Comau Robotics
Instruction Handbook

SMART5 SiX

Maintenance

CR00757661_en-01/2010.11

SUMMARY

PREFACE

Symbols used in the manual

The symbols for **WARNING, CAUTION** and **NOTES** are indicated below together with their significance

This symbol indicates operating procedures, technical information and precautions that if ignored and/or are not performed correctly could cause injuries.

This symbol indicates operating procedures, technical information and precautions that if ignored and/or are not performed correctly could cause damage to the equipment.

This symbol indicates operating procedures, technical information and precautions that it are important to highlight.

Reference documents

This document refers to the SMART5 SiX robot with standard outfitting.

The complete set of manuals that describe the robot system and control is composed of :

Comau	Robot SMART5 SiX	– Technical Specifications – Transport and installation – Maintenance – Electrical diagram

These manuals are to be integrated with the following documents:

Comau	C5G Control Unit	– Technical Specifications – Transport and installation – Guide to integration, safeties, I/O and communications – Maintenance – Use of Control Unit – Electrical diagram
	Programming	– EZ PDL2 Easy programming environment – PDL2 Programming Language Manual – Move programming

1. GENERAL SAFETY PRECAUTIONS

It deals with a general specification that apply to the whole Robot System. Due to ist significance, this document is referred to unreservedly in any system instruction manual.

This specification deals with the following topics:

– Responsibilities

– Safety Precautions.

1.1 Responsibilities

– The system integrator is responsible for ensuring that the Robot System (Robot and Control System) are installed and handled in accordance with the Safety Standards in force in the country where the installation takes place. The application and use of the protection and safety devices necessary, the issuing of declarations of conformity and any CE markings of the system are the responsibility of the Integrator.

– COMAU Robotics & Service shall in no way be held liable for any accidents caused by incorrect or improper use of the Robot System (Robot and Control System), by tampering with circuits, components or software, or the use of spare parts that are not included in the spare parts list.

– The application of these Safety Precautions is the responsibility of the persons assigned to direct / supervise the activities indicated in the Applicability sectionally are to make sure that the Authorised Personnel is aware of and scrupulously follow the precautions contained in this document as well as the Safety Standards in addition to the Safety Standards in force in the country in which it is installed.

– The non-observance of the Safety Standards could cause injuries to the operators and damage the Robot System (Robot and Control System).

The installation shall be made by qualified installation Personnel and should conform to all national and local codes.

1.2 Safety Precautions

1.2.1 Purpose

These safety precautions are aimed to define the behaviour and rules to be observed when performing the activities listed in the Applicability section.

1.2.2 Definitions

Robot System (Robot and Control System)
The Robot System is a functional unit consisting of Robot, Control Unit, Programming terminal and possible options.

Protected Area
The protected area is the zone confined by the safety barriers and to be used for the installation and operation of the robot

Authorised Personnel
Authorised personnel defines the group of persons who have been trained and assigned to carry out the activities listed in the Applicability section.

Assigned Personnel
The persons assigned to direct or supervise the activities of the workers referred to in the paragraph above.

Installation and Putting into Service
The installation is intended as the mechanical, electrical and software integration of the Robot and Control System in any environment that requires controlled movement of robot axes, in compliance with the safety requirements of the country where the system is installed.

Programming Mode
Operating mode under the control of the operator, that excludes automatic operation and allows the following activities: manual handling of robot axes and programming of work cycles at low speed, programmed cycle testing at low speed and, when allowed, at the working speed.

Auto / Remote Automatic Mode
Operating mode in which the robot autonomously executes the programmed cycle at the work speed, with the operators outside the protected area, with the safety barriers closed and the safety circuit activated, with local (located outside the protected area) or remote start/stop.

Maintenance and Repairs
Maintenance and repairs are activities that involve periodical checking and / or replacement (mechanical, electrical, software) of Robot and Control System parts or components, and trouble shooting, that terminates when the Robot and Control System has been reset to its original project functional condition.

Putting Out of Service and Dismantling
Putting out of service defines the activities involved in the mechanical and electrical removal of the Robot and Control System from a production unit or from an environment in which it was under study.
Dismantling consists of the demolition and dismantling of the components that make up the Robot and Control System.

Integrator
The integrator is the professional expert responsible for the installation and putting into service of the Robot and Control System.

Incorrect Use
Incorrect use is when the system is used in a manner other than that specified in the Technical Documentation.

Range of Action
The robot range of action is the enveloping volume of the area occupied by the robot and its fixtures during movement in space.

1.2.3 Applicability

These Specifications are to be applied when executing the following activities:

– Installation and Putting into Service;
– Programming Mode;
– Auto / Remote Automatic Mode;
– Robot axes release;
– Maintenance and Repairs;
– Putting Out of Service and Dismantling

1.2.4 Operating Modes

Installation and Putting into Service

- Putting into service is only possible when the Robot and Control System has been correctly and completely installed.
- The system installation and putting into service is exclusively the task of the authorised personnel.
- The system installation and putting into service is only permitted inside a protected area of an adequate size to house the robot and the fixtures it is outfitted with, without passing beyond the safety barriers. It is also necessary to check that under normal robot movement conditions there is no collision with parts inside the protected area (structural columns, power supply lines, etc.) or with the barriers. If necessary, limit the robot working areas with mechanical hard stop (see optional assemblies).
- Any fixed robot control protections are to be located outside the protected area and in a point where there is a full view of the robot movements.
- The robot installation area is to be as free as possible from materials that could impede or limit visibility.
- During installation the robot and the Control Unit are to be handled as described in the product Technical Documentation; if lifting is necessary, check that the eye-bolts are fixed securely and use only adequate slings and equipment.
- Secure the robot to the support, with all the bolts and pins foreseen, tightened to the torque indicated in the product Technical Documentation.
- If present, remove the fastening brackets from the axes and check that the fixing of the robot fixture is secured correctly.
- Check that the robot guards are correctly secured and that there are no moving or loose parts. Check that the Control Unit components are intact.
- If applicable, connect the robot pneumatic system to the air distribution line paying attention to set the system to the specified pressure value: a wrong setting of the pressure system influences correct robot movement.
- Install filters on the pneumatic system to collect any condensation.
- Install the Control Unit outside the protected area: the Control Unit is not to be used to form part of the fencing.
- Check that the voltage value of the mains is consistent with that indicated on the plate of the Control Unit.
- Before electrically connecting the Control Unit, check that the circuit breaker on the mains is locked in open position.
- Connection between the Control Unit and the three-phase supply mains at the works, is to be with a four-pole (3 phases + earth) armoured cable dimensioned appropriately for the power installed on the Control Unit. See the product Technical Documentation.
- The power supply cable is to enter the Control Unit through the specific fairlead and be properly clamped.
- Connect the earth conductor (PE) then connect the power conductors to the main switch.

– Connect the power supply cable, first connecting the earth conductor to the circuit breaker on the mains line, after checking with a tester that the circuit breaker terminals are not powered. Connect the cable armouring to the earth.

– Connect the signals and power cables between the Control Unit and the robot.

– Connect the robot to earth or to the Control Unit or to a nearby earth socket.

– Check that the Control Unit door (or doors) is/are locked with the key.

– A wrong connection of the connectors could cause permanent damage to the Control Unit components.

– The C5G Control Unit manages internally the main safety interlocks (gates, enabling pushbuttons, etc.). Connect the C5G Control Unit safety interlocks to the line safety circuits, taking care to connect them as required by the Safety standards. The safety of the interlock signals coming from the transfer line (emrgency stop, gates safey devices etc) i.e. the realisation of correct and safe circuits, is the responsibility of the Robot and Control System integrator.

In the cell/line emergency stop circuit the contacts must be included of the control unit emergency stop buttons, which are on X30. The push buttons are not interlocked in the emergency stop circuit of the Control Unit.

– The safety of the system cannot be guaranteed if these interlocks are wrongly executed, incomplete or missing.

– The safety circuit executes a controlled stop (IEC 60204-1 , class 1 stop) for the safety inputs Auto Stop/ General Stop and Emergency Stop. The controlled stop is only active in Automatic states; in Programming the power is cut out (power contactors open) immediately. The procedure for the selection of the controlled stop time (that can be set on SDM board) is contained in the Installation manual .

– When preparing protection barriers, especially light barriers and access doors, bear in mind that the robot stop times and distances are according to the stop category (0 or 1) and the weight of the robot.

Check that the controlled stop time is consistent with the type of Robot connected to the Control Unit. The stop time is selected using selector switches SW1 and SW2 on the SDM board.

– Check that the environment and working conditions are within the range specified in the specific product Technical Documentation.

– The calibration operations are to be carried out with great care, as indicated in the Technical Documentation of the specific product, and are to be concluded checking the correct position of the machine.

– To load or update the system software (for example after replacing boards), use only the original software handed over by COMAU Robotics & Service. Scrupulously follow the system software uploading procedure described in the Technical Documentation supplied with the specific product. After uploading, always make some tests moving the robot at slow speed and remaining outside the protected area.

– Check that the barriers of the protected area are correctly positioned.

Programming Mode

- The robot is only to be programmed by the authorised personnel.
- Before starting to program, the operator must check the Robot System (Robot and Control System) to make sure that there are no potentially hazardous irregular conditions, and that there is nobody inside the protected area.
- When possible the programming should be controlled from outside the protected area.
- Before operating inside the Protected Area, the operator must make sure from outside that all the necessary protections and safety devices are present and in working order, and especially that the hand-held programming unit functions correctly (slow speed, emergency stop, enabling device, etc.).
- During the programming session, only the operator with the hand-held terminal is allowed inside the Protected Area.
- If the presence of a second operator in the working area is necessary when checking the program, this person must have an enabling device interlocked with the safety devices.
- Activation of the motors (Drive On) is always to be controlled from a position outside the range of the robot, after checking that there is nobody in the area involved. The Drive On operation is concluded when the relevant machine status indication is shown.
- When programming, the operator is to keep at a distance from the robot to be able to avoid any irregular machine movements, and in any case in a position to avoid the risk of being trapped between the robot and structural parts (columns, barriers, etc.), or between movable parts of the actual robot.
- When programming, the operator is to avoid remaining in a position where parts of the robot, pulled by gravity, could execute downward movements, or move upwards or sideways (when installed on a sloped plane).
- Testing a programmed cycle at working speed with the operator inside the protected area, in some situations where a close visual check is necessary, is only to be carried out after a complete test cycle at slow speed has been executed. The test is to be controlled from a safe distance.
- Special attention is to be paid when programming using the hand-held terminal: in this situation, although all the hardware and software safety devices are active, the robot movement depends on the operator.
- During the first running of a new program, the robot may move along a path that is not the one expected.
- The modification of program steps (such as moving by a step from one point to another of the flow, wrong recording of a step, modification of the robot position out of the path that links two steps of the program), could give rise to movements not envisaged by the operator when testing the program.
- In both cases operate cautiously, always remaining out of the robot's range of action and test the cycle at slow speed.

Auto / Remote Automatic Mode

– The activation of the automatic operation (AUTO and REMOTE states) is only to be executed with the Robot System (Robot and Control System) integrated inside an area with safety barriers properly interlocked, as specified by Safety Standards currently in force in the Country where the installation takes place.

– Before starting the automatic mode the operator is to check the Robot and Control System and the protected area to make sure there are no potentially hazardous irregular conditions.

– The operator can only activate automatic operation after having checked:
  • that the Robot and Control System is not in maintenance or being repaired;
  • the safety barriers are correctly positioned;
  • that there is nobody inside the protected area;
  • that the Control Unit doors are closed and locked;
  • that the safety devices (emergency stop, safety barrier devices) are functioning;

– Special attention is to be paid when selecting the automatic-remote mode, where the line PLC can perform automatic operations to switch on motors and start the program.

Robot axes release

– In the absence of motive power, the robot axes movement is possible by means of optional release devices and suitable lifting devices. Such devices only enable the brake deactivation of each axis. In this case, all the system safety devices (including the emergency stop and the enable button) are cut out; also the robot axes can move upwards or downwards because of the force generated by the balancing system, or the force of gravity.

Before using the manual release devices, it is strongly recommended to sling the robot, or hook to an overhead travelling crane.

– Enabling the brake releasing device may cause the axes falling due to gravity as well as possible impacts due to an incorrect restoration, after applying the brake releasing module. The procedure for the correct usage of the brake releasing device (both for the integrated one and module one) is to be found in the maintenance manuals.

– When the motion is enabled again following the interruption of an unfinished MOVE, the track recovery typical function may generate unpredictable paths that may imply the risk of impact. This same condition arises at the next automatic cycle restarting. Avoid moving the Robot to positions that are far away from the ones provided for the motion restart; alternatively disable the outstanding MOVE programmes and/or instructions.

Maintenance and Repairs

– When assembled in COMAU Robotics & Service, the robot is supplied with lubricant that does not contain substances harmful to health, however, in some cases, repeated and prolonged exposure to the product could cause skin irritation, or if swallowed, indisposition.
First Aid. Contact with the eyes or the skin: wash the contaminated zones with abundant water; if the irritation persists, consult a doctor.
If swallowed, do not provoke vomiting or take anything by mouth, see a doctor as soon as possible.

- Maintenance, trouble-shooting and repairs are only to be carried out by authorised personnel.
- When carrying out maintenance and repairs, the specific warning sign is to be placed on the control panel of the Control Unit, stating that maintenance is in progress and it is only to be removed after the operation has been completely finished - even if it should be temporarily suspended.
- Maintenance operations and replacement of components or the Control Unit are to be carried out with the main switch in open position and locked with a padlock.
- Even if the Control Unit is not powered (main switch open), there may be interconnected voltages coming from connections to peripheral units or external power sources (e.g. 24 Vdc inputs/outputs). Cut out external sources when operating on parts of the system that are involved.
- Removal of panels, protection shields, grids, etc. is only allowed with the main switch open and padlocked.
- Faulty components are to be replaced with others having the same code, or equivalent components defined by COMAU Robotics & Service.

After replacement of the SDM module, check on the new module that the setting of the stop time on selector switches SW1 and SW2 is consistent with the type of Robot connected to the Control Unit.

- Trouble-shooting and maintenance activities are to be executed, when possible, outside the protected area.
- Trouble-shooting executed on the control is to be carried out, when possible without power supply.
- Should it be necessary, during trouble-shooting, to intervene with the Control Unit powered, all the precautions specified by Safety Standards are to be observed when operating with hazardous voltages present.
- Trouble-shooting on the robot is to be carried out with the power supply cut out (Drive off).
- At the end of the maintenance and trouble-shooting operations, all deactivated safety devices are to be reset (panels, protection shields, interlocks, etc.).
- Maintenance, repairs and trouble-shooting operations are to be concluded checking the correct operation of the Robot System (Robot and Control System) and all the safety devices, executed from outside the protected area.
- When loading the software (for example after replacing electronic boards) the original software handed over by COMAU Robotics & Service is to be used. Scrupulously follow the system software loading procedure described in the specific product Technical Documentation; after loading always run a test cycle to make sure, remaining outside the protected area
- Disassembly of robot components (motors, balancing cylinders, etc.) may cause uncontrolled movements of the axes in any direction: before starting a disassembly procedure, consult the warning plates applied to the robot and the Technical Documentation supplied.
- It is strictly forbidden to remove the protective covering of the robot springs.

Putting Out of Service and Dismantling

– Putting out of service and dismantling the Robot and Control System is only to be carried out by Authorised Personnel.

– Bring the robot to transport position and fit the axis clamping brackets (where applicable) consulting the plate applied on the robot and the robot Technical Documentation.

– Before stating to put out of service, the mains voltage to the Control Unit must be cut out (switch off the circuit breaker on the mains distribution line and lock it in open position).

– After using the specific instrument to check there is no voltage on the terminals, disconnect the power supply cable from the circuit breaker on the distribution line, first disconnecting the power conductors, then the earth. Disconnect the power supply cable from the Control Unit and remove it.

– First disconnect the connection cables between the robot and the Control Unit, then the earth cable.

– If present, disconnect the robot pneumatic system from the air distribution line.

– Check that the robot is properly balanced and if necessary sling it correctly, then remove the robot securing bolts from the support.

– Remove the robot and the Control Unit from the work area, applying the rules indicated in the products Technical Documentation; if lifting is necessary, check the correct fastening of the eye-bolts and use appropriate slings and equipment only.

– Before starting dismantling operations (disassembly, demolition and disposal) of the Robot and Control System components, contact COMAU Robotics & Service, or one of its branches, who will indicate, according to the type of robot and Control Unit, the operating methods in accordance with safety principles and safeguarding the environment.

– The waste disposal operations are to be carried out complying with the legislation of the country where the Robot and Control System is installed.

1.2.5 Performance

The performances below shall be considered before installing the robot system:

– Stop distances

– Mission time (typ. case).

Stop distances

– With Robot in programming modality (T1), if you press the sttop pushbutton (red mushroom-shaped one on WiTP) in category 0 (secondo norma EN60204-1), you will obtain:

Tab. 1.1 - Stop spaces in programming modality (T1)

Mode	Expected speed	Case	Stopping time	Stopping space
T1	250 mm/s	Nominal	120 ms	30 mm
		Limit	500 ms	125 mm

Tab. 1.2 - Safety electronics reaction time in programming modality (T1)

Mode	Expected speed	Case	Stopping time
T1	250 mm/s	For the safety inputs of the SDM module (e.g. stop pushbutton of TP in wired version)	150 ms
		For the stop stop and enabling device inputs from the TP in wireless version, when the safety wire trasmission is active.	
		For the time-out of stop input and enabling device from TP in wireless version, when the safety wire transmission is lost or interrupted.	350 ms

– Considering the Robot in automatico modality, under full extension, full load and maximmum speed conditions, if you press the stop pushbutton (red mushroom-shaped one on WiTP) in category 1 (according to norm EN60204-1) you will trigger the Robot complete stop with controlled deleration ramp.
Example: for Robot NJ 370-2.7 you will obtain the complete stop in about 85 ° motion, that correspond to about 3000 mm movement measured on TCP flange. Under the said conditions, the stopping time for Robot NJ 370-2.7 is equal to 1,5 seconds.

Mission time (typ. case)

– We remind you that the safety system efficiency covering is equal to 20 years (**mission time** of safety-related parts of control systems (SRP/CS), according to EN ISO 13849-1).

2. PREVENTIVE MAINTENANCE

2.1 Overview

The robot requires very little maintenance. However, lubrication and the checks listed below must be performed at regular intervals to ensure efficiency.

Before starting any type of operation, read with care Chap.1. - General Safety Precautions on page 7
The robot must be serviced with the system turned off: the main circuit breaker MUST be in the OFF position.

Robots must be serviced regularly and accurately in order to maintain the original operating characteristics.

2.2 Lubrication

The type and amount of product to be used and the frequency of operations are described in Tab. 2.1 - SMART5 SiX Lubrication table on page 18.

The lubrication points and the layout of the lubrication filling and drainage caps are identified in Fig. 2.1 - SMART5 SiX Lubrication points on page 19 and shown in Tab. 2.2 - Position of oil and grease fill-up and drainage caps on page 20.

2.3 Precautions regarding the use of lubricants

At the COMAU works all robots are lubricated using products that do not contain any harmful substances. However, in some cases, repeated and prolonged exposure to such products may cause irritation of the skin and they may be harmful if swallowed.

In case of contact with the eyes or skin: rinse the affected areas with copious amounts of water; should irritation persist, seek medical advice.
If swallowed, do not induce vomiting or administer anything by mouth; seek medical advice immediately.

Tab. 2.1 - SMART5 SiX Lubrication table

Ref.	Lubrication points	Q.ty 1st filling	Q.ty 2nd filling	Type of lubricant	Frequency
1	Axis 1 reducer	2,4 kg *(5.29 lb)* 2,67 l	1,75 kg *(3.86 lb)* 1,94 l	***OIL*** **KLUBEROIL** GEM 1- 320 **FUCHS** Renolin CLP 320 **ELF** Reductelf 320 **SHELL** Omala 320 **MOBIL** Mobilgear 600 XP 320 **ESSO** Spartan EP 320 **TEXACO** Meropa 320	15000 hours
2	Axis 4 reducer	0,5 kg *(1.10 lb)* 0,56 l	0,35 kg *(0.77 lb)* 0,39 l		
3	Axis 2 reducer	0,45 kg *(0.99 lb)* 0,50 l	0,43 kg *(0.95 lb)* 0,48 l	***OIL*** **OPTIMOL** Optigear 150	
4	Axis 3 reducer	0,38 kg *(0.84 lb)* 0,42 l	0,37 kg *(0.82 lb)* 0,41 l		
5	Axis 5 reducer	0,014 kg *(0.031 lb)*	-	***GREASE*** **HARMONIC DRIVE** **Special grease 4B N°2**	
6	Axis 6 reducer	0,020 kg *(0.044 lb)*	-		
7	Axis 6 angle transmission	0,01 kg *(0.02 lb)*	-	***GREASE*** **FUCHS** Renolit Unitemp 2 **SHELL** Albida Grease RL2 **ESSO** Unirex N2 **TEXACO** Starplex EP2 **MOBIL** Mobilith SHC 100	5000 hours
8	Axis 5 angle transmission	0,020 kg *(0.044 lb)*	-		
9	Axis 6 angle transmission	0,020 kg *(0.044 lb)*	-		

The quantity of lubricant indicated for the first filling refers to filling after a new assembly has been installed.

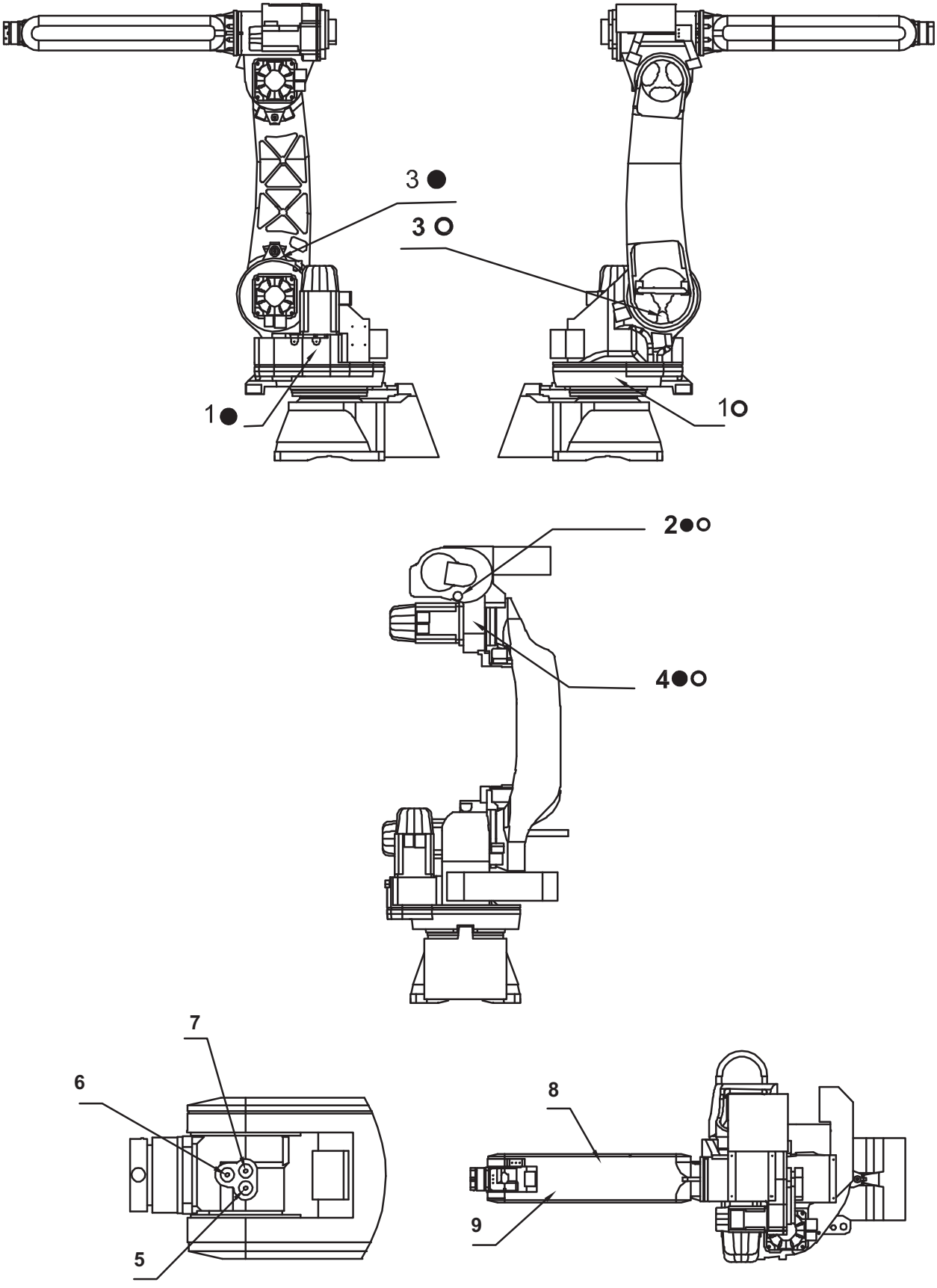
The quantity indicated for the second filling refers to the topping up of lubricant drained from the assembly, considering the indicative time to drain off between 10 and 15 minutes. The time required to drain off the lubricant depends on its viscosity and the temperature of the environment where the operation takes place.

To speed up oil drainage and fill-up operations, unscrew the caps of the air vents in the reducers.

The lubricants specified in the table cannot be mixed together.

When filling, the use of quantities greater than those indicated in the table could cause overflow, or in the worst cases, damage the sealing gaskets.

Fig. 2.1 - SMART5 SiX Lubrication points

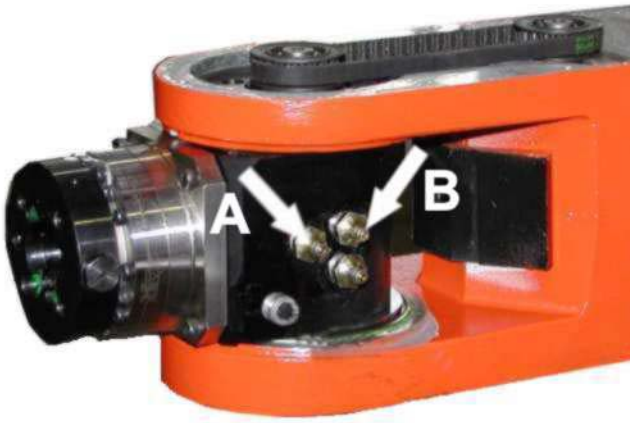
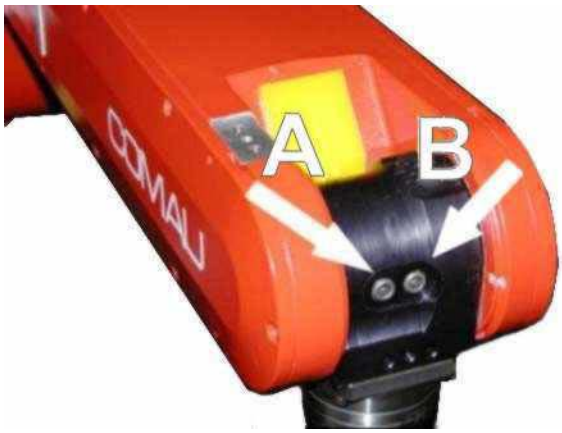
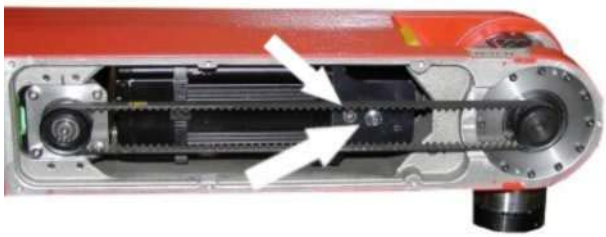


symbols used in the figure:
●= Oil filler cap; **O** = Oil drainage cap

Tab. 2.2 -Position of oil and grease fill-up and drainage caps

Ref.1 - Oil drainage from axis 1 reducer 	Ref.1 - Axis 1 reducer oil filling 
Ref.3 - Bleeding (A) and oil drainage (B) from axis 2 reducer 	Ref.3 - Axis 2 reducer oil filling 
Ref.4 - Oil drainage-filling (A) and bleeding (B) from axis 3 reducer 	Ref.2 - Axis 4 reducer oil drainage-filling 

Tab. 2.2 -Position of oil and grease fill-up and drainage caps (Continued)

<table>
<tr>
<td>– Ref.5 Grease nipple axis 5 reducer (C))
 
</td>
<td>– Ref.6 Grease nipple axis 6 reducer (A)
– Ref.7 Axis 6 angle transmission grease nipple (B)
 
</td>
</tr>
<tr>
<td>Ref.6: Air bleeding hole axis 6 reducer (D);
 
</td>
<td>– Ref.5 Grease nipple axis 5 reducer(A)
– Ref.6 Air bleeding hole angle transmission axis 6 (B)
 
</td>
</tr>
<tr>
<td>Ref.8: Axis 5 angle transmission grease nipple / Air bleeding hole;
  </td>
<td>Ref.9 Axis 6 angle transmission grease nipple / Air bleeding hole
  </td>
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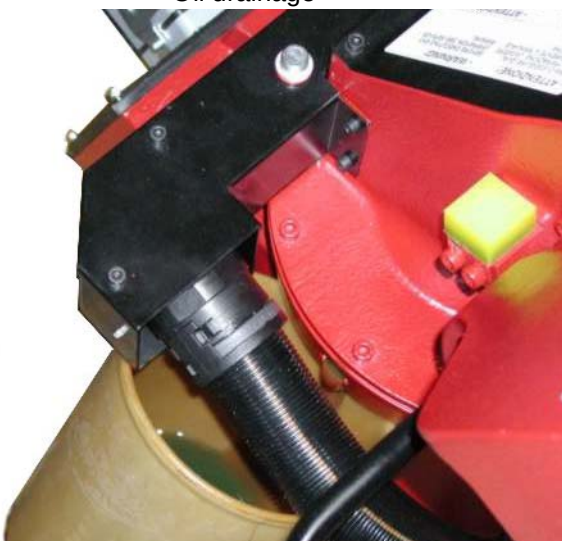
2.4 Notes for replacing lubricants

2.4.1 Axis 1

For the oil drainage and filling from axis 1, remove the plugs located on the reducer box (Tab. 2.2, Ref.1 - Oil drainage from axis 1 reducer, Ref.1 - Axis 1 reducer oil filling)

Oil drainage	Oil filling
	

2.4.2 Axis 2

For the oil drainage and filling from axis 2, remove the plugs located on the reducer box (Tab. 2.2, Ref.3 - Bleeding (A) and oil drainage (B) from axis 2 reducer, Ref.3 - Axis 2 reducer oil filling)

Oil drainage	Oil filling
	

2.4.3 Axis 3

For the oil drainage and filling from axis 3, the hole located on the forearm (Tab. 2.2 Ref.4 - Oil drainage-filling (A) and bleeding (B) from axis 3 reducer) can be used,

positioning it either downward or upwards

Oil drainage	Oil filling
	

2.4.4 Axis 4

For the oil drainage and filling from axis 4 the hole located on the forearm can be used, positioning it either downwards or upwards (Tab. 2.2 Ref.2 - Axis 4 reducer oil drainage-filling)

Oil drainage	Oil filling
	

2.4.5 Axes 5-6 kinematics lubrication

Before greasing the angle transmission and the reducers of axes 5 - 6, remove the air bleeding plugs specified in the following procedures.

2.4.5.1 Angle transmission axes 5 - 6 lubrication

a. Remove the wrist guards from the left and right side unscrewing the fastening screws with a 2.5mm T wrench.

b. Remove the plug from the air bleeding hole of the angle transimission indicated in the figure.

Angle transmission axis 5

Angle transmission axis 6

c. Cover the driving belt to protect it from the grease that will flow out from the bleeding hole during lubrication.

d. Introduce the prescribed grease (see Tab. 2.1 - SMART5 SiX Lubrication table on page 18) through the grease nipple **until clean grease flows out from the bleeding hole.**

e. Remove the excess grease from the bleeding hole. f. **Do not refit the plug on the bleeding hole** and move the robot axis for 5 minutes to evenly distribute the lubricant inside the assembly. g. Refit the plug on the bleeding hole. h. Reassemble the wrist side covers	

2.4.5.2 Axis 5 reducer lubrication

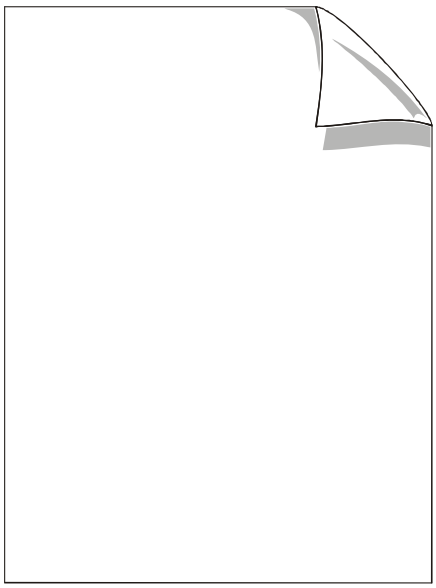
a. Remove the reducer air bleeding plug from the wrist casing.	
b. Introduce the prescribed grease (see Tab. 2.1 - SMART5 SiX Lubrication table on page 18) through the grease nipple **until clean grease flows out from the bleeding hole.**	
c. **Do not refit the plug on the bleeding hole** and move the robot axis for 5 minuts to evenly distribute the lubricant inside the assembly. d. Refit the plug on the bleeding hole.	

2.4.5.3 Axis 6 reducer lubrication

a. Remove the reducer air bleeding plug from the wrist casing.	
b. Introduce the prescribed grease (see Tab. 2.1 - SMART5 SiX Lubrication table on page 18) through the grease nipple **until clean grease flows out from the bleeding hole.** c. **Do not refit the plug on the bleeding hole,** move the robot axis for 5 minutes to evenly distribute the lubricant inside the assembly. d. Refit the plug on the bleeeding hole.	

2.4.5.4 Axis 6 gears

a. Remove the air bleeding hole plug indicated in the figure from the wrist casing.	
b. Introduce the prescribed grease (see Tab. 2.1 - SMART5 SiX Lubrication table on page 18) through the grease nipple **until clean grease flows out from the bleeding hole.**	
c. **Do not refit the plug on the bleeding hole** and move the robot axis for 5 minutes to evenly distribute the lubricant inside the assembly. d. Refit the plug on the bleeding hole.	



3. EXTRAORDINARY MAINTENANCE

3.1 Overview

The instructions for replacing the main robot parts following a mechanical breakdown or due to wear are set forth in the maintenance charts below.

Please read Chap.1. - General Safety Precautions on page 7 carefully before carrying out any maintenance operations.
The robot must be serviced with the system turned off: the main circuit breaker MUST be in the OFF position.

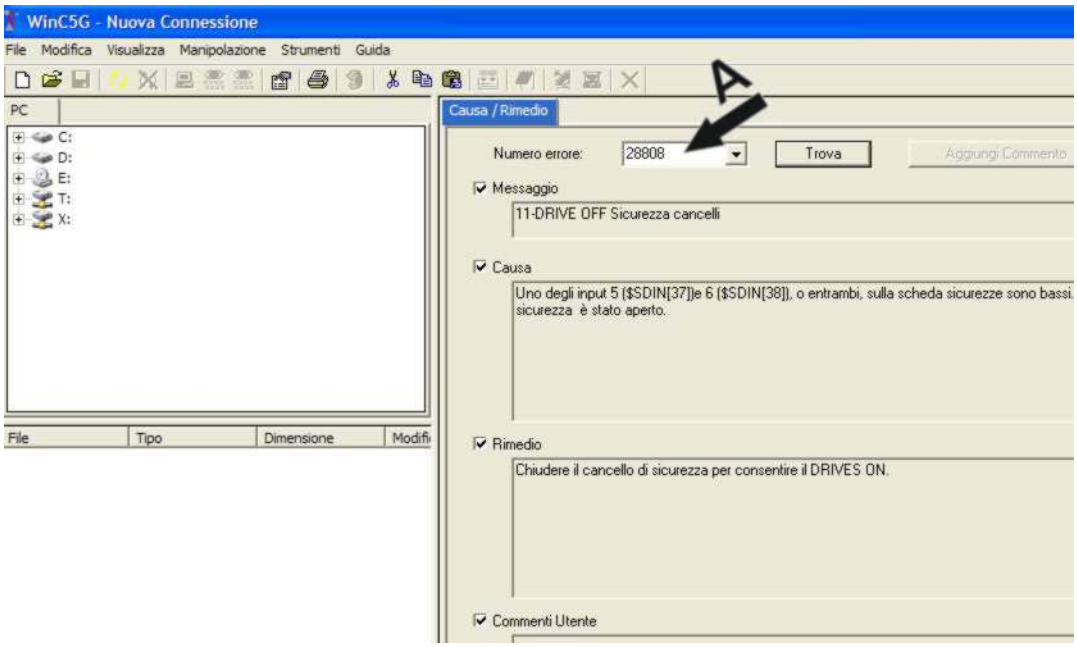
Robots must be serviced regularly and accurately in order to maintain the original operating characteristics.

3.2 Diagnostics

The system detects any robot malfunctions and notifies the operator of these by means of error messages, which are displayed in the lower part of the teach pendant.
These messages differ according to the importance of the fault and are divided into families.

WinC5G software can be used to make the error messages more comprehensible, identify the cause of the error that generated the message and define the relative solution.
The main software window (Fig. 3.1) is used to display the information described above.
To recall information, indicate the error code in field (A).

Fig. 3.1 - Main WinC5G window referring to error codes



3.3 Notes for assembly

Extraordinary maintenance operations must be performed by technicians using the appropriate tools and in accordance with all the standard operating procedures even if these are not expressly mentioned, including the following:
Check the O-rings, valve seals and bearings for any signs of wear and replace these if necessary;

- When reassembling parts, always proceed as follows:
- Apply the recommended thread adhesive to screw threads, see Tab. 3.2 - Typical uses of AREXONS products on page 33
- Use recommended products on sealing surfaces and to fasten componens, see Tab. 3.3 - Adhesive sealants and fasteners on page 33;
- Tighten screws and/or nuts to the prescribed tightening torque, see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32
- Apply AREXONS 52A22 to the outside diameter of seals for rotating shafts and rubber sealing plugs.
- Use FUCHS ANTICORIT DFW to protect any exposed machined surfaces.
- When assembling double-lipped rotating seals or in case of a double seal, fill the gap between the two lips with "NLGI NR.2" performance grade grease.

Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%)

d x l	Class 8.8 screws	Class 10.9 screws	Class 12.9 screws
3x 0,5	1,5	1,9	2,3
4x 0,7	3,1	4,3	5,2
5x 0,8	6	8,5	10,1
6x1	10,4	14,6	17,5

Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%)

d x l	Class 8.8 screws	Class 10.9 screws	Class 12.9 screws
8x1,25	24,6	34,7	41,6
10x1,5	50,1	70,5	84,6
12x1,75	84,8	119	143
14x2	135	190	228
16x2	205	288	346
20x2,5	400	562	674
24x3	691	971	1170

A tolerance of ± 10% is allowed on tightening torques of screws and locknuts for preloading of bearings

Tab. 3.2 - Typical uses of AREXONS products

Material	Screws up to M6	Screws from M8 upwards	Plugs and fittings
Aluminum	52A22	52A22	35A72
Aluminum with Heli-coil	52A22	52A43	-
Steel	52A22	52A43	35A72
Cast iron	52A22	52A43	35A72

Tab. 3.3 - Adhesive sealants and fasteners

Application	AREXONS
Sealant for flat surfaces	35A73
Polyurethane sealant	S006
Bearing fasteners	56A41
High strength fasteners	56A48

3.4 Disposal of parts

Used oil and grease **MUST BE DISPOSED OF IN ACCORDANCE WITH THE LAWS IN FORCE IN THE COUNTRY IN WHICH THE ROBOT IS INSTALLED.**
Should it become necessary to dispose of all or part of the robot, the various parts to be disposed of MUST be collected separately (for example, iron with iron and plastic with plastic). Such parts MUST also be disposed of in accordance with the laws in force in the country in which the robot is installed.

3.5 Usage instructions for the brake releasing device

When motive power is missing, the robot axes can be moved using the brake releasing devices and suitable lifting means. Such devices allow only to disable the brake of each axis. In that case, all system safety devices (including the emergency stop and enabling pushbutton) are cut-off.

Status:	–	Power available, C5G on.
Material:	–	Brake releasing device installed on Robot.

Equipment:

– Suitable lifting means to support the Robot axes subject to gravity

Preliminary procedures / notes

During the brake releasing procedure, the operator shall not stand nearby robot parts that can move upward or downward due to forces produced by the balancing system or to gravity.
The Robot axes that may drop due to gravity shall be supported using suitable lifting means (crane, bridge crane).
For this procedure at least 2 operators are required: one controlling the crane or bridge crane and the other controlling the axis brake releasing.
The dynamic braking function could be damaged due to faults occurring on the same actuating section in the C5G or to the missing electric connection of the motors: in that case the brake releasing will cause the axis dropping.
In case of proper operating of the dynamic braking, the risk of axis dropping cannot be avoided but the drop will be slowed down.

– In order to be able to operate the integrated brake releasing device requires:
  - that electric power is delivered to the Control Unit.
  - that the Control Unit is on with 24Vdc section available and working properly.
  - that the Robot is connected to the Control Unit.
  - that the motors are off (Drive OFF). When the motors are in Drive ON, pressing the pushbutton will not achieve any effect.
– The axis motion freedom is opposed and slowed down by the dynamic braking.

Operating procedure
a. Support the robot axes that are subject to gravity by means of a crane or bridge crane. Use ropes or bands, but do not use chains. Refer to the Robot manual to identify the points that are most suitable to sling the Robot.
b. To release the brake of the Robot axes: • Press the pushbuttons (A) singolarly. • Each pushbutton features the wording identifying the corresponding axis.
c. We recommend to control the brake releasing by pressing the pushbutton shortly and contemporaneously reducing gradually the tension of the ropes used to support the axes that are subject to gravity.
d. The control is active for the time the action is performed: at the release, the motion stops thanks to the brake action.

Follow-up procedure
– Not required.

3.6 AXIS 1 MOTOR: complete replacement

Status:	–	This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position.
	–	Move axis 1 of the robot to a position in which the motor is accessible
Spare part:	–	Axis 1 motor: code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81
Equipment:	–	5 and 6 mm male hex T wrench
	–	Lever approximately 400 mm long
Fastening components:	–	M8 x 20 socket head cap screws for motor; q.ty 4
	–	M6 socket head cap screws for pinion, q.ty 1
	–	Sealant for surfaces, see Tab. 3.2

Preliminary operations / notes

– Disconnect the electrical connectors from the motor.

Some components inside the motor could be damaged if subject to violent impacts: do not use a hammer or beat against the motor during disassembly and reassembly.
The improper use of hammers or other tools on the motor will undermine the validity of the guarantee.

Disassembly

a. Use the 6 mm wrench to unscrew the 4 M8 x 20 mm socket head cap screws used to fasten the motor to the body of the axis 1 reducer.

b. Remove the motor from the axis 1 reducer flange. If necessary insert a lever in the notch provided on the reducer and apply a torque to separate the motor from the reducer flange

Do not use a hammer or beat against the motor when disassembling.

Disassembly (Continued)

c. Stand the motor on a flat surface or transfer it to a work bench in order to remove the pinion.

d. Use the 5 mm male hex T wrench to unscrew the 6 mm socket head cap screw that fastens the pinion to the driving shaft and remove the pinion.

Reassembly

a. Clean and lubricate the driving shaft and then key the pinion to this.

b. Tighten the M6 screw used to fasten the pinion to the driving shaft to the correct torque, see Tab. 3.1.

c. Clean the motor coupling flange and apply the specific oil seal (see Tab. 3.3 - Adhesive sealants and fasteners on page 33).

Reassembly (Continued)

d. Reassemble the motor on the reducer by performing the disassembly procedure in reverse.

When reassembling, apply the prescribed sealant to the screws and tighten all the screws to the prescribed tightening torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32).

When tightening screws, apply a radial force to the motor to compensate for any mesh clearance.

e. Calibrate the axis after completing all reassembly operations. (see Fig. 7.4 - Axis 1 calibration on page 101).

3.7 AXIS 3 MOTOR: complete replacement

Status:	–	This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position. **When the motor is removed axis 3 is released: block the axis in a safe position to prevent any uncontrolled upward or downward movements that could injure any operators who may be standing close to the robot.**
Spare part:	–	Axis 3 motor: code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81
Equipment:	–	T wrench with 6mm male hex with 4mm male hex
	–	Lever approximately 400 mm long
Fastening components:	–	M8 x 20 mm socket head cap screws for motor, q.ty 4
	–	M5 x 20 mm socket head cap screws for pinion, q.ty 1
	–	Sealant for surfaces, see Tab. 3.3

Preliminary operations / notes

When the motor is removed axis 3 is released. Before commencing make sure that the axis is blocked in a position where it is safe from any uncontrolled movements of the masses applied to the robot.

a. Move axis 3 to the end of its negative stroke or make sure that the forearm is supported in an appropriate manner while disassembling the motor.

b. Disconnect the electrical connectors from the motor.

Procedure	
a. Drain the oil from the axis 3 reducer as indicated in Chap.2.4.3 - Axis 3 on page 22. b. Unscrew the 4 fastening screws (A) of the motor using a 6mm T wrench	
c. If necessary insert an angled lever into the specific notches on the column of the robot to detach the motor from the reducer flange.	
d. Remove the motor from its location seat and transfer it to the bench.	

Procedure (Continued)

e. Using a T wrench with 4mm male hex, unscrew the M5 socket head cap screw and remove the pinion from the driving shaft.

Reassembly

a. Clean and lubricate the surfaces used to couple the pinion to the driving shaft.

b. Key the pinion, taking care not to knock against the driving shaft and tighten the M5 socket head cap screw to the prescribed torque (see Tab. 3.1) to secure the axis.

c. Apply the oil sealant to the motor coupling flange (see Tab. 3.3 - Adhesive sealants and fasteners on page 33).

d. Reassemble the motor on the reducer following the removal procedure in reverse, and tighten the 4 M8x20 socket head cap screws that fasten the motor using a 6mm T wrench.

When reassembling, apply the prescribed sealant to the screws and tighten all the screws to the prescribed tightening torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.

e. Fill the reducer with the prescribed lubricating oil (see Chap.2.4.3 - Axis 3 on page 22 and Tab. 2.1 - SMART5 SiX Lubrication table on page 18)

f. Calibrate the axis after completing all reassembly operations. (see Fig. 7.6 - Axis 3 calibration on page 103).

3.8 AXIS 2 MOTOR: complete replacement

Status:	–	This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position. **When the motor is removed axis 2 is released. The axis must therefore be moved to rest against the stop pads at the end of its negative stroke to prevent any uncontrolled upward or downward movements that could injure any operators who may be standing close to the robot.**
Spare part:	–	Axis 2 motor: code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81;
Equipment:	–	T wrench: with 6mm male hex with 4mm male hex
	–	Lever approximately 400 mm long
	–	Ropes for hoisting
Fastening components:	–	M8 x 30 mm socket head cap screws for motor, q.ty 4
	–	M5 socket head cap screws for pinion, q.ty 1
	–	Sealant for surfaces, see Tab. 3.3

Preliminary operations / notes

When the motor is removed axis 2 is released. Before commencing make sure that the axis is blocked in a position where it is safe from the effects of any uncontrolled movements of the masses applied to the robot.

Some components inside the motor could be damaged if subject to violent impacts: do not use a hammer or beat against the motor during disassembly and reassembly.

The improper use of hammers or other tools on the motor will undermine the validity of the guarantee.

– If possible, depending on the specific robot configuration, move axis 2 **to the end of its negative stroke so that it rests against the stop pads** as illustrated in the following figure; **if this is not possible, block the forearm to prevent any uncontrolled robot movements when the motor is detached.**

– Disconnect the electrical connectors from the motor

Disassembly	
a. Drain the oil from the axis 2 reducer as indicated in Chap.2.4.2 - Axis 2 on page 22. b. Use the 8 mm T wrench to unscrew the 4 fastening screws (A) on the motor.	
c. Insert an angled lever into the specific notches on the robot column to remove the motor from the reducer flange.	
d. Take the motor to the bench and remove the pinion from the driving shaft, unscrewing the axial M5 socket head cap screw using a 4mm T wrench	

Reassembly

a. Clean and lubricate the surfaces used to couple the pinion to the driving shaft.

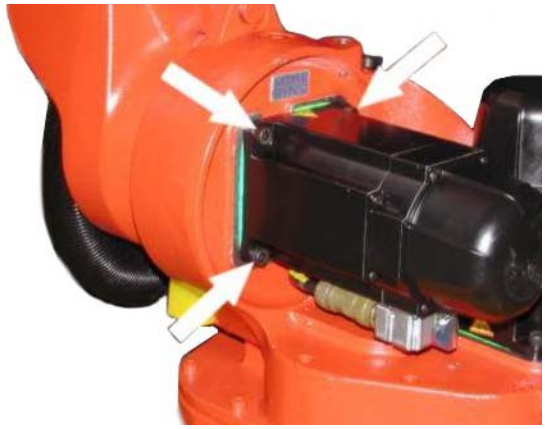
b. Clamp the pinion without knocking on the driving shaft, and tighten the axial M5 socket head cap screw to the specified torque using a 4mm T wrench see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32

c. Apply the oil sealant to the motor coupling flange (see Tab. 3.2 - Typical uses of AREXONS products on page 33).

d. Reassemble the motor on the reducer by performing the disassembly procedure in reverse.

e. Fill the reducer with the prescribed lubricating oil (see Tab. 2.1 - SMART5 SiX Lubrication table on page 18).

f. Calibrate the axis after completing all reassembly operations (see Fig. 7.5 - Axis 2 calibration on page 102).



When reassembling, apply the prescribed sealant to the screws and tighten all the screws to the prescribed tightening torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.

3.9 AXIS 4 MOTOR: complete replacement

Status:	–	This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position. **When the motor is removed axis 4 is released: block the axis in a safe position to prevent any un-controlled upward or downward movements that could injure any operators who may be standing close to the robot.**
Spare part:	–	Axis 4 motor: code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81;
Equipment:	–	T wrench: with 6 mm male hex with 4 mm male hex
Fastening components:	–	M8 x 20 mm socket head cap screws for motor, q.ty 4
	–	M5 x 85 socket head cap screws for pinion, q.ty 1

Preliminary operations / notes

Some components inside the motor could be damaged if subject to violent impacts: do not use a hammer or beat against the motor during disassembly and reassembly.
The improper use of hammers or other tools on the motor will undermine the validity of the guarantee.

When the motor is removed the axes are released: it is important to block the axes to prevent these from falling due to gravity.

– Move axis 3 until the axis of the motor is vertical or block the forearm to prevent any uncontrolled movements of the masses applied to the robot when the motor is removed.

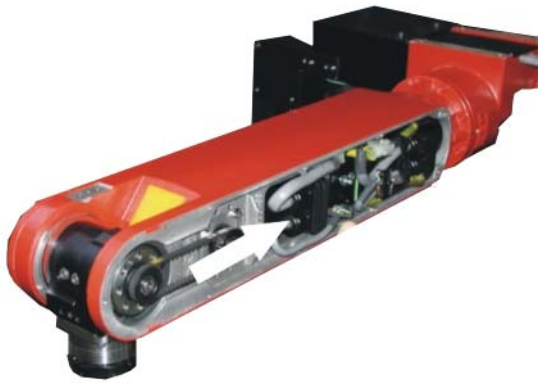
Disassembly	
g. Unscrew the 4 fastening screws on the electric connectors guard and remove the guard	
h. Remove the electric connectors from the wiring	
i. Remove the 4 M8x20 socket head cap screws that fasten the motor to the reducer. j. Remove the motor from the reducer flange, applying a torque with a lever inserted in the reducer notch k. Remove the motor and take it to the bench.	

Disassembly (Continued)	
l. Use a 4mm T wrench to unscrew the M5x85 socket head cap screw that fastens the pinion and remove it from the driving shaft	

Reassembly	
a. Clean and lubricate the surfaces used to couple the pinion to the driving shaft. b. Key the pinion, taking care not to knock against the driving shaft, and block the clamp by tightening the 4 mm socket head cap screw to the prescribed torque, see Tab. 3.1 c. Clean the coupling surface on the motor and remove any traces of old sealant.	
d. Apply the oil sealant to the motor coupling flange (see Tab. 3.3 - Adhesive sealants and fasteners on page 33).	

Reassembly (Continued)	
e.	Reassemble the motor on the reducer by performing the disassembly procedure in reverse.  **When reassembling, apply a radial force to the motor to compensate for any mesh clearance between the pinion and the gear.** **Tighten all the screws to the prescribed tightening torque (see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32).**
f.	Connect the motor power supply electric connectors (see the figure in step h. of the Disassembly)
g.	Refit the motor electric connectors guard on the forearm (see the figure in step g. of the Disassembly)
h.	If the oil was drained prior to disassembly, fill the reducer with the prescribed lubricant (see Tab. 2.1 - SMART5 SiX Lubrication table on page 18).
i.	Calibrate the axis after completing all reassembly operations. (see Fig. 7.7 - Axis 4 calibration on page 104).

3.10 AXIS 5 MOTOR DRIVE TRANSMISSION ASSY: complete replacement



Status:

– This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position.

The removal of the transmission assembly causes the release of axis 5, therefore before starting the disassembly of the transmission assembly, clamp the axis in a secure position to prevent uncontrolled upward or downward movement that could cause injuries to the operators near the robot.

Material:

– Axis 5 motor drive transmission assy: code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81 ; weight 2 kg *(4.41 lb)*

Equipment:

– 4 mm, 3 mm, 2.5 mm male hex T wrench
– Belt tensioning tool (code CR82221816)

Fastening components:

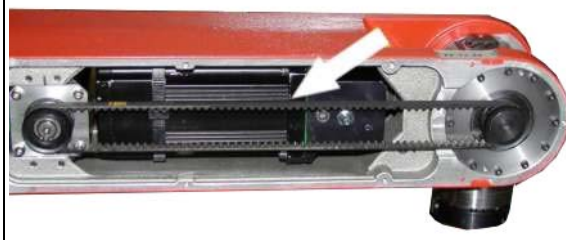
– M5 x 12mm socket hd cap screws for motor; q.ty 4
– M4 x 10 socket hd cap screws for belt cover; q.ty 9
– M4 socket hd cap screws for belt pulley; q.ty 4

Preliminary operations / notes

Some components inside the motor could be damaged if subject to violent impacts: do not use a hammer or beat against the motor during disassembly and reassembly.
The improper use of hammers or other tools on the motor will undermine the validity of the guarantee.

When the motor is removed the axes are released: it is important to block the axes to prevent these from falling due to gravity.

– If the robot functioning allows, position the robot arm in calibration position as shown in the figure.

Disassembly	
a. Remove the two wrist guards (right and left) unscrewing the 4 fastening screws with a 2.5 mm wrench.	
b. Cut the axis 5 motor cable clamping straps that can be reached from the left side of the wrist. c. Remove the motor power supply electric connectors.	
d. Loosen the 4 screws that fasten the motor using a 4 mm T wrench.	
e. From the right side of the wrist, remove the belt from the toothed pulleys	
f. From the left side of the wrist remove the motor drive transmission assembly together with the belt drive toothed pulley. **Check the belt for wear and replace if necessary**	

Reassembly

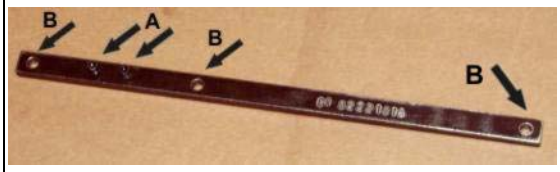
a. From the left side of the wrist, insert the motor drive transmission assembly inside the wrist.

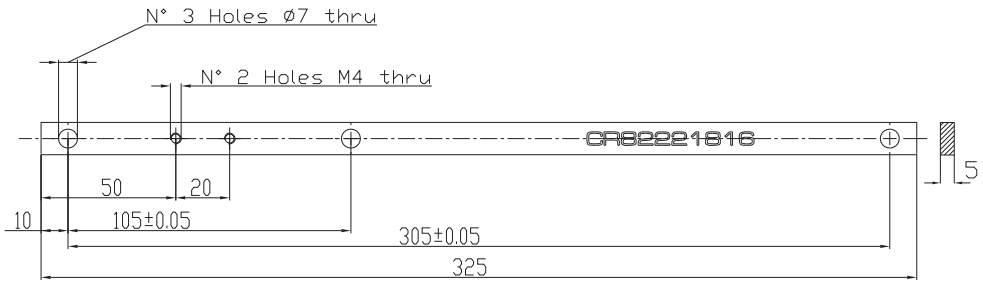
b. Tighten, but do not lock the 4 M5x12 screws complete with flat and cut washers, to fasten the motor.

c. Fit the timing belt on the motor drive transmission assembly pulleys.

d. Arrange the belt tensioning tool (code CR82221816) shown in the figure, that consists of :

– a lever with two holes for M4 screws (A) and three Ø 7mm through holes (B)
– two M4 screws.





Reassembly (Continued)	
e. Tighten the M4 screws included in the tensioning tool on the two toothed pulleys.	
	
f. Clamp the lever of the tensioning tool on the head of the screws on the pulleys to define with precision the centre distance between the toothed pulleys, and as a consequence, the belt tension.	
g. Check the clamping of the belt, then tighten the 4 M5x12 screws complete with flat and cut washers, to fasten the motor (see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.	

Reassembly (Continued)

h. Connect the electric connectors and strap the electric cables.

:**Attach the wires to the motor cable glands with ties, as shown in the figure, so that the pins of the connectors are not subject to traction and mechanical stresses during the robot operation .**

i. Refit the wrist side guards.

j. Calibrate axis 5 (see Fig. 7.8 - Axis 5 calibration on page 106).

When reassembling, apply the prescribed sealant to the screws and tighten all the screws to the prescribed tightening torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.

3.11 AXIS 6 MOTOR DRIVE TRANSMISSION ASSY: complete replacement

Status:

– This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position.

The removal of the transmission assembly causes the release of axis 6, therefore before starting the disassembly of the transmission assembly, clamp the axis in a secure position to prevent uncontrolled upward or downward movement that could cause injuries to the operators near the robot

Material:

– Axis 6 motor drive transmission assy:code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81 weight 2 kg *(4.41 lb)*

Equipment:

– 4 mm, 3 mm, 2.5 mm male hex T wrench
– Belt tensioning tool (code CR82221816)

Fastening components:

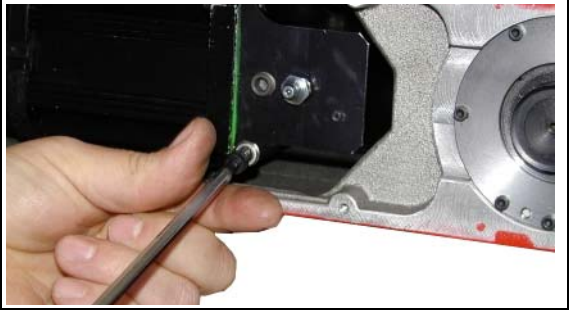
– M5x12mm socket hd cap screws for motor; q.ty 4
– M4 X10 socket hd cap screws for belt cover; q.ty 9
– M4 socket hd cap screws for belt pulley; q.ty 4

Preliminary operations / notes

Some components inside the motor could be damaged if subject to violent impacts: do not use a hammer or beat against the motor during disassembly and reassembly.
The improper use of hammers or other tools on the motor will undermine the validity of the guarantee.

When the motor is removed the axes are released: it is important to block the axes to prevent these from falling due to gravity.

– If the robot functioning allows, position the robot arm in calibration position as shown in the figure

Disassembly	
a. Remove the wrist guards from the right and left sides unscrewing the fastening screws with a 2.5 mm T wrench.	
b. Cut the axis 6 motor cables clamping straps that can be reached from the right side of the wrist. c. Remove the motor power supply electric cables.	
d. Loosen the 4 fastening screws of the axis 5 motor transmission assembly using a 4 mm T wrench from the left side of the wrist.	
e. From the right side of the wrist, remove the axis 5 belt from the toothed pulleys.	
f. From the left side of the wrist unscrew the 4 M5 screws that fasten the axis 6 motor drive transmission assembly.	

Disassembly (Continued)

g. Remove the axis 6 motor drive transmission assembly with the belt drive toothed pulley.

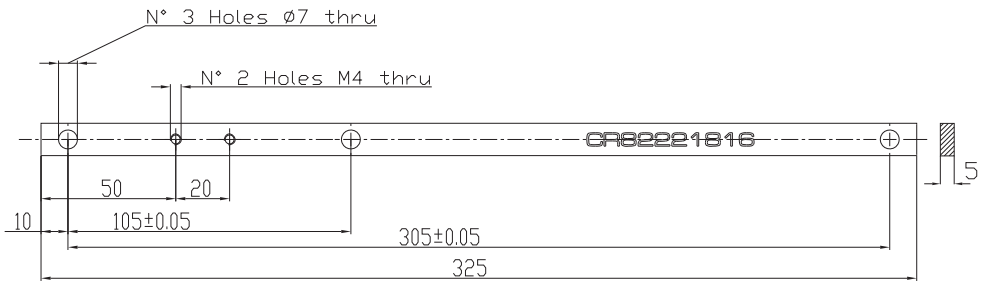
Check the belt for wear and replace if necessary.

Reassembly

a. Arrange the belt tensioning tool (code CR82221816) shown in the figure, that consists of :

– a lever with two holes for M4 screws (A) and three Ø 7mm through holes (B)

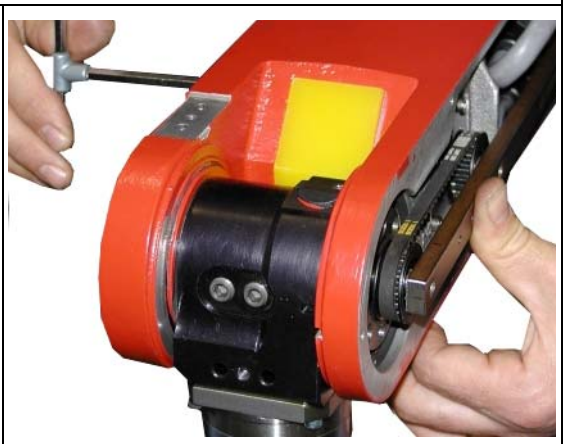
– two M4 screws.



Reassembly (Continued)	
b. Refit the axis 5 transmission assembly belt following the procedure described in par. Reassembly on page 52 of par. 3.10 AXIS 5 MOTOR DRIVE TRANSMISSION ASSY: complete replacement on page 50	
c. From the left side of the wrist, insert the axis 6 motor drive transmission assembly inside the wrist (see the figure in step g. of the Disassembly). d. Tighten, but do not lock, the 4 M5x12 screws complete with flat and cut washers, to fasten the motor drive transmission assembly	
e. Fit the timing belt on the motor drive transmission assembly and the reducer. f. Tighten the M4 screws, included with the tensioning tool, on the two toothed pulleys.	
g. Clamp the lever of the tensioning tool on the head of the screws on the pulleys to define with precision the centre distance between the toothed pulleys, and as a consequence, the belt tension.	

Reassembly (Continued)

h. Check the belt clamping, then tighten the 4 M 5x12 screws with flat and cut washer, to fasten the motor (see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32



i. Connect the electric connectors and strap the electric cables.

Attach the wires to the motor cable glands with ties, as shown in the figure, so that the pins of the connectors are not subject to traction and mechanical stresses during the robot operation.

j. Refit the wrist side guards.

k. Calibrate axis 6 (see Fig. 7.9 - Axis 6 calibration on page 108)

When reassembling, apply the prescribed sealant to the screws and tighten all the screws to the prescribed tightening torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.

3.12 AXIS 5 MOTOR DRIVE BELT: complete replacement

Status:

– This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position.

The removal of the axis 6 transmission assembly causes the release of axis 6, therefore before starting the disassembly of the transmission assembly, clamp the axis in a secure position to prevent uncontrolled upward or downward movement that could cause injuries to the operators near the robot.

Material:

– Axis 5 belt: GT 5MRcode see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81

Equipment:

– 4 mm, 3 mm, 2.5 mm male hex T wrench

– Belt tensioning tool (code CR82221816)

Fastening components:

– M5x12mm socket head cap screw for motor; Q.ty 4

– M4 X10 socket head cap screw for wrist guard Q.ty 9

Preliminary operations / notes

– If the robot functioning allows, position the robot arm in calibration position as shown in the figure

Disassembly

a. Remove the wrist guards from the right and left sides unscrewing the fastening screws with a 2.5 mm T wrench

Disassembly (Continued)

b. From the left side of the wrist unscrew the 4 screws that fasten the axis 5 motor transmission assembly using a 4mm T wrench to release the geared motor assembly.

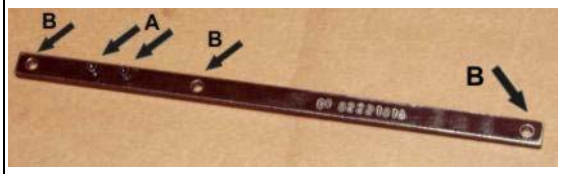
c. From the right side of the wrist, move the geared motor assembly and remove the axis 5 belt from the toothed pulleys.

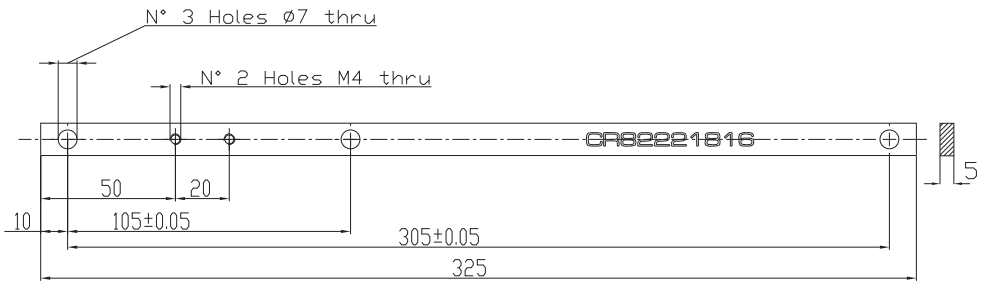
Reassembly

a. Arrange the belt tensioning tool (code CR82221816) shown in the figure, that consists of :

– a lever with two holes for M4 screws (A) and three Ø 7mm through holes (B)

– two M4 screws.





Reassembly (Continued)

b. Clamp the new belt on the axis 5 transmission assembly and reducer pulleys.

c. Tighten the M4 screws included in the tensioning tool on the two toothed pulleys.

d. Centre the lever holes on the head of the M4 screws on the pulleys and correct the centre distance between.

e. Clamp the motor drive transmission assembly to the wrist, screwing the 4 M5x12 screws complete with flat and cut washer.

f. Refit the wrist side guards.

g. Calibrate axis 5 (see Fig. 7.8 - Axis 5 calibration on page 106)

When reassembling, apply the prescribed sealant to the screws and tighten all the screws to the prescribed tightening torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.

3.13 AXIS 6 MOTOR DRIVE BELT: complete replacement

Status:

– This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position.

The removal of the transmission assembly causes the release of axis 6, therefore before starting the disassembly of the transmission assembly clamp the axis in a secure position to prevent uncontrolled upward or downward movement that could cause injuries to the operators near the robot.

Material:

– Axis 6 motor drive belt GT 5MR-300-6 code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81

Equipment:

– 4 mm, 3 mm, 2.5 mm male hex T wrench
– Belt tensioning tool

Fastening components:

– M5x12mm socket head cap screws for motor; q.ty 4
– M4 X10 socket head cap screws for wrist guard; q.ty 9

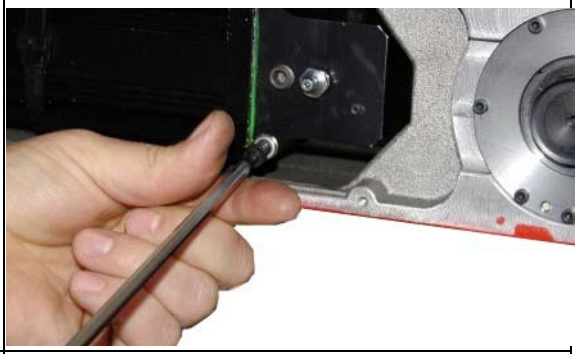
Preliminary operations / notes

– If the robot functioning allows, position the robot arm in calibration position as shown in the figure

Disassembly

a. Remove the wrist guards from the right and left sides unscrewing the fastening screws with a 2.5 mm T wrench

b. From the left side of the wrist, unscrew the 4 M5 fastening screws of the axis 6 motor drive transmission assembly



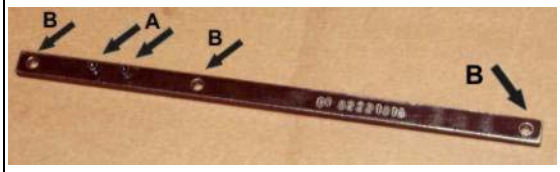
c. From the right side of the wrist, remove the axis 5 belt from the toothed pulleys.

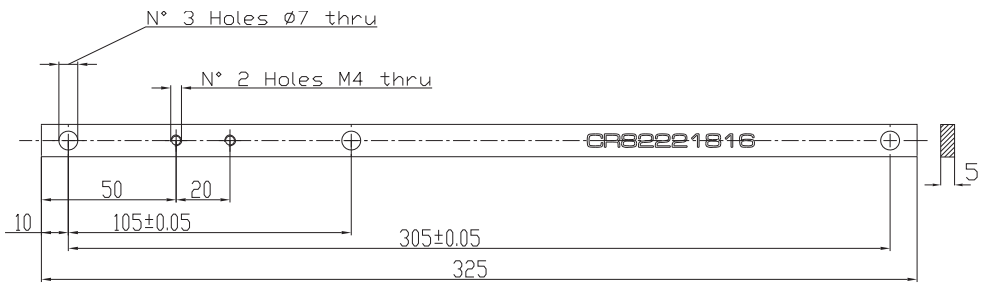
Reassembly

a. Arrange the belt tensioning tool (code CR82221816) shown in the figure, that consists of :

– a lever with two holes for M4 screws (A) and three Ø 7mm through holes (B)

– two M4 screws



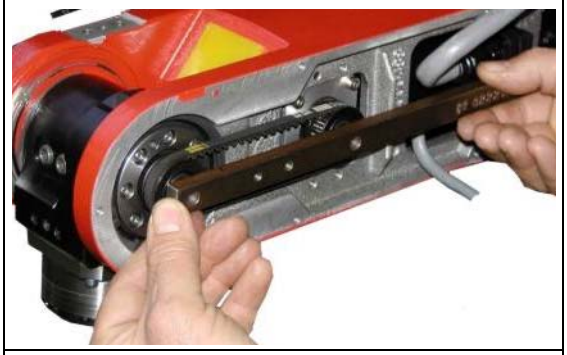


Reassembly (Continued)

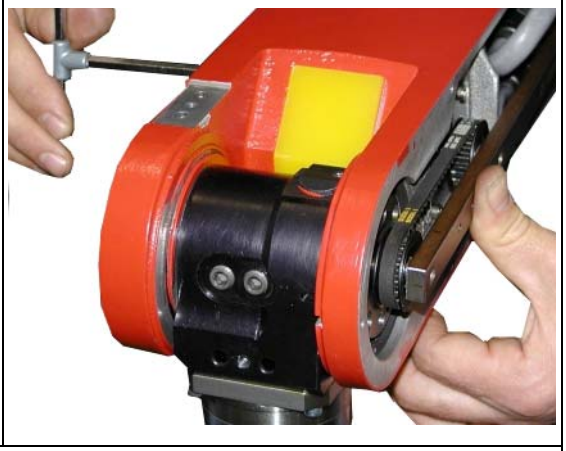
b. Fit the new timing belt on the pulley of the axis 6 motor drive transmission assembly and reducer.

c. Tighten the M4 screws included in the tensioning tool on the two toothed pulleys.

d. Centre the lever holes on the head of the M4 screws on the pulleys and correct the centre distance between the pulleys, adjusting as a consequence the belt tension.



e. Tighten the 4 M5x12 screws with flat and cut washer, to fasten the geared motor assembly (see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32



f. Refit the wrist side guards.

g. Calibrate axis 6 (see Fig. 7.9 - Axis 6 calibration on page 108)

When reassembling, apply the prescribed sealant to the screws and tighten all the screws to the prescribed tightening torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32).

3.14 WRIST ASSEMBLY: complete replacement

Status:	–	This procedure must be carried out with the system turned off. The main circuit breaker on the cell controller MUST be in the OFF position.
Material:	–	Wrist assembly, code see: Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81
Equipment:	–	5 mm hex wrench
	–	M6 puller for pin
Fastening components:	–	Hex head screw M6 x 20, q.ty 8
	–	Parallel pin Ø6x20mm with puller hole

Preliminary procedures / Notes
– Remove the fixtures and any outfitting installed on the robot wrist – Set the robot pulse in a convenient position so that the securing screws can be reached

Disassembly procedure	
a. Remove the wrist side guards.	

Disassembly procedure (Continued)

b. Disconnect the electrical connections of the axis 5-6 motors.

c. With a 5 mm hex wrench unscrew the 8 screws fastening the wrist to the forearm.

d. Support the wrist and take it from its location seat in the forearm body.

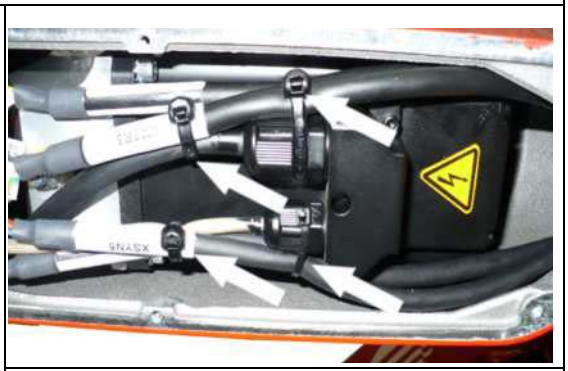
When removing, cautiously extract the electric cables from the rear of the wrist.

e. Take the wrist to the bench and remove the parallel pin Ø6 x 20 mm from its seat.

Reassembly

a. Reassemble, following the removal procedure in reverse. Insert the wiring from the rear of the wrist, passing it at the sides of the motor, and re-strap the cables.

Attach the wires to the motor cable glands with ties, as shown in the figure, so that the pins of the connectors are not subject to traction and mechanical stresses during the robot operation (refer to par. 3.10 and par. 3.11)



b. After reassembly, calibrate axes 4, 5 and 6 (see Calibration of axes 4, 5, 6 - Fig. 7.7, Fig. 7.8 and Fig. 7.9).

When reassembling, apply the prescribed sealant to the screws and tighten all screws to the prescribed torque (see Tab. 3.2 - Typical uses of AREXONS products on page 33 and Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.

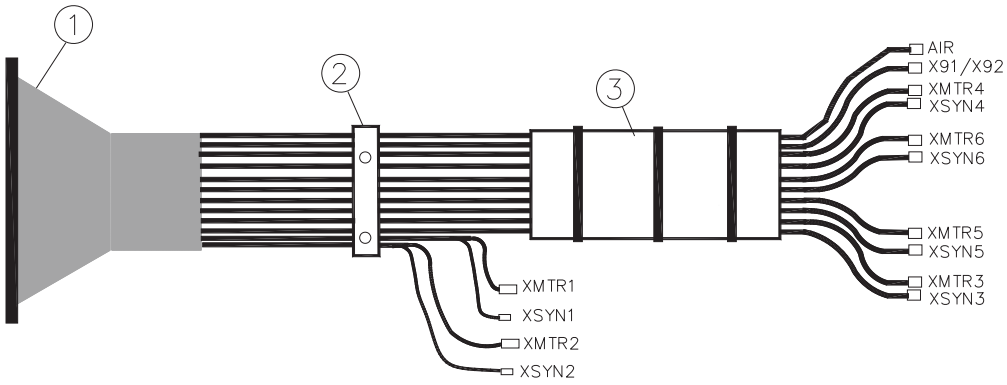
3.15 1-2-3-4-5-6 Axis Motors: Wiring Replacement

Status:	–	The procedure is to be carried out with the system off: the main switch of the cell controller MUST be in OFF (shut off) position.
Spare part:	–	Wiring on robot SMART5 SiX 6-1.4.
Equipment:	–	Allen wrench 2,5 - 3 - 5 mm;
	–	Fixed wrench 19 - 22 mm;
	–	Straight blade screwdriver
Fastening components:	–	Socket straight head cap screws M3 Hexagon socket countersunk head screws M4 Hexagon socket head screws and M6

Preliminary procedures / notes

The cables are not to be twisted and the connectors are to be protected against impacts;
When assembling apply to the screws and fittings the prescribed sealant (see Tab. 3.2 - Tabella impieghi tipici dei prodotti AREXONS a pag. 30) excepted the hose fittings and tighten all the screws to the prescribed tightening torque (see Tab. 3.1 - Coppia di serraggio viti T.E. e T.C.E.I. (Nm ± 10%) a pag. 30;
Lubricate with one of the following lubricants:
- KLUBER POLYLUB GLY801;
- OPTIMOL OPTITEMP RB1.

Fig. 3.2 - General overview of the cable pack



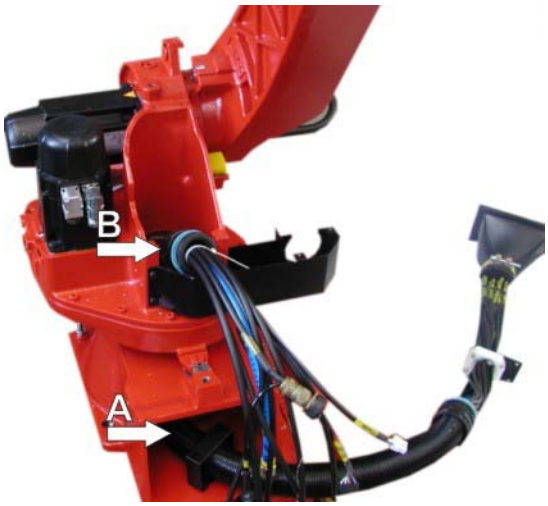
1. Switching with rubber sheath (bellow);
2. Rotating busher axis 1;
3. Corrugated sheath.

Assembly procedure

a. If the Robot functioning permits, bring the axes to calibration position to replace the cables bundle.
Remove the protection cover of the Robot axis 1 cavity.

a. Disconnect the ground wiring and cut the plastic straps that clamp the cables. Insert the wiring upper part through the hole on the robot base (A) passing it through the axis 1 cavity of the robot (B).

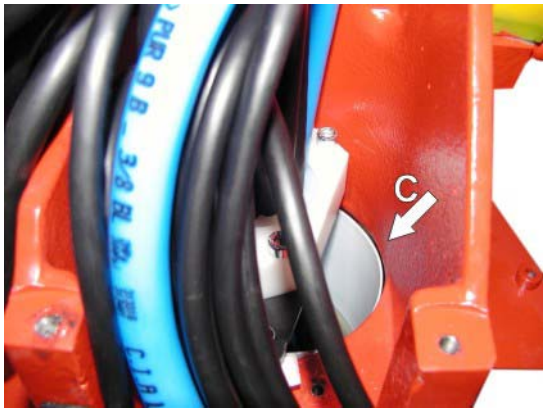
Move the complete cable pack grabbing it from the switching and not from cables.



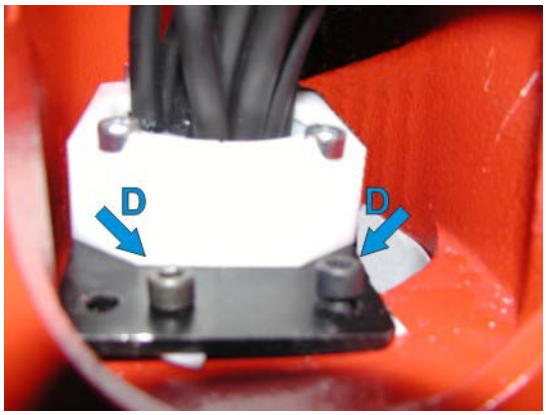
b. Fix the connectors panel on the robot base.
Use no. 4 hexagon socket head screws M6x20.

Assembly procedure (Continue)

c. Insert the protection in Teflon inside the axis 1 cavity of the robot (C).

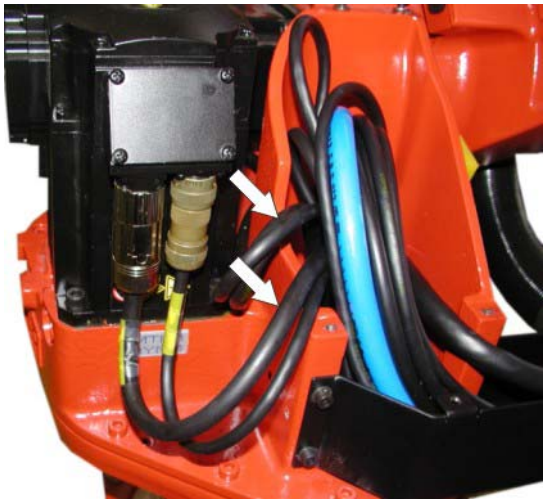


d. Fasten the rotating bushing supporting bracket axis 1 using no.2 hexagon socket head screws M6x16 (D). Insert between the bracket and the robot smelted edge the protection in Teflon.
The bracket is to be fastened toward the left side of the cavity, rear robot view.



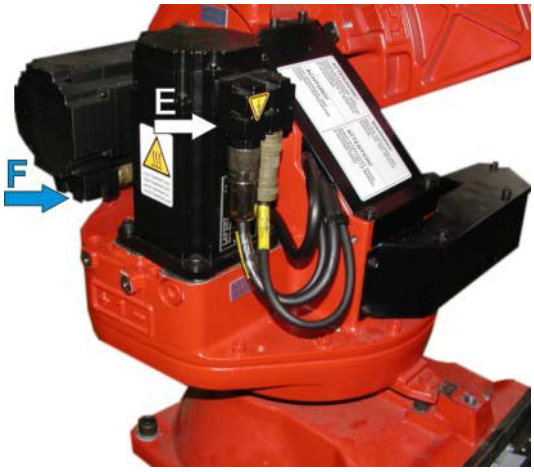
Check that the bushing is free to rotate.
Check that the cable pack inside the robot base is not tightened when the machine i in extreme positions.

e. Extract the four connection cables of the axis 1and axis 2 motors of the suitable hole on the robot base side.

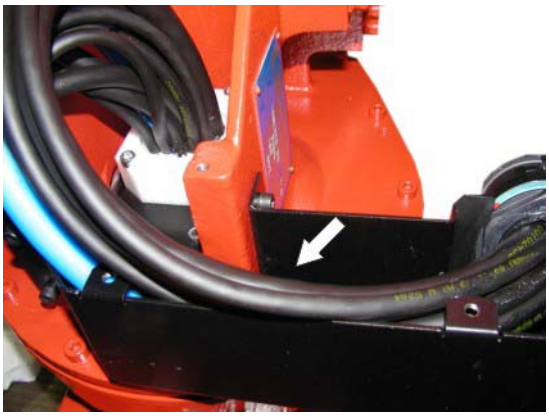


Assembly procedure (Continue)

f. Connect the two connectors (MTR1 and SYN1) to the motor axis 1 and the two connectors (MTR2 and SYN2) to the axis 2 motor (E and F). Band the cables in order to avoid to lay them on the ground or on the motor case.



g. Insert the cable pack and the air tube inside the cable trays.



h. Fix the straight fitting of the corrugated sheath, on the foreseen flange, screwing until the end the plastic M50 nut (G).

The fitting shall be tightened with adequate tightening torque in order to avoid breaks and deformation.

Assembly procedure (Continue)

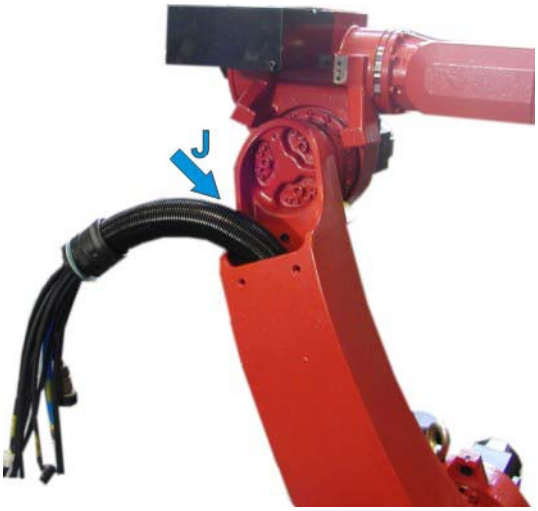
i. Insert the cable package through the containing bracket (H) and then inside the lever axis 2 of the robot (I).

j. Assemble the blocking device of the sheath on the supporting bracket, as shown in the picture. Use no. 2 hexagon socket head screws M6x70.

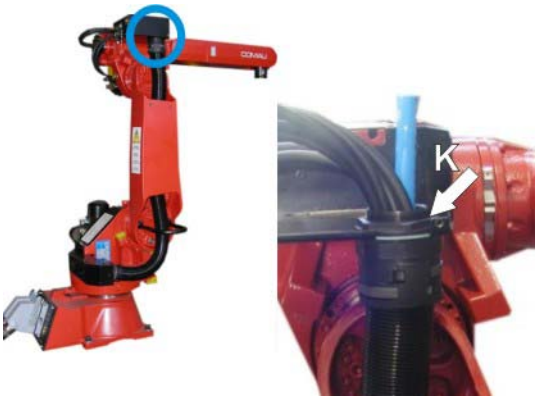
k. Continue with assembling of the supporting bracket of the sheath inside the axis 2 lever of the robot, as shown in the picture.
Use no. 2 hexagon socket head screws M6x16.

Assembly procedure (Continue)

l. Let the cable pack go out from the upper cavity of the axis 2 lever of the robot (J). Remove the guard from the services box on axis 3 of the robot and insert, through the lower hole, the electric cables and air tube.



m. Fasten the corrugated sheath straight fitting to the services box, by means of plastic M50 nut, as shown in figure (K).

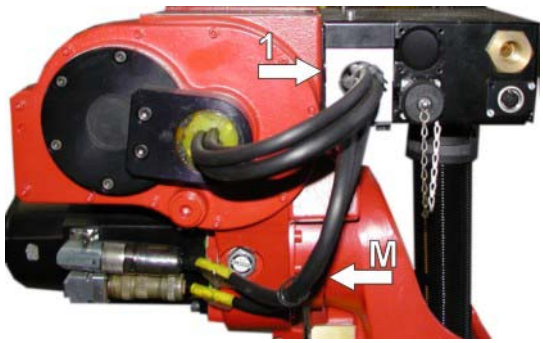


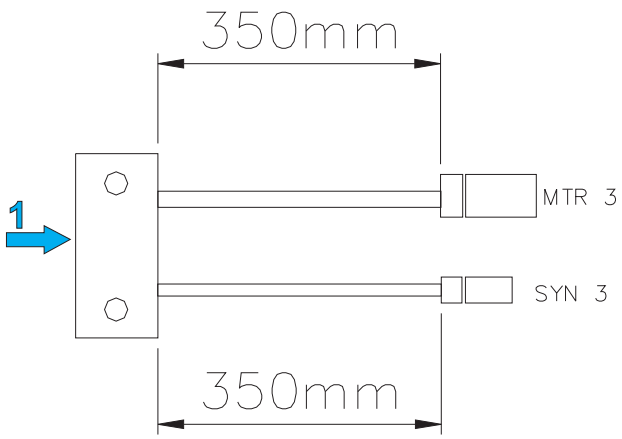
The fitting shall be tightened with adequate tightening torque in order to avoid breaks and deformation .
Check that the corrugated sheath does not show any deformation, that it is parallel to the robot lever and does not come out.
Check that the cable pack and the air tube are not tightened or compressed, when the machine is in the extreme positions.

n. Extract the motor cables axis 3, 5 and 6 from the upper hole of the service box as shown in figure (L).

Assembly procedure (Continue)

o. Connect the connectors (MTR3 and SYN3) to the motor axis 3 (M).
The cables (M), from the services box to the motor axis 3 shall respect the length of 350 mm as shown in the diagram.
Band the cables in order to avoid to lay them on the ground or on the motor case.





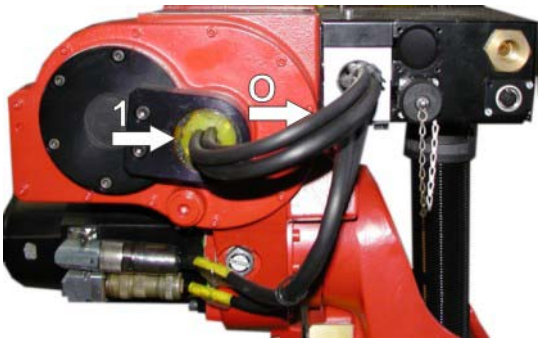
1. Aluminium blocking device

p. Fasten the cables of the axis motors 3, 5 and 6 by means of the aluminium blocking device screwed on the services box (N).
Use no. 2 hexagon socket head screws M6x60 with no. 2 M6 nuts.

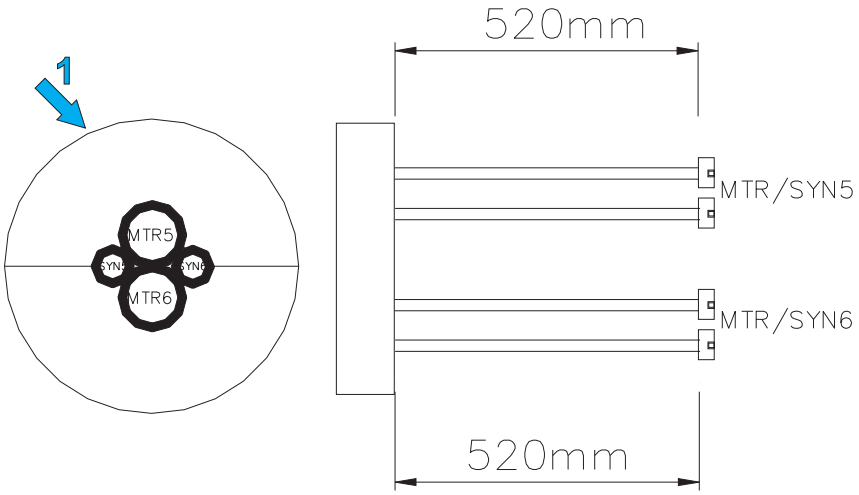
Check that the cable packs are not tightened or compressed, when the machine is in the extreme positions.

Assembly procedure (Continue)

q. Fasten on the rotating bushing the cable pack (O) of the axis 5 and 6 of the robot respecting the distances and positions indicated in the picture below. Use no. 2 hexagon socket head screws M6x20.

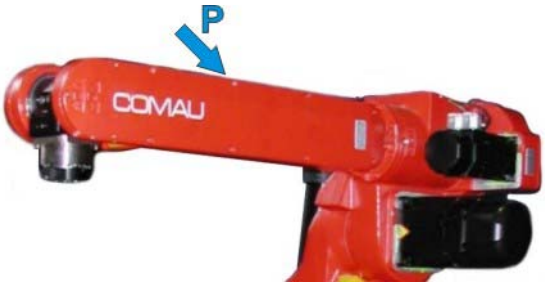


Check that the tightening of the screws is suitable in order not to provoke the bushing deformation.



1. Sleeve bushing

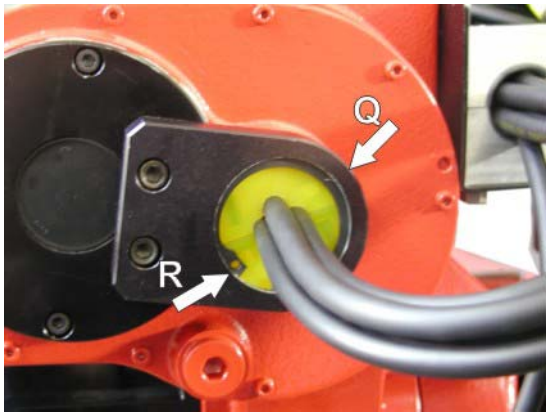
r. Remove the right cover of the wrist (P), front view of the robot. Insert the cable pack for axis 5 and 6 inside the robot wrist.



Assembly procedure (Continue)

s. Insert the bushing in the foreseen seat after having greased it, as shown in the picture (Q).
Insert the Seeger stopping ring (R).

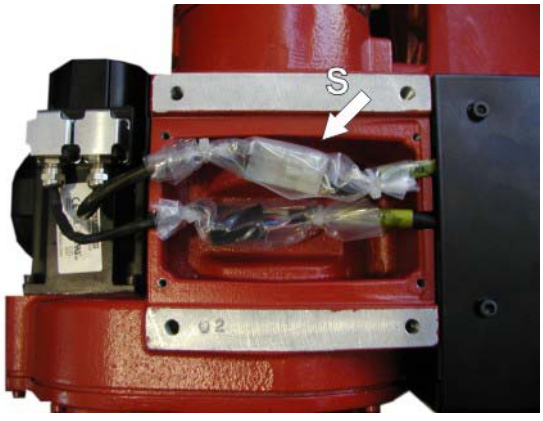
Check at the end of assembling that the bushing is free to move.



t. Connect the two connectors (MTR5 and SYN5) to the motor axis 5 and the two connectors (MTR6 and SYN6) to the axis 6 motor. Band the cables in order not to avoid that they are too tighten during robot operation, as shown in figure.

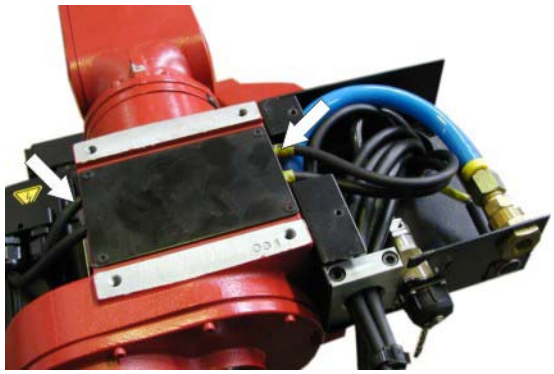
u. Assemble the side cover of the wrist, previously removed, be sure not to pinch the cables and not to press the electric connectors.

v. Remove the electric connector cover axis 4 of the robot. Connect the connectors (MTR4 and SYN4) to the motor axis 4. Cover the connections with a nylon tube about 100 mm long and block it on the ends with some bands as shown in figure (S).



Assembly procedure (Continue)

w. Insert connection cables in the foreseen seats with small rubber tubes installed on the cables, in order to guarantee higher resistance and to fasten the protection guard.
Use no. 4 hexagon socket countersunk head screws M4x10.



Before fastening the guard check that there are any pinched cables between the guard and the supporting plate on the robot.

x. Fix the connectors x91 on the services box (T).
Use no. 4 Socket straight head cap screws M3x10.
Fasten the protection plug of the X91 connector to one of its fixing screws.

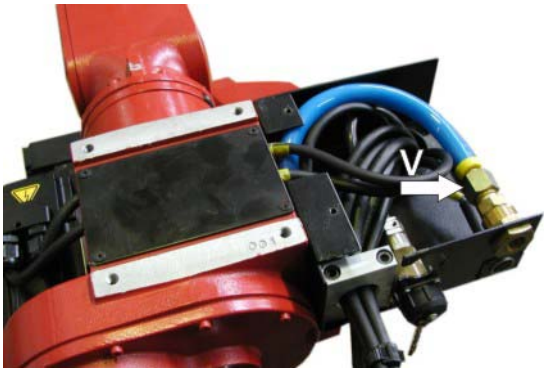
Check that the connector is assembled with the reference notch upward.

y. Fasten the connector X92 (U) inserting the cable through the eyelet present on the services box and fasten the connector support in the foreseen seat.
Use no. 4 Socket straight head cap screws M3x10.

Check that the connector is assembled with the reference notch downward.

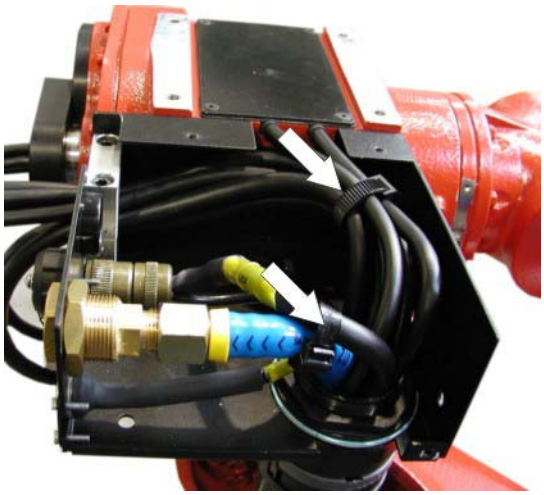
Assembly procedure (Continue)

z. Connect the air tube to the foreseen fitting (V) present on the service box.
Tighten the fitting using the 22mm wrench as a counter-wrench. The fitting on the service box **shall not rotate**.



Check that, in the most critical robot position for wiring, do not occur any anomalous torsions and fall in air pressure.

aa. Fix the cables, inside the service box, using some bands as shown in picture.
Insert the protection guard on the services box using no. 4 hexagon socket head screws M6x12.



ab. Insert the guard on the cable tray (W) and on the axis 1 cavity on the robot base (X) using no. 8 hexagon socket head screws M6x12.

Uninstall procedure

To disassemble the cable pack carry out on reverse order the operations starting from the step ab., described previously.

4. LIST OF SPARE PARTS

The lists of the spare parts are given below, divided as follows

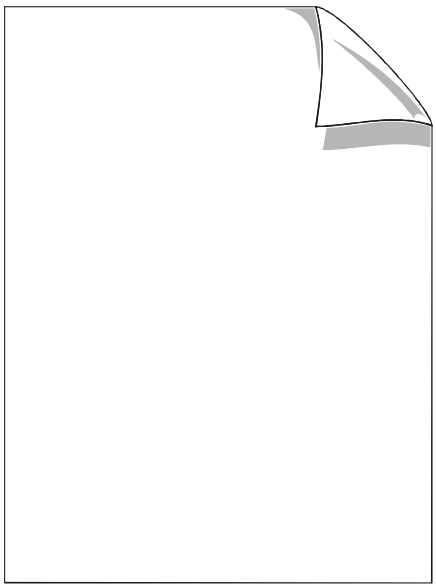
– Tab. 4.1 - SMART5 SiX mechanical spare parts on page 81
– Tab. 4.2 - SMART5 SiX electrical spare parts on page 81

Tab. 4.1 - SMART5 SiX mechanical spare parts

COMAU Code	Description	Robot Axis	Q.ty
CR82350032	Motor ; 3,5 Nm-IP67	1- 3	2
CR82350042	Motor ; 5 Nm-IP67	2	1
CR82350010	Motor ; 0,35 Nm-IP67	4-5-6	3
CR82343820	Wahser (130x205x25,4)	1	1
CR82221012	Clamp-gear assembly	1	1
CR82309106	Reduction unit RV 50-E-153	2	1
CR82309102	Reduction unit RV 25-E-141	3	1
81780709	Pinion z= 19; m =0,8	4	1
00300910	Rotating shaft seal 60x85x8 type 4	4	1
00345550	Single lip seal ring 40x47x4	4	1
CR82221339	Axis 6 motor drive belt; GT 5MR-300-6	6	1
CR82221340	Axis 5 motor drive belt; GT 5MR -500-6	5	1
CR82221990	Axis 5 motor drive transmission assembly	6	1
CR82221991	Axis 6 motor drive transmission assembly	5	1
CR82221900	Wrist unit (axes 5-6)	5-6	1
CR82223034	Rotating shaft seal 125x150x12 type 4 (axis1)	1	1
82281033	Rotating shaft seal 190x160x15 type 4 (axis1)	6	1
00300774	Seal ring OR N° 50 ∅ 1,78 -133,10 (axis1)	1	1
CR82223100	Calibration protection kit		1

Tab. 4.2 - SMART5 SiX electrical spare parts

COMAU Code	Description	Q.ty
CR18904080	Wiring on board robot	1



5. OPTIONS

5.1 General

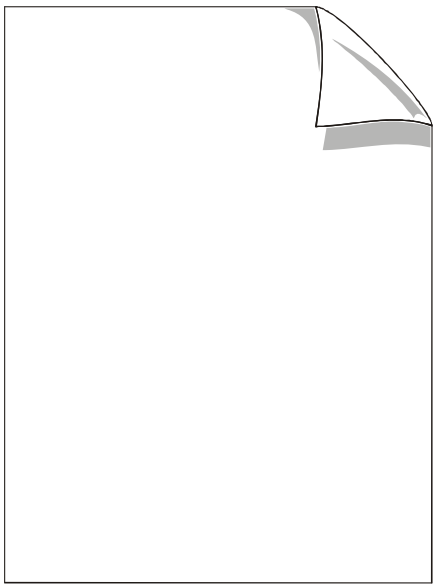
The following table shows a list of the available mechanic options and the quantity that may be installed on the robot; this chapter includes a description of some options, for which a detailed installation procedure is required

Tab. 5.1 - List of available options

Code	Designation	Qty installed
CR82222200	ADJUSTABLE MECHANIC LIMIT STOP UNIT, AXIS 1 (code CR82222200): assembly	1
CR82222300	ADJUSTABLE MECHANIC LIMIT STOP UNIT, AXIS 2 (code CR82222300): assembly	1
CR82222400	Set of screws ands pins for robot mounting	1
CR82222600	Levelling plate unit	1
CR82222100	Manual calibration kit	1
CR81783801	Calibrated fixture unit (code 81783801)	1
CR82223000	Arc welding outfitting unit	1
CR 82221809 CR 82221810 CR 82221811 CR 82221813	Support	1
CR 82221812	Support (code CR82221812)	1

Before starting any operation, carefully read Chap.1. - General Safety Precautions on page 7.
Robot maintenance operations have to be carried out with system powered down: the main switch MUST BE OFF.

Before starting any assembly operation, read the Chap. Notes for assembly on page 32 to get acquainted with the general regulations and the specific fixing gears.



5.2 ADJUSTABLE MECHANIC LIMIT STOP UNIT, AXIS 1 (code CR82222200): assembly

Status:	–	This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position.
Material:	–	Adjustable mechanic limit stop unit, axis 1: CR82222200
Equipment:	–	Wrenches for socket hd cap screws, 8 mm
Fastening components:	–	M10 x 25 socket hd cap screws; q.ty 6

Preliminary operations / notes

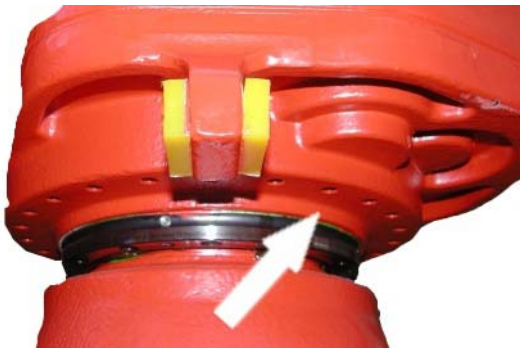
– Remove any equipment/piping installed on the robot, which interfere with the fixing seat of the mechanic stoppers.

– The adjustable mechanic limit stop unit, axis 1, permits to limit the stroke of axis 1 in both working directions, by steps of 15°; should it be necessary to limit the axis stroke in one direction only, only one stopper of two shall be used.

On re-assembly, apply sealant to screws, according to provisions (see Tab. 3.2 - Typical uses of AREXONS products on page 33) and tighten all screws at the preset driving torque (see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32).

Assembly

a. Clean the seats in the base, where the mechanic stoppers shall be fixed function of the robot travel.



Assembly (Continued)

b. Secure the mechanic stoppers to the robot base by means of the fastening screws M10x25.

5.3 ADJUSTABLE MECHANIC LIMIT STOP UNIT, AXIS 2 (code CR82222300): assembly

Status:	–	This procedure must be carried out with the system turned off: the main circuit breaker on the cell controller MUST be in the OFF position.
Material:	–	Adjustable mechanic limit stop unit, axis 2: CR82222300
Equipment:	–	Wrenches for socket hd cap screws, 6 mm;
	–	10 mm wrench
Fastening components:	–	M 8 x 16 socket hd cap screws, q.ty 8
	–	M 6 x 12 hex head screw, q.ty 2

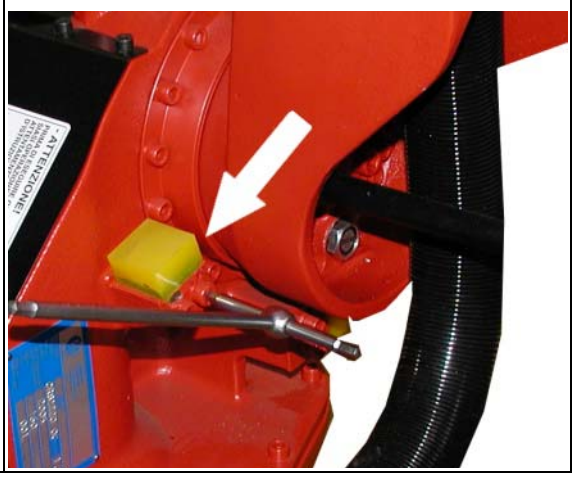
Preliminary operations / notes

– Remove any equipment installed on the robot, which interfere with the fixing seat of the mechanical stoppers.

Apply sealant to screws, according to provisions (see Tab. 3.2 - Typical uses of AREXONS products on page 33) and tighten all screws at the preset driving torque (see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32).

Assembly

a. Remove the axis 2 standard end of travel pads installed on the robot, using a 6mm socket wrench and clean the mounting surface



Assembly (Continued)

b. Choose the correct composition of spacers (B) according to the required stroke reduction, bearing in mind that:
- with one spacer a reduction of -15° is obtained;
- with two spacers a reduction of -30° is obtained.

c. Pre-assemble the spacers and the bracket with the M6x12 hex head screws.

d. Arrange the spacers and bracket on the column mounting surfaces and fasten them with two M8x16 socket head cap screws.

e. If required fit the second spacer to obtain a double stroke reduction.

f. Fasten the blocks on the spacers with two M8x16 socket head cap screws.

g. Check the assembly of all the components and tighten all the screws to the correct torque (see Tab. 3.1 - Tightening torque for hex head cap screws and socket head cap screws (Nm ± 10%) on page 32.

6. TURN-SET AND CALIBRATION - BASIC CONCEPTS

6.1 Foreword

The purpose of this chapter is to describe the basic concepts and the terminology for the management of robot axes position information. The description of the operating procedures is contained in the chapter TURN-SET AND CALIBRATION - OPERATING PROCEDURES, that specifically regards the **robot** used.

This chapter contains the basic information on the following topics:

– Terminology used

– Turn-set

– Calibration

6.2 Terminology

– *TRANSDUCER*: There are two types of position transducers: encoder and resolver.

– *NUMBER OF TRANSDUCER TURNS:* during the robot axis movement, the transducer may make several turns; the number of turns is initialised through the calibration or the turn-set.

– *AXIS VALUE:* the value of an axis contains all the information needed to determine the exact position of an axis in space;

– *VALUE RECONSTRUCTION:* when the Control Unit is powered on, the system software, among the various initialisations, reconstructs the value of the robot axes.
The system software checks this value; in fact, it checks that the difference between the reconstructed position and the position before shut-down is below a certain threshold. If the threshold is exceeded, the Control Unit displays the error **59411 - 08 Ax <num_ax> Arm <num_arm> movement after shut-down** and leaves it to the operator to check that the physical position of the robot corresponds to the new value.

– *CALIBRATION POSITION:* a pre-set position that has been checked using specific equipment (dial gauges, supports, calibration fixtures). The calibration position is a reference position in the robot working space that serves to initialise the value of each axis.

– *CALIBRATION CONSTANTS:* the calibration constant is the difference between the datum read by the transducer and the nominal position of the robot axis that the transducer should assume in that particular position of the robot axis. In fact, since the positioning of the transducer as to the robot joint is casual, (because it depends on how the transducer has been mounted), it is necessary to correct the actual position of the transducer according to the nominal position required by the robot axis.
The calibration constant is defined inside a transducer turn and is stored in variable $CAL_DATA. It is represented in motor turns and is a value between -0.5

(excluded) and +0.5 (included). The calibration constant described in variable $CAL_DATA can be read on the Teach Pendant, **SETUP** Page, **Calib**. subpage.

– *CALIBRATION ASCII FILE*: the calibration file UD:\SYS\<$SYS_ID>_CAL<num_arm>.PDL (where $SYS_ID indicates the system identification, for example NJ4_001) is an ASCII file with syntax of a PDL2 file, where the calibration constants ($CAL_DATA[n]) and other typical data of the robot are stored.

– *NVRAM:* the memory used to save the characteristic information of the robot associated to the Control Unit, the calibration constants and the length of the levers. It is on the CPU board of the Controller.

6.3 Turn-set

The purpose of the turn-set is to update the number of transducer turns only, should it occur that the when switched on again, the Control Unit has lost this value.

The operation consists in bringing the axis involved to the calibration position, using the locating notches, and giving the required command. No special equipment is needed, because **the only value initialised** is the number of turns of the transducer.

The **turn-set** operation is required when

– there has been axis movement with the control off (for example when the error **59411 - 08 Ax <num_ax> Arm <num_arm> movement after shut-down**) is displayed.

– events take place that cause the loss of the number of turns only, and therefore do not require the execution of the calibration procedure. On the Teach Pendant status window or on the PV video the text **Ar:TURN is displayed**.

According to whether the turn-set is executed with the robot in system calibration position or in user calibration position, we shall have:

– Turn-set on system calibration position

– Turn-set on user calibration position

– Turn-set for robot axes with multi-turn stroke

6.3.1 Turn-set on system calibration position

Enables the initialising of the number of transducer turns of the individual robot axes, in the **system calibration position** (calibration position pre-defined by COMAU Robotics).

For further information see System calibration ($CAL_SYS).

6.3.2 Turn-set on user calibration position

Enables the initialising of the number of transducer turns of the individual robot axes, in the **user calibration position** (“out of range” position defined by the user).

For further information see User calibration ($CAL_USER).

6.3.3 Turn-set for robot axes with multi-turn stroke

With robot axes that are able to execute the multi-turn stroke, it may happen that when carrying out the TURN SET procedure, the mechanical calibration notches are misaligned (this condition can occur when the robot axis, having made one or more

complete rotations, positions in a mechanical turn that is different to that of the original calibration).

Fig. 6.1 - Axis Positioning Error in TURN SET

In the above indicated condition, when moving the axis to align the notches, a positioning error message is shown on the terminal.

5409 - 02 Ax <num_asse> Arm <num_arm> joint position not sufficient accurate

If the above described conditions occur, do not send the TURN SET command (the axis would be calibrated in a wrong position), but restore the correct position by performing one of these procedures:

1. Turn the axis and make attempts to find the axis turn position where the original calibration was executed. Align the notches and run the TURN SET command. When the correct position has been resumed, the message **Command Completed** will appear on the Terminal

otherwise, as an alternative

2. Make the complete axis calibration (see Chapter **Turn-set and Calibration - Operating Procedures** in the **Maintenance** manual of the corresponding robot)

6.4 Calibration

The purpose of the calibration procedure is to establish the position of a robot axis referring it to an ideal robot. This makes it possible to initialise the values of the robot axes and to make the position variables used in the robot programs universal.

During the calibration procedure, when the desired axis is in the calibration position, two values are stored:

– the deviation, inside a transducer turn, between the value of the actual position and that of the axis nominal position,
– the number of transducer turns.

The notches on the individual axes make it possible to execute future turn-set operations on a robot that has already been installed.

Remember that executing the calibration operation (on the Teach Pendant, SETUP Page, Calib subpage, Calib (CAC) command) just having positioned the robot axes on the locating notches, without using the suitable equipment, is an operation that does not guarantee the necessary robot positioning precision.

The recovery of the calibration (executed by COMAU), if necessary, is to be executed when first putting the robot into operation.

Subsequently, the calibration does not need to be executed again, unless there is a mechanical failure that involves the replacement of a component of the kinematic chain, or in the case of impacts that damage the robot structure.

The basic concepts are described below for:

– System calibration
– User calibration

6.4.1 System calibration

To initialise the robot axis values in the **system calibration position** (calibration position predefined by COMAU Robotics - $CAL_SYS).

To determine the correct calibration position, special equipment has to be used (dial gauges, supports, etc.) to determine with the necessary precision the position of each individual axis.

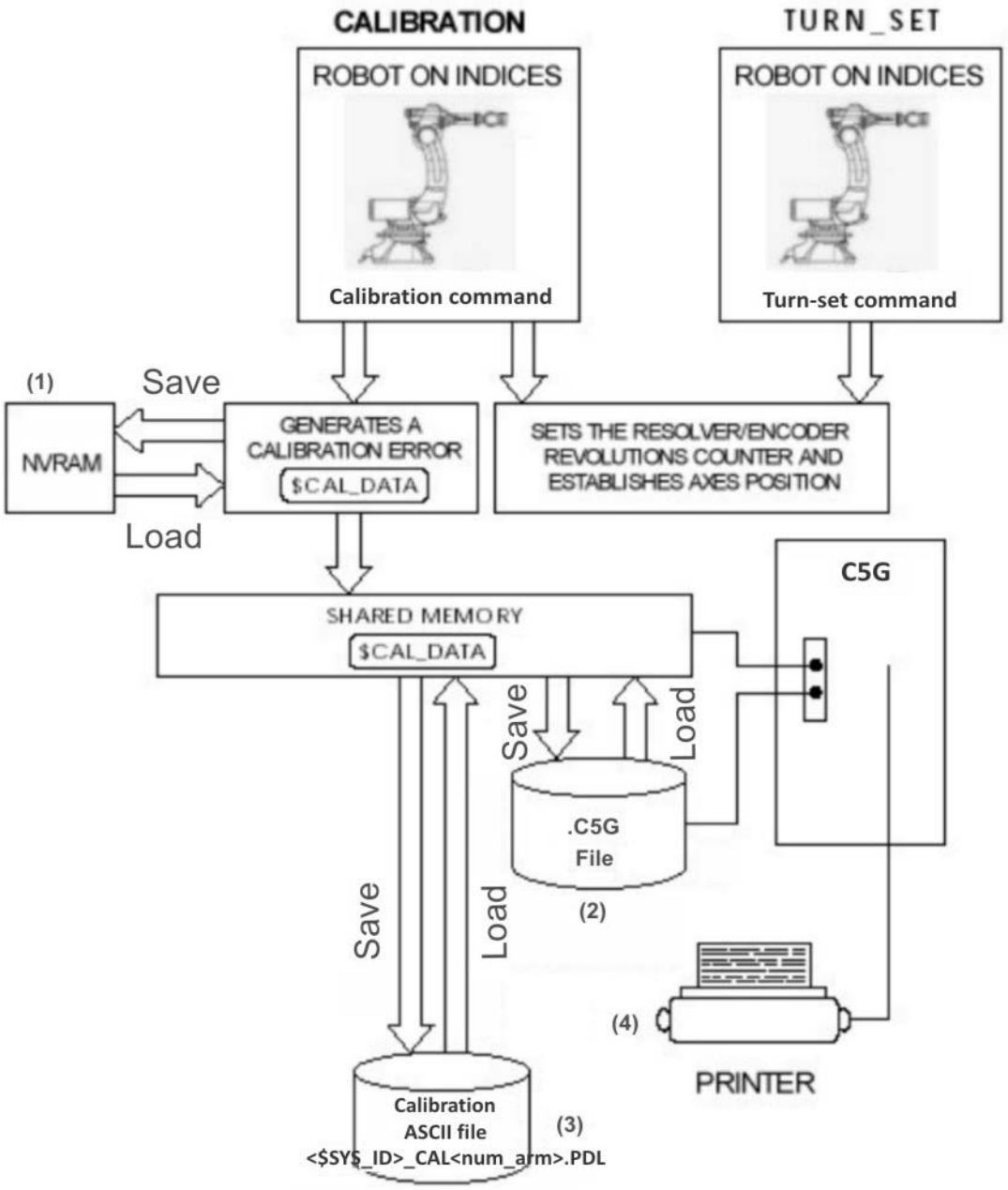
6.4.2 User calibration

User calibration defines a new **calibration position that is different to that of the system**.

This type of calibration (commonly called **out-of-range calibration**) can be used when the system position is difficult to reach once the robot is inserted in the final application, and therefore it becomes necessary to define a different calibration position, called user calibration position ($CAL_USER).

It is the responsibility of the user to provide the appropriate instruments and to check the correct positioning of the robot in any user re-calibrations, especially regarding the arrangement of the locating notches.

Fig. 6.2 - Summary of Calibration and Turn-Set Operations



SAVING CALIBRATION CONSTANTS

1. NVRAM
2. UD:\SYS in .C5G file
3. UD:\SYS in the calibration ASCII file ($<SYS_ID>_CAL<num_arm>.PDL)
4. Hard copy

7. TURN-SET AND CALIBRATION - OPERATING PROCEDURES

The purpose of this chapter is to describe the operating procedures for turn-set and calibration; information is given on the following subjects:

- Turn-set
- Calibration constants recovery
- System calibration using fixtures
- User calibration
- Calibration using the locating notches

It is to be noted that after mechanical disassembly operations that change the robot geometry or are necessary to give maximum robot positioning precision, it is necessary to execute the System calibration using fixtures.

The precision level obtained during a calibration, whether by means of a fixture or through the location notches, influences the final precision of the robot position.
If the calibration is not very accurate, the Tool Center Point and the fixtures installed could reach technological points of the work cycle with less precision than that obtained with the previous calibration.

The robot interchangeability and its precision are ensured by keeping a correct positioning of the base and the TOOL , performing precise doweling and accurate calibration

The functional description of the calibration and the turn-set is contained in Chap.6. - Turn-Set and Calibration - Basic Concepts on page 89.

The calibration position of the SMART5 SIX robot, that is defined by the alignment of all the axis notches, is shown in Fig. 7.1 - Robot calibration position on page 95.

Fig. 7.1 - Robot calibration position

1. Calibration index axis 1
2. Calibration index axis 2
3. Calibration index axis 3
4. Calibration index axis 4
5. Calibration index axis 5
6. Calibration index axis 6

Tab. 7.1 - Joint positions in calibration ($CAL_SYS)

Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
0°	0°	-90°	0°	+90°	0°

7.1 Turn-set

This procedure has to be executed if the Control Unit knows the calibration constants, but has lost the information regarding the number of transducer turns, which could, for instance, be caused by an electrical disconnection of the motors.

If it is required to execute the Turn-set of a calibrated robot, error *59438 SAX: drive off for dynamic model disable* will be displayed if the turn-set for one axis has been requested, or *59439 SA: drive off for dynamic model disable for* turn-set of all axes *(option *).*
The robot will be put in DRIVE OFF and the motor turn will automatically be lost.

a. Bring the robot axes on the locating notches to the most precise position possible that can be obtained by sight: the system will warn the operator with error **59409 SAX: *joints position not accurate enough*** and then will display error **59421 SAX: *a positive recording is required*** and/or error **59422 SAX: *a negative recording is required*** to reach the correct position.

The degree of precision obtained when making the calibration influences the final precision of the robot positioning

b. If the arm number is not specified, the default arm is used, whereas the axis number must always be specified. To indicate all the arm axes, enter an asterisk (*).

c. With the robot positioned correctly set the **CAT** (**Configure Arm Turn-set**) instruction
(see Fig. 7.1 - Robot calibration position on page 95).

d. After the **CAT instruction, the system re-calculates the correct number of transducer turns according to the calibration position** ($CAL_SYS). The operation is only to be executed on the axis that has lost the count; if there are several axes in this situation it is better to run the turn-set of one axis at a time. In particular, if there are axes with mechanical positioning influences it is necessary to operate first on the influencing axis and then on the influenced axis (follow the sequence axes 4,5,6).

The Turn-set has the option: */User* to recalculate the number of transducer turns with reference to the user calibration ($CAL_USER).

7.2 Calibration constants recovery

During the use of the Control Unit, events may take place that cause the loss of the calibration constants without requiring the re-execution of the calibration procedure. It can happen that:

– the text **Ar:CAL** is shown on the status window; this means that there are no problems and no intervention is necessary

– the status window displays the message **Ar:TURN**; this means that an operation is required to reset the transducer turn (**turn-set**).
To find which axis (or axes) is/are in fault, there is the instruction **Display Arm Status** (**DAS**)

– the status window shows the text **Ar:- - -**; this can happen, for instance, after a new version of software has been loaded, or other situations in which the calibration data has been lost.
This **does not mean** that a calibration procedure has to be executed. Usually it is sufficient to use **CARL** (**Configure Arm Reten_Mem Load**) to recover the data from NVRAM - MCP, or otherwise use **CARL/F** (**Configure, Arm, Reten_Mem, Load/File**) to recover the data from the calibration ASCII file.

After the calibration data has been recovered, run the Turn-set to re-initialize the number of transducer turns.

7.3 System calibration using fixtures

Calibration using fixtures has to be executed after mechanical disassembly operations that change the robot geometry, or if it is necessary to make a precise check on the calibration position.
The degree of precision obtained when making the calibration influences the final precision of the robot positioning. If the calibration is not very accurate, the Tool Center Point and the fixtures installed could reach technological points of the work cycle with less precision than that obtained with the previous calibration.

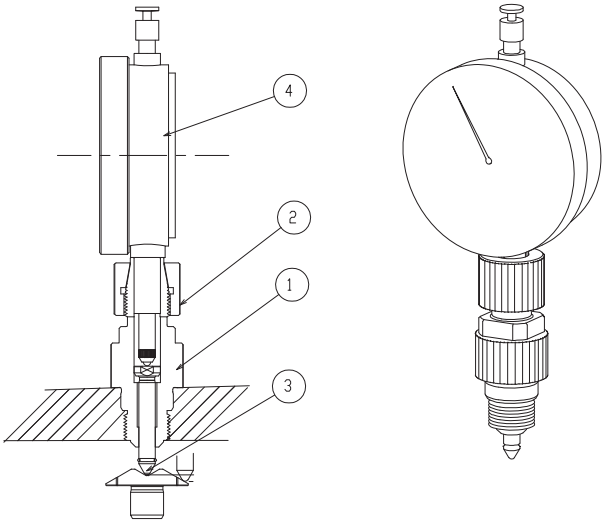
The robot position corresponding to function $CAL_SYS and defined for calibration using fixtures is shown in Fig. 7.1 - Robot calibration position on page 95

If it is required to calibrate a robot that has already been calibrated, error *59438 SAX: drive off for dynamic mode disable* will be generated if the calibration is for one axis, or error *59439 SA: drive off for dynamic mode disable if it is for* calibration of all axes (*option* *). The robot will be put in DRIVE OFF and the calibration constant and the motor turn will be automatically lost.

The calibration of axes 1-2-3 requires the use of an appropriate dial indicator holder (see Fig. 7.2 a.) screwed onto the pre-engineered seat on each axis of the robot: the dial indicator is used to measure the minimum point with reference to the fixed index consisting of a V-shaped notch: the position of the robot at the lowest reading is the calibration position. For the calibration of axes 4-5-6 the dial gauge holder is mounted on the surfaces provided on the forearm and on the wrist, using a specific interfacing support (Fig. 7.2 b.).

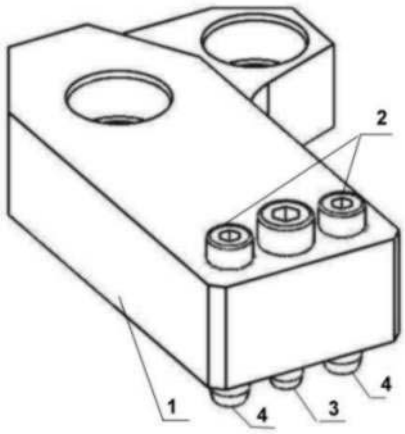
Fig. 7.2 - Kit for manual calibration

a. **Axes calibration fixture**



1	Dial indicator holder
2	Cone-shaped locknut
3	Sensing head
4	Dial indicator

b. **Fixture support for axes 4-5-6**



1	Calibration block
2	Socket head cap screw M4x10 - 8.8 - ISO 4762 (Q.ty 2)
3	Socket head cap screw M5x25 - 8.8 - ISO 4762 (Q.ty 1)
4	Parallel pins ISO 8734 - 6x20 - B - St

The housings for the dial gauge holder fixture and the location indexes are protected by specific guards.

The calibration has to be carried out in progressive sequence, starting from axis 1 and continuing with axes 2, 3, 4, 5 and 6. The following rules that arise from the axis positioning mechanical influences are also to be borne in mind.

– If axis 4 is calibrated, also axes 5 and 6 have to be recalibrated.

– If it is necessary to calibrate axis 5, also axis 6 has to be recalibrated.

– The calibration of one wrist axis (4, 5 or 6) requires that the other wrist axes not involved in the calibration are positioned on the calibration notches.

7.3.1 Preliminary operations

a. Activate programming mode **(St: PROGR**) on the Control Unit.

b. Take the Teach Pendant from its housing.

c. Press the **Enabling Device** on the Teach Pendant, to power on the drives.

d. **Remove the protection guards from the threaded seats for dial gauge holder fixture attachment and from the calibration locating notches.**

All the instructions entered from the keyboard are to be confirmed by pressing ENTER. Some require a further confirmation from the operator through the question Are you sure?; in such cases select Y (yes) and confirm with ENTER

7.3.2 Axes positioning check

When the enable device on the Teach Pendant is released (DRIVE OFF) slight axis movement may be caused, generated by the gravity of the applied loads; these become more evident if the HOLD TO RUN functions are executed in quick succession.

While calibration is being carried out, activation/deactivation of the drives **(HOLD TO RUN)** should be cut down to a minimum, to prevent possible slight axis movement. The system automatically recovers these movements, bringing the axes to the correct calibration position, provided these have been previously calibrated.

The repositioning of the axes can be checked on the Teach Pendant, reading the joint values through the commands **Display - Arm - Joint (F2; F1; F4)**.

Following every HOLD TO RUN of the system, check on the Teach Pendant that the axes return to the correct calibration position.
If the axes do not return to the correct position, the calibration procedure will have to be started again from the beginning.

7.3.3 Axes Calibration

The robot calibration has to be executed with no loads applied to the axes (tool, gripper, etc.) except axis 1.

The calibration procedure is similar for all axes and can be summarized in the following steps:

a. Remove the protections from the attachment seats of the dial gauge holder fixture and the calibration locating notches.

b. Using the Teach Pendant move the robot axes to calibration position (see Fig. 7.1 - Robot calibration position on page 95) so that the moving index coincides with the fixed index.

c. Fit the dial gauge holder fixture in the seat then screw the dial gauge into the fixture to pre-load the dial gauge pointer by a few millimeters (approx. 2.5 mm).

d. Slowly, (not more than 5% - GEN-OVR < 5%), turn the axis to be calibrated **moving from negative direction to positive**, until the dial gauge indicates the minimum point.

If the minimum point is passed, return to the start position and repeat the measurement, always moving the robot axis from negative to positive so as to offset any mechanical play of the axis.

e. After finding the minimum point on the dial gauge, give the calibration command, proceeding as follows:

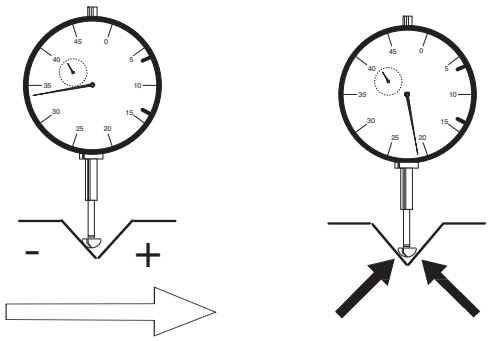
e.1 On the Teach Pendant keyboard, select **CAC** (Configure Arm Calibrate).

e.2 Select the arm for calibration and confirm with ENTER.

e.3 Select the axis for calibration and confirm with ENTER.

f. The calibration constants are stored in the variable $ARM_DATA[num_arm].CAL_DATA, in the calibration ASCII file, in file.C5G, in NVRAM.

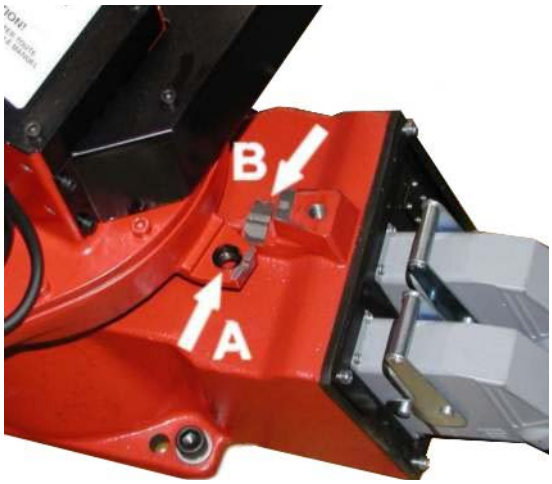
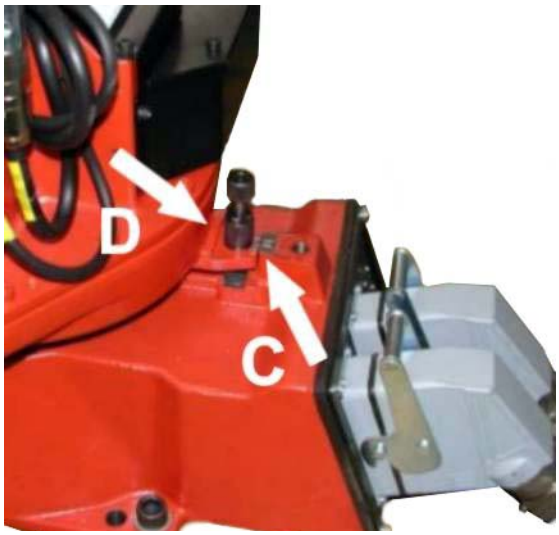
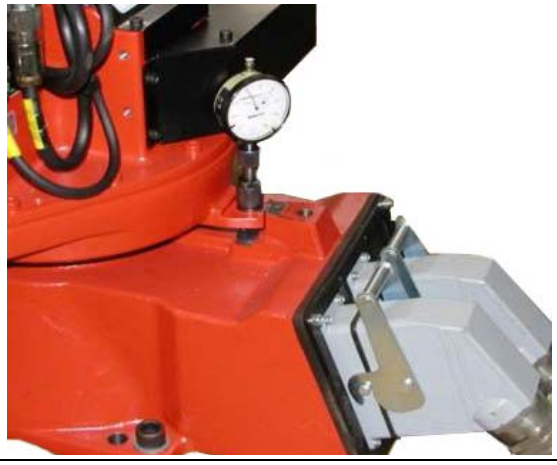
Fig. 7.3 - Axis movement direction in calibration



The following figures show the operating steps to calibrate the individual axes:

- Fig. 7.4 - Axis 1 calibration on page 101
- Fig. 7.5 - Axis 2 calibration on page 102
- Fig. 7.6 - Axis 3 calibration on page 103
- Fig. 7.7 - Axis 4 calibration on page 104
- Fig. 7.8 - Axis 5 calibration on page 106
- Fig. 7.9 - Axis 6 calibration on page 108

Fig. 7.4 - Axis 1 calibration

a. Remove the protections from the reference index (B) and seat (A) for the attachment of the dial gauge holder fixture.	
b. Align by sight the calibration notches (C). c. Fit the dial gauge holder fixture (D).	
d. Finding the minimum reading on the dial indicator, which is the calibration point. **If the minimum point has been passed, return to the start position and repeat the measurement, always moving the robot axis from negative direction to positive**	

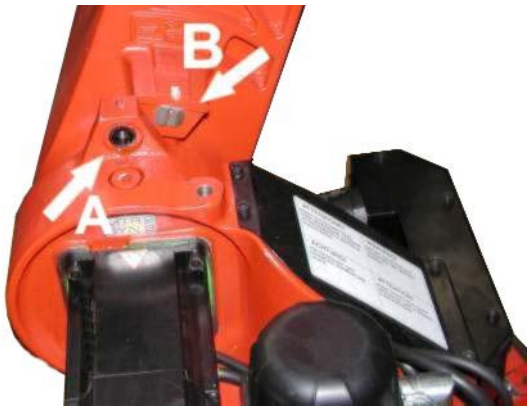
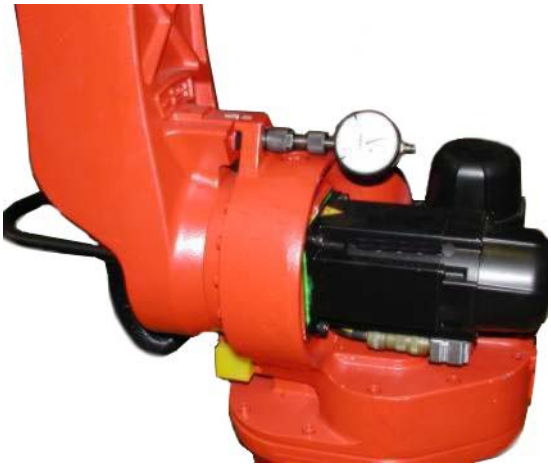
e. On the Teach Pendant keyboard, select **CAC** (Configure Arm Calibrate).

f. Select the arm for calibration and confirm with ENTER.

g. Select the axis for calibration and confirm with ENTER.

h. Remove the fixture and refit the guards on the calibration notches.

Fig. 7.5 - Axis 2 calibration

a. Remove the protection from the calibration locating notch (B) and from the seat (A) for attachment of the dial gauge holder fixture.	
b. Align by sight the calibration locating notches (C). c. Assemble the dial gauge holder fixture (D).	
d. Find the minimum point on the dial gauge that corresponds to the calibration point. **If the minimum point has been passed, return to the start position and repeat the measurement always moving the robot axes from negative direction to positive.**	

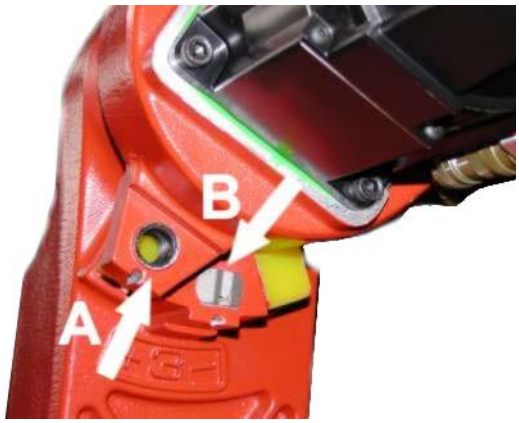
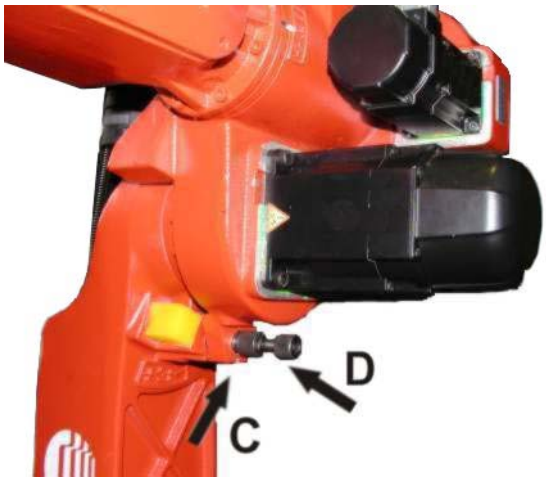
e. On the Teach Pendant keyboard, select **CAC** (Configure Arm Calibrate).

f. Select the arm for calibration and confirm with ENTER.

g. Select the axis for calibration and confirm with ENTER.

h. Remove the fixture and refit the guards on the calibration notches.

Fig. 7.6 - Axis 3 calibration

a. Remove the protection from the calibration reference index (B) and the seat (A) to attach the dial gauge holder fixture.	
b. Align by sight the calibration locating notches (C). c. Fit the dial gauge holder (D) fixture.	
d. Fit the dial gauge on the fixture. e. Find the minimum point on the dial gauge that corresponds to the calibration point. **If the minimum point is passed, return to the start position and repeat the measurement always moving the robot axis in the direction from negative to positive**	

f. On the Teach Pendant keyboard, select **CAC** (Configure Arm Calibrate).

g. Select the arm for calibration and confirm with ENTER.

h. Select the axis for calibration and confirm with ENTER.

i. Remove the fixture and refit the guards on the calibration notches.

Fig. 7.7 - Axis 4 calibration

a. Removal of the protection from the calibration location index (A).	
b. Align by sight the calibration locating notches (B).	
c. Assembly of support (C) for calibration fixture. Position the support and fasten it with an M5 socket head cap screw and two parallel pins dia. 6x20. d. Check the perfect planarity of the block with the resting surface. **If necessary, use a plastic hammer when assembling the support**	

e. Dial gauge holder support (D) assembly on the forearm surface provided	
f. Assembling the dial indicator on the holder. g. Finding the minimum reading on the dial indicator, which is the calibration point. **If the minimum reading has been passed, return to the starting position and repeat the measurement always moving the robot axis in the negative to positive direction.**	
h. On the Teach Pendant keyboard, select **CAC** (Configure Arm Calibrate). i. Select the arm for calibration and confirm with ENTER. j. Select the axis for calibration and confirm with ENTER.	
k. Remove the dial gauge holder using a screw-type puller and refit the protections on the calibration notches	

Fig. 7.8 - Axis 5 calibration

a. Removal of the calibration location index (A) protection b. Align by sight the calibration locating notches (B)	
c. Assembly of support (C) for the calibration fixture. Position the support and secure it with the two parallel pins dia. 6x20 and the M5x25 socket head cap screw d. Check the perfect planarity of the block with the resting surface. **If necessary, use a plastic hammer when assembling the support**	
e. Assembling the dial indicator holder (D).	

Fig. 7.8 - Axis 5 calibration (Continued)

<table>
<tr>
<td>f. Assembling the dial indicator on the holder.

g. Finding the minimum reading on the dial indicator, which is the calibration point.

If the minimum reading has been passed, return to the starting position and repeat the measurement always moving the robot axis in the negative to positive direction.</td>
<td> 
</td>
</tr>
<tr>
<td colspan="2">h. On the Teach Pendant keyboard, select CAC (Configure Arm Calibrate).

i. Select the arm for calibration and confirm with ENTER.

j. Select the axis for calibration and confirm with ENTER.</td>
</tr>
<tr>
<td>k. Remove the dial gauge holder using a screw-type puller

l. Refit the previously removed protections on the calibration index</td>
<td> 
</td>
</tr>
</table>

Fig. 7.9 - Axis 6 calibration

a. Removal of the calibration location index (A) protection	
b. Align by sight the calibration locating notches (B)	
c. Assembly of dial gauge holder support (D) Position the support and secure it with the two parallel pins dia. 6x20 and the M5x25 socket head cap screw d. Make sure that it is perfectly level with the supporting surface	

Fig. 7.9 - Axis 6 calibration (Continued)

e. Assembly of calibration fixture (E)	
f. Assembling the dial indicator on the holder. g. Finding the minimum reading on the dial indicator, which is the calibration point. **If the minimum reading has been passed, return to the starting position and repeat the measurement always moving the robot axis in the negative to positive direction.**	
h. On the Teach Pendant keyboard, select **CAC** (Configure Arm Calibrate). i. Select the arm for calibration and confirm with ENTER. j. Select the axis for calibration and confirm with ENTER.	
k. Remove the dial gauge holder using a screw-type puller l. Refit the previously removed protections on the calibration indexes	

7.4 User calibration

The calibration command allows certain options (that can be activated by pressing the **SHIFT** and **9**,**/** keys at the same time on the Teach Pendant) to define a robot calibration position different to that of the system (out of range calibration) as shown inFig. 7.1 - Robot calibration position on page 95.
These functions can be used:

– **/Learn**
used to bring the robot to the desired position and set the **CAC/L command**. At this point the position of the robot is stored in the system variable $ARM_DATA[num_arm].CAL_USER.
However, to carry out this operation it is first necessary to carry out a system calibration (Configure Arm Calibrate without options).

– **/User**
used to execute a calibration on the position stored in the system variable $ARM_DATA[num_arm].CAL_USER as specified above. After this operation has been executed, the calibration constant is stored in the same system variable used for the system calibration constant ($CAL_DATA).

7.5 Calibration using the locating notches

The calibration by means of the notches enables a quick but improper calibration that has a limited precision and may not restore the robot movement precision required by the specific application.
Calibration using the notches consists in bringing the robot axes onto the calibration notches, aligning them by sight without using specific fixtures and executing the calibration commands axis by axis as specified in
par. 7.3.3 Axes Calibration on page 99 in step e. (CONF ARM CALIB commands).

If it is required to execute the Turn-set of a calibrated robot, error *59438 SAX: drive off for dynamic model disable* will be displayed if the turn-set for one axis has been requested, or *59439 SA: drive off for dynamic model disable for* turn-set of all axes *(option *).*
The robot will be put in DRIVE OFF and the motor turn will automatically be lost.

a. After the robot has been correctly positioned, start the calibration as follows:

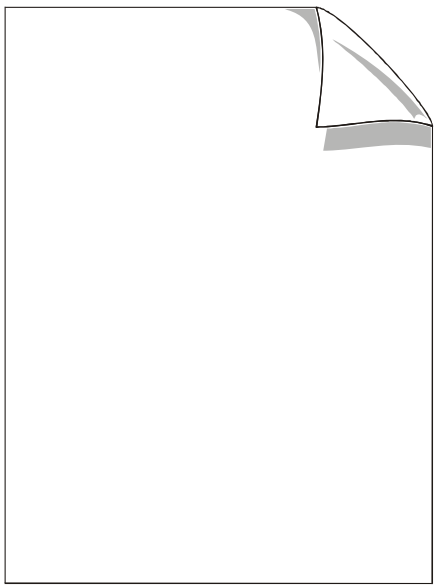
a.1 On the Teach Pendant keyboard, select CAC (Configure Arm Calibrate).

a.2 Select the arm for calibration and confirm with ENTER.

a.3 Select the axis for calibration and confirm with ENTER.

The calibration constants are stored in the variable $ARM_DATA[num_arm].CAL_DATA, in the calibration ASCII file, in file.C5G, in NVRAM - MCP.

There are also other options that can be used with the calibration commands (activated by pressing together the **SHIFT** and **9**,*I* keys on the Teach Pendant) to define a robot calibration position out of range that is different to that of the system, see par. 7.4 User calibration on page 110.



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