic testing is required, but radiographic testing is required provided that the joint configuration will provide valid results. For outside diameter >50 mm and where it is not technically possible to carry out ultrasonic testing, a radiographic testing shall be carried out provided that the joint configuration will provide valid results.

Table 4 — Acceptance levels for imperfections

ISO 5817 Ref. no.	ISO 6520-1 Ref. no.	Designation	Level 1	Level 2 Quality level to ISO 5817
1.1	100	Crack	Not permitted	B (not permitted)
1.5	401	Lack of fusion (incomplete fusion)	Not permitted	B (not permitted)
1.6	4021	Incomplete root penetration	Not permitted	B (not permitted)
1.7	5011 5012	Continuous undercut Intermittent undercut	No specific requirements	C
1.9	502	Excess weld metal (butt weld)	No specific requirements	C
1.10	503	Excessive convexity (fillet weld)	No specific requirements	C
1.11	504	Excess penetration	No specific requirements	C
1.12	505	Incorrect weld toe	No specific requirements	C

[a] If required by the application standard or specified, micro crack sensitive materials may need specific examination.

Appendix 4 – Acceptance Criteria for Welds in Steel Structures

Source: Building Department's Code of Practice for the Structural Use of Steel, 2011

Table 14.3b - Acceptance criteria for welds in steel structures

Feature	Parameter	Weld type	Particular conditions[a]		Figure reference in Table 14.3d	Acceptance criteria for normal quality[b c] (All dimensions in mm)	Remedial action for non-conforming welds[d]
Overall weld geometry	Location[e]	All	—		—	$D \pm 10$	E
	Weld type	All	—		—	D	E
	Extent (length)	All	—		—	$D + 10 - 0$	E
Profile discontinuities	Actual throat thickness	All	—		i, ii, iii	$a, s \geq D$ (50) $a, s \leq D + 5$	R DS
	Leg length	Fillet	—		i	$z \geq D$ (50)	E
	Toe angle (interface and inter-run)	All	Transverse Longitudinal		i, ii i, ii	$\theta \geq 90°$ $\theta \geq 90°$	DS/R DS/R
	Excess weld metal	Butt	Transverse Longitudinal		ii ii	$h \leq 6$ $h \leq 6$	DS DS
	Incomplete groove or concave root	Butt	Transverse Longitudinal		ii ii	$h \leq 0$ (50) $h \leq 0.1t$	R E
	Linear misalignment	Butt All All	Transverse butt Transverse cruciform Longitudinal		iv v iv, v	$h \leq D + 0.2t$ $h \leq D + 0.4t$ $h \leq D + 0.4t$	E E E
Surface breaking discontinuities	Undercut[f]	All Fillet All	Transverse (not lap joint) Transverse (lap joint) Longitudinal		iv, v v iv, v	$h_1 + h_2 \leq 0.05t$ l – NL $h_1 + h_2 \leq 0.03t$ $l \leq 10$ $h_1 + h_2 \leq 0.1t$	R R R R R
	Lack of root penetration	S/S Butt	Transverse Longitudinal		iii iii	*NP* *NP*	R R
	Porosity	All	Transverse Longitudinal		vi vi	$d \leq 2$ $\sum d \leq 10$ [100] $d \leq 2$ $\sum d \leq 20$ [100]	R R R R
	Lack of fusion	All	—		vii	NP	R
	Cracks	All	At crater Not at crater		vii	NP NP	R R
			All		vii	$h \leq 3$	R
Sub-surface discontinuities	Lack of fusion/root penetration, slag lines	Butt	Transverse	Full depth $h_1 < 6$ $h_1 > 6$	vii vii vii	$\sum l \leq 1.5t$ [100] $l \leq 10$ $l_1 \geq 10$ l – NL l_1 – NL	R R R R R
			Longitudinal	Full depth $h_1 < 6$ $h_1 > 6$	vii vii vii	$\sum l \leq 3t$ [100] l – NL l_1 – NL l – NL l_1 – NL	R R R R R
—	Root gap	Fillet P/P Butt	—		i, v	$h \leq 2$ (100), 3	R
—	Cracks	All	—		—	NP	R
—	Lamellar tears	All	Transverse Longitudinal		—	NP[g]	E

Table 14.3b - Acceptance criteria for welds in steel structures (cont'd)

Abbreviated terms			
D	As specified on drawings	a	For definition of orientation see Table 14.3c.
DS	Dress smoothly	b	Thickness applies to minimum member thickness at weld in question. For thicknesses greater than 20 mm "*t*" shall be taken as 20 mm. Where permitted size "*h*" if a discontinuity is related to "*t*" the maximum permitted value shall be not less than 0.3 mm in any case.
E	Refer to engineer	c	Where more than one requirement is given both shall apply. Where a repair is necessary an approved procedure shall be used.
NL	No limit	d	If on increasing the scope of inspection, further non-conformances are found, the scope shall be increased to 100% for the joint type in question.
NP	Not permitted (applies to discontinuities which are detectable by NDT methods in Table 14.3a)	e	Subject to any other locational requirements.
R	Repair by welding to approved procedure	f	"Lap" shall apply to any fillet welded attachment whose length in the longitudinal direction exceeds 50 mm.
≥	Greater than or equal to (i.e. not less than)	g	Lamellar tears may only be accepted in the longitudinal welds if the extent does not exceed limits for lack of fusion in transverse welds.
≤	Less than or equal to (i.e. not greater than)		
∑	Sum of		
( )	Length of weld over which measurement may be averaged (mm)		
[ ]	Length of weld over which the summation is made (mm)		
L	Length parallel to the weld axis		
S/S	Single sided butt weld		
P/P	Partial penetration butt weld		

Appendix 5 – Facility Set-up

Item	Facility Item	Criteria / Requirements for Welding Processes	Remarks / Technical Reference.
1.	Workplace	The test laboratory should be operated under a Quality, Health and Safety System. Where appropriate, the test laboratory should provide suitable Personnel Protection Equipment (PPE) and curtain to protect the eyes of robot operator and other personnel close to the work place from the emitted strong beam of light. The workplace should be fitted for testing and be equipped with adequate and stable supply of electrical power and adequate Illumination. The workplace should be ventilated with adequate supply of fresh air and proper discharge of contaminated air particles during gas welding and flame cutting. The test laboratory should be spacious to allow the movement of welding robots. The workplace should be structurally fitted to prevent damage from any detrimental effects of weather or other issues which may affect the quality performance test and safety of personnel. Regarding storage and handling of oxygen and acetylene gas cylinders, the workplace should comply with: 8. Cap 95 Fire Services Ordinance and its Code of Practice 9. Code of Practice – Safety and Health at Work for Gas Welding and Flame Cutting under FIU Ordinance	Layout plan with emergency escape route should be provided and displayed. Provision of three phase circuits with 380V a. c. 50 Hz for some welding robots which require more power inputs. Maximum allowable lighting power density (LPD) should be maintained at 15 W/m^2 as per Table 5.4 of Building Energy Code (BEC). Appropriate mechanical ventilation measures should be equipped to provide fresh air for dilution of toxic fumes and contaminants in the air. Local exhaust facilities should be in place to help removing the contaminants out of the workspace and to prevent accumulation of flammable mixture in localized region. Unless it is permitted by relevant authority, not more than one set of oxygen and acetylene gas cylinders is allowed to be kept in the workplace. Proper Fire Services systems are in place. Fence-off the working areas from other areas.
2.	Equipment, tools, and devices	All welding-related equipment should be matched to the respective welding processes, the working tasks, and the design of the final product Electrical equipment used for welding operation comply with IEC/TS 62081, and HKSAR Ordinance Cap 406 and its Electricity (Wiring) Regulations. Gas supply machine used for gas welding should comply with FIU Ordinance, Regulations and Code of Practice for Gas Welding and Flame Cutting. When necessary, devices for measuring welding parameters such as arc voltage, welding current, wire feed rate, travel speed, and shielding / purging gas flow rates, and also for monitoring the pre-heat and inter-pass temperatures, are available either as part of the welding apparatus or by providing portable equipment.	Applicable to Electrical Arc Welding and Gas Welding The specifications such as Power Factor and Voltage / Current variation, and the electrical parts protection of welding machines should comply with the latest edition of HKSAR Ordinances, corresponding Regulations and Code of Practice 1. Cap 460, the Electricity (Wiring) Regulations and its Code of Practice, 2. Cap 59, the Factories and Industrial Undertakings Ordinance (FIUO) and its Regulations 3. Code of Practice – Safety and Health at Work for Gas Welding and Flame Cutting under FIUO

		Valid calibration status of measurement and testing devices used must be maintained when the test is performed.	4. Cap 95 Fire Services Ordinance and its Code of Practice 5. Measurement of welding parameters is optional.
3.	Welding Processes	It covers welds made by: a. Auto metal-arc welding with covered electrode b. Self-shielded tubular welding c. Metal inert gas Welding; MIG welding d. Metal active gas welding; MIG welding e. Tubular-cored metal-arc welding with active gas shield f. Tubular-cored metal-arc welding with inert gas shield g. Tungsten inert gas welding; TIG welding	An independent room or designated area with curtain where proper ventilation equipment is installed to maintain the air quality of the workplace. Robot operator and the inspection personnel must wear suitable PPE before start of welding work to protect their face, eye and body.
4.	Storage and Handling of parent metals and welding consumables	Testing laboratory should keep parent metals in good condition suitable for welding test. Parent metals and welding consumables should be stored and processed in accordance with the best practice – to retain identification and avoid damage and deterioration of their material characteristics. Welding consumables should be matched to the parent metals and the selected welding process, and stored and handled in accordance with the recommendations of the suppliers.	Typical condition is dry and no dew found on the packing.
5.	Information on test paper and drawings	Designations and symbols of the welded joints should follow the requirement of ISO 2553 or EN 22553.	The weld joints must be clearly marked on the examination drawing at a reasonable size.
6.	Set-up for fabrication and inspection	Jigs, fixtures and manipulators should be used, in order that the welding can be carried out in the most suitable welding position. The sequence of assembly and welding should be carried out in such a way that all welds can be easily examined via visual inspection.	The jigs, fixtures and manipulators should be rigid and convenient to use
7.	Inspection and documentation	Inspection and test reports should be documented and sent for compilation of the Evaluation Report within one week after completion of the welding test.	N/A

Appendix 6 – Testing Environment

Item	Testing Environment Condition	Criteria / requirements	Remarks / Technical Reference
1.	Robot mounting	Mounting should be in accordance with the robot supplier's recommendations	With reference to robot supplier's specifications or other publicly available information
2.	Conditions prior to testing	The robot should be completed assembled and fully operational. All necessary levelling measurement, alignment procedures and functional test instructions must be available and followed.	Appropriate robot supplier's procedures, instruction and testing methods
		If pre-heating of the test specimen is needed, follow the set-up of the test bench in the CIC Trade Test Centre.	Set-up of the test bench similar to the CIC Trade Test Centre.
3.	Operating conditions	The normal operating conditions should be stipulated by the robot supplier. Particular safety precautions to operation should be specified by the robot supplier prior to testing. For functional performance test, the Travel surface conditions for Indoor usage (source: ISO 18646-2: 2019 cl. 4.3): 3. Type of surface required – Hard, even and horizontal 4. Coefficient of friction of surface: 1 .0	Normal operation conditions include requirements for electrical, hydraulic and pneumatic power, power fluctuations and disturbances, maximum safe operating limits.
4.	Environmental conditions for normal operation	During functional performance test, typical Indoor Environmental conditions (source: ISO 18646-2: 2019 cl. 4.2) should be maintained at: 3. Range of relative humidity : 0% - 80% ; 4. Range of illumination:100 lux – 1000 lux For outdoor application, the Outdoor Environmental conditions should be kept under normal outdoor usage or according to the robot supplier's specifications or recommendations	Environmental conditions include temperature, relative humidity (RH), electromagnetic and electrostatic fields, radio frequency interference, atmospheric contaminants, and altitude limits should be declared in the test report. (Ref. ISO 18646-2 cl. 4.2 and Annex A cl A.3 and ISO 9946)

5.	Temperature of testing environment	For functional performance test, the Indoor Environmental conditions (source: ISO 18646-2: 2019 cl. 4.2): 5. Range of ambient temperature (Θ): 10ºC - 30ºC 6. The test temperature should be maintained at (Θ ± 2) ºC Relative humidity (RH) of spray test room may be kept between 0% - 80%, optimized RH is 40% - 50 %. For outdoor application, the Outdoor Environmental conditions (Ref: ISO 18646-2: 2019 Annex A) should be kept under normal outdoor usage or according to the robot supplier's specifications or recommendations	If situation is allowed, the robot and the measuring instruments should have been kept under the test environment long enough (preferably overnight) so that they are in a thermally stable condition before testing. They should be protected from draughts and external thermal radiation like sunlight, heaters. Relative humidity may not induce obvious impact to the welding material, workpieces and the welds.

Appendix 7 – Document Quality Control

*Remark: The documents and records throughout the Scheme are referred to, but not limited to, hard copy or soft copy or electronic copy of information and data, as well as Rights of Intellectual Properties, including Patent, Licenses and Copyrights.

Following documents and records*, where applicable, are required for audit:

Documents should be kept for initial audit and surveillance audits	
1.	Business Registry or other legal documents as a proof of registry as a legal entity
2.	Safety-related Risk Assessment and Safety Precaution measures
3.	Manual / Procedure for Set-up including Mounting of Construction Robot and relevant Records
4.	Manual / Procedure for Disassembly of Construction Robot and relevant Records
5.	Manual / Procedure/ Handbook for Operation with Emergency Control measures
6.	Manual / Procedure/ Handbook and Schedule for Maintenance and relevant Records
7.	Authorization Documents / Records
8.	Key Production Procedures and Records
9.	Internal Quality Assurance Procedures and Quality Control Records
10.	Pre-work Risk Assessment Record (on-site)
11.	Product Quality and Safety Inspection Record (on-site)
12.	Product Catalogue (latest version)
13.	Technical Specification Data Sheet (latest version)
14.	Drawings / Electrical Circuit Diagram (where applicable)
15.	Test Reports (Internal / External)
16.	Test Certificates
17.	Training Records of Robot Operator, Robot Users and Company Representative
18.	Safety-related Incident or Accident Occurrence Reports and follow-up
19.	Quality performance related nonconforming issues
20.	Post-delivery Complaint received
21.	Warning Letter or Summit received regarding offence of local statutory or regulatory regulations, and violence of contractual requirements

Following document quality control activities, not limited to, should be followed:

1. Before each piece of documented information is created and updated, appropriate identification and description (e.g. title, date, author or reference number), and format (e.g. language, software version, graphics) and media (e.g. paper, electronic) have been established, reviewed and approval for suitability and adequacy.
2. The documents and records, not limited to the above table, should be adequately protected (e.g. from loss of confidentiality, improper use, or loss of integrity or unintended alternations) ; stored and preserved (e.g. software licences, permits to use, electronic / digital information).
3. The documents and records, not limited to the above table, when distributed, access, retrieval and use should be properly controlled (e.g. distributed to whom, grant of access right and right of use).
4. The documents and records, not limited to the above table, should be kept in a defined retention period, typically not less than 3 years.
5. Any changes, including version number, of the documents and records, not limited to the above table, should be clearly identified and traceable.

Appendix 8 – Audit Planning Matrix for a 3-year Cycle

Areas / Documents to be available for audit	Initial Audit	First SV	Second SV	Re-audit
Business Registry or other legal documents as a proof of registry as a legal entity	✓			✓
Safety-related risk assessment and safety precaution measures	✓	✓	✓	✓
Set-up and Mounting Manual / Procedure to describe safety hazards, risk, and precaution measures to be taken during initial set-up and subsequent set-up in case of re-location at site.	✓	✓	✓	✓
Disassembly Manual / Procedure to describe safety hazards, risk, and precaution measures to be taken during disassembly and re-location at site.	✓	✓	✓	✓
Operation Manual	✓	✓	✓	✓
Maintenance Manual	✓	✓	✓	✓
Maintenance Schedule and Records		✓	✓	✓
Authorization Documents / Records	✓	✓	✓	✓
Key Production Procedures and Records	✓	✓	✓	✓
Internal Quality Assurance Procedures and Quality Control Records	✓	✓	✓	✓
Pre-work Risk Assessment Record (on-site)	✓	✓	✓	✓
Product Quality and Safety Inspection Record (on-site)	✓	✓	✓	✓
Product catalogue	✓			✓
Technical Specification Sheet (where applicable)	✓			✓
Drawings (where applicable)	✓			✓
Test Reports (Internal / external)	✓			✓
Test Certificates	✓			✓
Training Records of Robot Operator	✓	✓	✓	✓
Safety related incident or accident occurrence reports and follow-up		✓	✓	✓
Quality performance related nonconforming issues		✓	✓	✓
Post-delivery complaint received		✓	✓	✓
Warning letter or summit received regarding offence of local statutory or regulatory regulations, and violence of contractual requirements	✓	✓	✓	✓
Technical Aspects*	✓	✓	✓	✓

*Remark: Technical aspects, not limited to, battery protection, stability, distance monitoring, where applicable, are required to be covered in audits, and each SV.

Appendix 9 – Key Contents of Set-up Manual, Operation Manual and Maintenance Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot operator and close stakeholders who are involved for the set-up of robot.	Relevant stakeholders must be communicated about their role and responsibility.
2.	Required conditions, facility, environment, and resources for the set-up of robot at site.	Conditions may include licenses issued from various government departments, isolated works area and power supply. Environment should include situation of adverse weather and critical site conditions. Resources here include legal employment of qualified / authorized personnel and authorized vehicles.
3.	A robot set-up methodology should include the followings: - Description of the set-up and mounting methods at different situations in details. - Risk assessment and precaution measures should be included.	If the set-up methodology is required to be examined by an Authorized Person (AP), the robot operator has to assist the AP for processing the examination. The robot operator should conduct a pre-work risk assessment prior to the set-up and mounting of the certified construction robot at site. Where possible, the methodology should be illustrated or accompanied with self-explanatory sketches, diagrams, or drawings.
4.	The person / party who approves / endorses the structural safety of the set-up / mounting for robot using at site.	If the set-up is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer), or Site-in-charge, approval / endorsement results has to be obtained prior to the use of the robot, documented and retained.
5.	Emergency Contacts should be included in the set-up manual.	The emergency contacts should be accessible 24 hours per day.

Operation Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot supplier and robot operator	Robot supplier has responsibility to update the robot operator of any issue related to the operation of robot without delay. The Certified Robot Supplier should delegate the company representative to carry out a random inspection on the Product Quality and Operational Safety in relation to the Certified Construction Robot at site on regular time-basis and/ or batch/ log-basis of product. A sampling plan to define sampling frequency and sampling rate should be incorporated in the Operation Manual Typical sampling rate should be at least 10% of accountable figures of outputs.
2.	Required conditions, facility, environment, and resources for the operation of robot at site	Conditions may include power supply, works area, access, use approval issued by relevant authority. Environment should include situation of adverse weather and critical site conditions. Resources here include trained and authorized robot operators.
3.	Operation of a robot should include the followings: - Intended uses of the robot and its controls - Function of the robot and each control mode - Scheduled safety and function checks of the robot (e.g. e-stop) - Warning of risk to personnel during robot operation - Instruction to prevent unauthorized use - Description of the operation of the robot in details. - Risk assessment and precaution measures should be included.	Where possible, the operation should be illustrated or accompanied with self-explanatory sketches or diagrams. The robot operator should conduct pre-work risk assessment before start of daily work at site, and prior to significant changes (e.g., re-location of construction robot work area) at site.

4.	The person / party who approves / endorses the operation of robot at site.	If operation is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer) or Site-in-charge, such approval or endorsement result has to be obtained prior to the fully operation of the robot, documented and retained.
5.	Emergency Control measures including emergency contacts should be specified in the operation manual.	Emergency Control measures should include all possible mobile control means for the construction robot from causing further adverse impact to personnel, environment, property, and assets. The emergency contacts should be accessible 24 hours per day.

D. Maintenance Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot supplier and robot operator.	Robot supplier has responsibility to update the robot operator of any issue related to the maintenance of robot without delay.
2.	Required conditions, facility, environment, and resources for the maintenance of robot at site.	Conditions may include power supply, access, maintenance area and spare parts needed. Facilities and tooling required for maintenance should be listed out in the maintenance manual. Environment should include situation of adverse weather and critical site conditions. Resources here include trained and authorized robot operators.
3.	Maintenance of a robot should include the followings: - Methodology for identifying or detecting defects - Type and frequency of maintenance of the robot - Information necessary for maintenance - Warning of risk to personnel and safety precaution measures to be taken before and during robot maintenance - Description of routine preventive maintenance of the robot in details. - Instruction for changing critical parts. - A sample template of preventive maintenance and corrective maintenance records - Risk assessment and precaution measures should be included.	Where possible, the maintenance procedures should be illustrated or accompanied with self-explanatory sketches or diagrams. Type of maintenance can be preventive maintenance, corrective maintenance, and predictive maintenance. Maintenance Schedule/ Plan should be established before 1st SV audit. Template of maintenance reports/ checklist should be ready before 1st SV audit.
4.	The person / party who approves / endorses the maintenance result for the robot at site	If maintenance result is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer) or Site-in-charge, such approval or endorsement result has to be obtained prior to resuming the robot to duty, documented and retained.
5.	Emergency Contacts should be included in the maintenance manual.	The emergency contacts should be accessible 24 hours per day.

E. Disassembly Manual

Item	Key Contents	Remarks
1.	Role and Responsibilities of robot operator and close stakeholders who are involved in the disassembly of the robot.	Relevant stakeholders must be communicated about their role and responsibility.
2.	Required conditions, facility, environment, and resources for the disassembly of robot at site	Conditions may include licenses issued from various government departments and power supply. Resources here include legal employment of qualified / authorized personnel and authorized vehicles
3.	A robot disassembly methodology should include the followings: - Description of the disassembly or dis-mounting method of the robot at different situations in details, - Risk assessment and precaution measures should be included.	If the disassembly methodology is required to be examined by AP, the robot operator has to assist the AP for processing the examination. Where possible, the methodology should be illustrated or accompanied with self-explanatory sketches, diagrams, or drawings.
4.	The person / party who approves / endorses the disassembly methodology for the robot	If the disassembly of the robot is required to be approved / endorsed by AP (e.g. Registered Structural Engineer, Registered Professional Engineer), or Site-in-charge, approval or endorsement result has to be obtained prior to the disassembly of the robot, documented and retained.
5.	Emergency Contacts should be included in the disassembly manual	The emergency contacts should be accessible 24 hours per day

Appendix 10 – Immunity and Emission test requirements and limits according to CR-1-08TS-02: 2021 and CR-1-08TS-03: 2021 technical specifications and made reference to IEC 61000-4-3 ; IEC 61000-4-4; IEC 61000-4-5 ; IEC 61000-4-8

Table Im1 – Immunity test requirement at Enclosure Port

Item no.	Type of Immunity Test	Limits
Im1.1	Electrostatic discharge	±1 kV (contact discharge) ±8 kV (air discharge)
Im1.2	Radiated, radio-frequency electromagnetic field	80 ~ 1000 MHz 10 Volt/m 80 % AM @ 1kHz
Im1.3	Radiated, radio-frequency electromagnetic field	1.4 ~ 6.0 GHz 3 Volt/m 80 % AM @ 1kHz
Im1.4	Power frequency magnetic field	50 Hz 30 A/m

Table Im 2 - Immunity test requirement at Telecommunications Port

Item no.	Type of Immunity Test	Limits
Im2.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im2.2	Electrical Fast Transient Immunity Test	±1 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im2.3	Surge Immunity Test line to earth	1.2/50 (8/20) T_r/ T_h ns ±1 kV (open circuit test voltage)

Table Im 3 - Immunity test requirement at Low voltage DC mains Port

Item no.	Type of Immunity Test	Limits
Im3.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im3.2	Electrical Fast Transient Immunity Test	±1 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im3.3	Surge Immunity Test line to earth line to line	1.2/50 (8/20) T_r/ T_h ns ±1 kV (open circuit test voltage) ±0.5 kV (open circuit test voltage)

Table Im 4 - Immunity test requirement at Low voltage AC mains Port

Item no.	Type of Immunity Test	Limits
Im4.1	Radiated, radio-frequency common mode Immunity Test	0.15 MHz ~ 80 MHz 10 Volt 80 % AM @ 1kHz
Im4.2	Electrical Fast Transient Pulse Immunity Test	±2 kV (open circuit test voltage) 5/50 T_r/ T_h ns 100 kHz
Im4.3	Surge Immunity Test line to earth line to line	1.2/50 (8/20) T_r/ T_h ns ±2 kV (open circuit test voltage) ±1 kV (open circuit test voltage)
Im4.4	Voltage Dip	0 % residual voltage after 1 cycle
		40 % residual voltage after 10 cycles
		70 % residual voltage after 25 cycles
Im4.5	Voltage Terminated	0 % residual voltage after 1 cycle

Table Em1 - Emission requirement at Low voltage AC mains Port - Limit of Conducted Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em1	Low voltage AC Mains	0.15 MHz to 0.5 MHz	79 dB (μV) quasi-peak 66 dB (μV) average	
		0.5 MHz to 30 MHz	73 dB (μV) quasi-peak 60 dB (μV) average	

Table Em2 - Emission requirement at Telecommunications / Network Port – Voltage Disturbance Limit at Asymmetric / Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em2	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	97 ~ 87 dB (μV) quasi-peak 84 ~ 74 dB (μV) average	
		0.5 MHz to 30 MHz	87 dB (μV) quasi-peak 74 dB (μV) average	

Table Em3 - Emission requirement at Telecommunications / Network Port – Current Disturbance Limit at Asymmetric / Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em3	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	53 ~ 43 dB (μV) quasi-peak 40 ~ 30 dB (μV) average	
		0.5 MHz to 30 MHz	43 dB (μV) quasi-peak 30 dB (μV) average	

Table Em4 - Emission requirement at Telecommunications / Network Port – Current Limit of (Asymmetric) Transmission Common Mode for Class 'A' Disturbance [dB (μV)]

Item no.	Port	Frequency range	Limits	Remarks
Em4	Telecommunications / Network Port	0.15 MHz to 0.5 MHz	53 ~ 43 dB (μV) quasi-peak 40 ~ 30 dB (μV) average	
		0.5 MHz to 30 MHz	43 dB (μV) quasi-peak 30 dB (μV) average	

Glossary

ORDINANCES, REGULATIONS and CODES OF PRACTICE in HKSAR

Cap 59 Factories & Industrial Undertakings Ordinance (F&IU)

Cap 59I F&IU (Construction Sites (Safety)) Regulations

Cap 59N F&IU (Spraying of Flammable Liquids) Regulations

Cap 59Q F&IU (Guarding and Operation of Machinery) Regulations

Cap 59T F&IU (Noise at Work) Regulations

Cap 59W F&IU (Electricity) Regulations

Cap 59AC F&IU (Suspended Working Platform) Regulations

Cap 59AI F&IU (Gas Welding and Flame Cutting) Regulations

Cap 400 Noise Control Ordinance and Regulations

Cap 509 Occupational Safety and Health Ordinance

Cap 406 Electricity Ordinance and Electricity (Wiring) Regulations

Cap 51 Gas Safety Ordinance

Cap 295 Dangerous Goods ordinance

Cap 311 Air Pollution Ordinance - Air Pollution Control (Volatile Organic Compounds) Regulation

Guidelines Notes on the Trials of autonomous vehicles

Code of Practice for the Electricity (Wiring) Regulations, Electrical and Mechanical Services Department

Code of Practice for the Structural Use of Steel, Building Department

Code of Practice for Safety and Health at Work for Gas Welding and Flame Cutting, Labour Department

Code of Practice for Safe Use and Operation of Suspended Working Platforms, Labour Department

Guidance Notes on Paint Spraying and Related Coating Processes, Labour Department

General Specification for Building Maintenance Works in Residential Buildings, BS Div., The Hong Kong Institute of Surveyors

Hong Kong Housing Authority Specification Library (Feb. 2019 ed.)

CIC Trade Test Centre's General Welder Trade Test pack

CIC Trade Test Centre's Painting Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.)

CIC Trade Test Centre's Plasterer Skilled Worker Trade Test Mock Practical Test Paper (2020 ed.)

Link: https://www.elegislation.gov.hk/

STANDARDS & REFERENCES

EC Directive 2006/42/EC on Machinery (17 May 2006)

ISO / IEC Standards:

ISO 1513: 2010 – Paints and varnishes – Examination and preparation of test samples

ISO/ IEC 2382 : 2015 Information Technology – Vocabulary

ISO 2808 : 2019 Paints and varnishes – Determination of film thickness

ISO 3691-4 : 2020 Industrial trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems

*ISO 8373: 2012 Robots and Robotic devices – Vocabulary

ISO 9283:1998 Manipulating industrial robots – Performance criteria and related test, Equivalent standards (GB/T12642 -2013)

ISO 9946: 1999 – Manipulating industrial robots – Presentation of characteristics

*ISO 10218-1 : 2011 Robots and robotic devices – Safety requirements for industrial robots –

Part 1: Robots - Equivalent standards : (GB 11291.1-2011) (ANSI RIA R15.06) (UL1740)

*ISO 10218-2 : 2011 Robots and robotic devices – Safety requirements for industrial robots –

Part 2: Robot systems and integration - Equivalent standards : (GB 11291.2-2013), (ANSI RIA R15.06)

(UL1740)

*ISO 12100: 2010 Safety of machinery – General principles for design- Risk assignment and risk reduction - Equivalent standards : (GB/T15706 -2010)

ISO 13849-1 : 2015 Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design

ISO 14732: 2013 Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials

ISO 15614-1:2017 + corrigenda July 2017 and May 2018 Specification and qualification of welding procedures for metallic materials – Welding procedure test Equivalent standard : (BS EN ISO 15614-1:2017)

ISO /IEC 17065: 2012 Conformity assessment – Requirements for bodies certifying products, processes and services

ISO 18646-1:2016 Robotics — Performance criteria and related test methods for service robots — Part 1: Locomotion for wheeled robots

ISO 18646-2:2019 Robotics — Performance criteria and related test methods for service robots — Part 2: Navigation

ISO 22915-1: 2016 Industrial trucks – Verification of stability – Part 1: General

*IEC 60204-1: 2016 Safety of machinery – electrical equipment of machines Part 1 : General requirements - Equivalent standards : (EN 60204-1:2018), (GB/T 5226.1- 2019), (UL 508A) (NFPA 79)

IEC 60529: 1989+AMD 1:1999 + AMD2: 2013 +five corrigenda from Jan 2003 to Jan. 2019 – Degrees of Protection provided by enclosures (International Protection (IP) Code)

IEC 60896-21:2004 Stationary lead-acid batteries

IEC 61000-4-3:2020 Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency electromagnetic field immunity test

IEC 61000-4-4:2012 Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/ burst immunity test

IEC 61000-4-5:2017 Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test

IEC 61000-4-8:2009 Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test

IEC 62619:2017 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications

EN / BS EN / BS Standards:

* EN 60204-1: 2018 Safety of machinery – electrical equipment of machines Part 1 : General requirements - Equivalent standards : (GB/T 5226.1- 2019) (UL 508A) (NFPA 79) (IEC 60204-1: 2016)

BS EN 197-1: 2011 Composition, specifications, and conformity criteria for common cements

BS EN 1011-1: 2009 Welding – Recommendations for welding of metallic materials Part 1: General guidance for arc welding

BS EN 1015-11: 2019 Methods of test for mortar for masonry. Part 11 : Determination of flexural and compressive strength of hardened mortar.

BS EN 1015-12: 2016 Methods of test for mortar for masonry – Part 12 : Determination of adhesive strength of hardened rendering and plastering mortars on substrates. Equivalent standard : (ASTM C1860-20)

BS EN 16985: 2018 Spray booths for organic coating material – Safety requirements

BS EN 60529:1992 + A2:2013 Degrees of protection provided by enclosures (IP Code)

BS 6150: 2019 Painting of buildings – Code of Practice

GB Standards, and relevant Specifications and Regulations:

*GB 11291.1-2011 工业环境用机器人 安全要求 第 1 部分：机器人 (Robots for industrial environments-Safety requirements- Part 1: Robot). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

*GB 11291.2-2013 机器人与机器人装备 工业机器人的安全要求 第 2 部分：机器人系统与集成 (Robots and robotic devices. Safety requirements for industrial robots. Part 2: Robot systems and integration). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

GB 15579.1-2013 弧焊设备 第 1 部分焊接电源 (Arc welding equipment-part 1: Welding power sources). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

GB 50169-2016 电气装置安装工程接地装置施工及验收规范 (Code for construction and acceptance of grounding connection electric equipment installation engineering). 中华人民共和国国家质量监督检验检疫总局、中华人民共和国住房和城乡建设部.

GB 50300-2001 建筑工程施工质量验收统一标准(含条文说明) (Unified standard for constructional quality acceptance of building engineering). 中华人民共和国国家质量监督检验检疫总局、中华人民共和国住房和城乡建设部.

*GB/T 5226.1-2019 机械电气安全机械电气设备 第 1 部分通用技术条件 (Electrical safety of machinery—Electrical equipment of machines—Part 1: General requirements). 国家市场监督管理总局、中国国家标准化管理委员会.

GB/T 12642-2013 工业机器人 性能规范及其试验方法 (Industrial robots - Performance criteria and related test methods). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

GB/T 15706-2012 机械安全 设计通则 风险评估与风险减小 (Safety of machinery-general principles for design-risk assessment and risk reduction). 中华人民共和国国家质量监督检验检疫总局、中国国家标准化管理委员会.

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UL 3100 Outline of Investigation for Automated Guides Vehicles

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Techncial Requirements for Construction Robots for Painting, Plastering and Welding (April 2023)

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