ROBOTICS
MAN AND MACHINE

Arm - TX series 90 family

Characteristics

D18327604B - 08/2005

STÄUBLI

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CHAPTER 1

DESCRIPTION

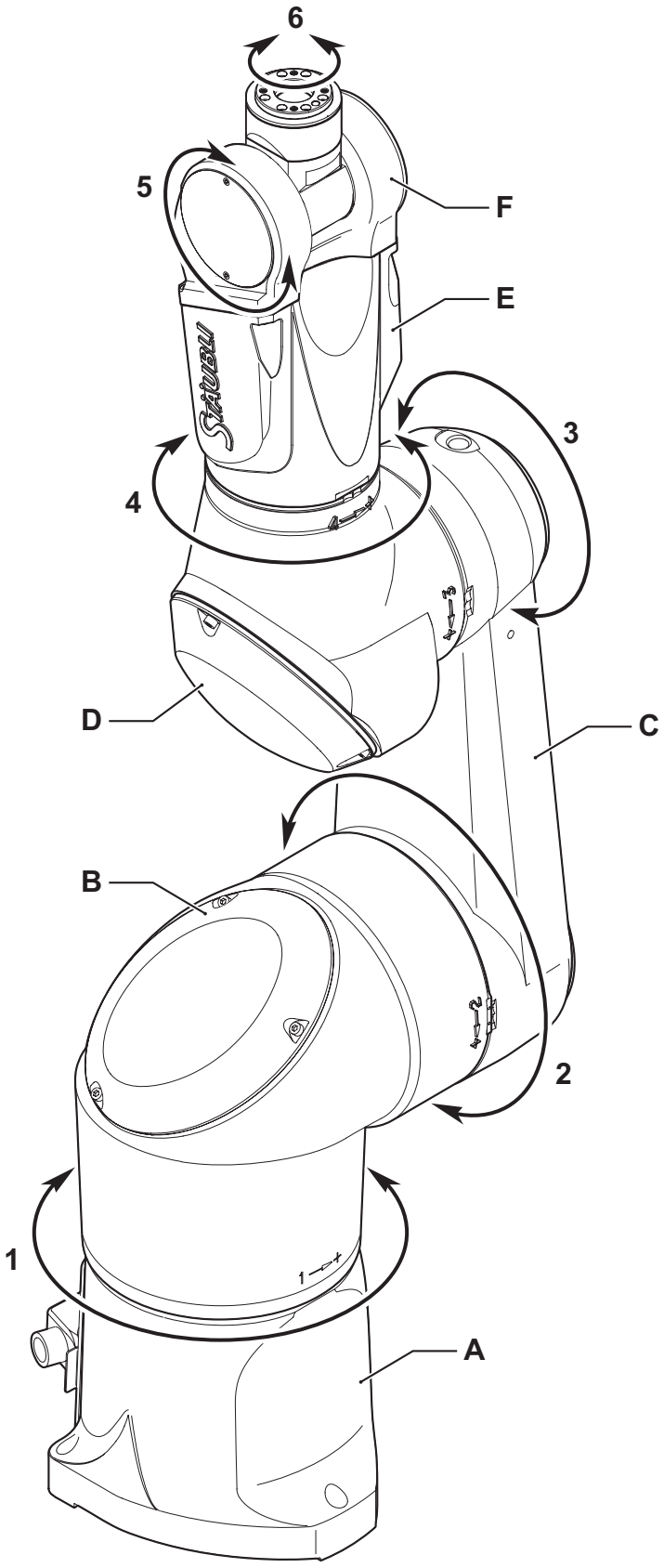

Figure 1.1

1.1. IDENTIFICATION

Manufacturer's plate on each robot.

There is a plate riveted on the controller and arm (see figure 1.2).

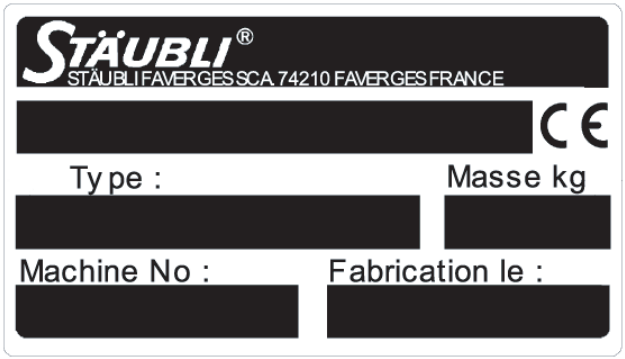

Figure 1.2

For all requests concerning information, replacement part orders, or requests for intervention, please state the type and the serial number of the machine concerned, as set out on the manufacturer's plate.

1.2. GENERAL PRESENTATION

The arm consists of segments or members interconnected by joints **(figure 1.1).**

Movements on the arm joints are generated by servomotors coupled with position sensors. Each of these motors is equipped with a parking break.

This reliable and robust assembly associated with an innovative counting system allows the absolute position of the robot to be known at all times.

The arm assembly is sufficiently flexible and is able to perform a great variety of applications.

Example: Handling of loads, assembly, process, application of adhesive beads, control/check and clean room applications. This list is not restrictive: for further information, please consult us.

The various elements of the robot's arm are: the base **(A)**, the shoulder **(B)**, the arm **(C)**, the elbow **(D)**, the forearm **(E)** and the wrist **(F) (figure 1.1).**

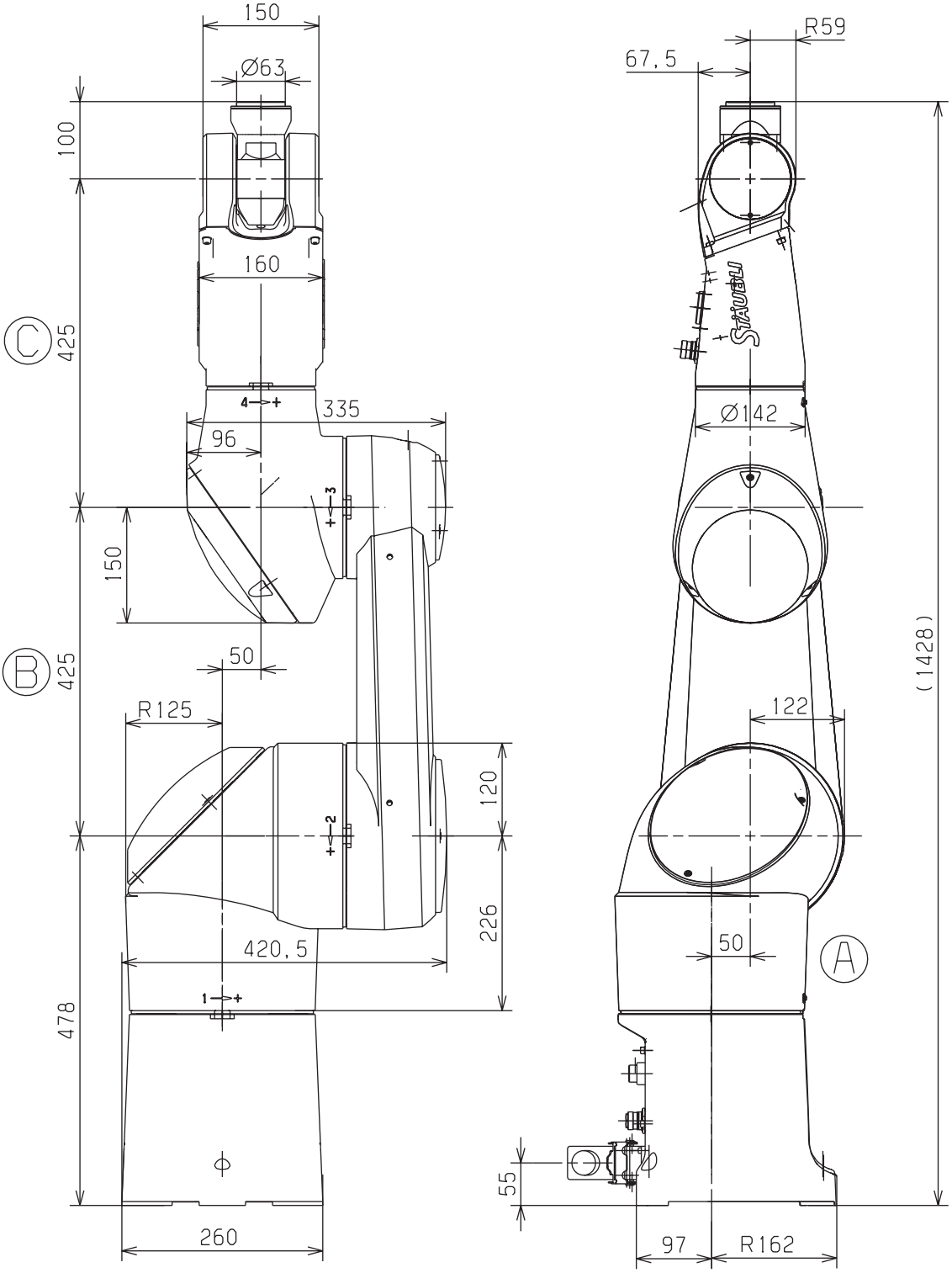

Figure 1.3 - Standard arm

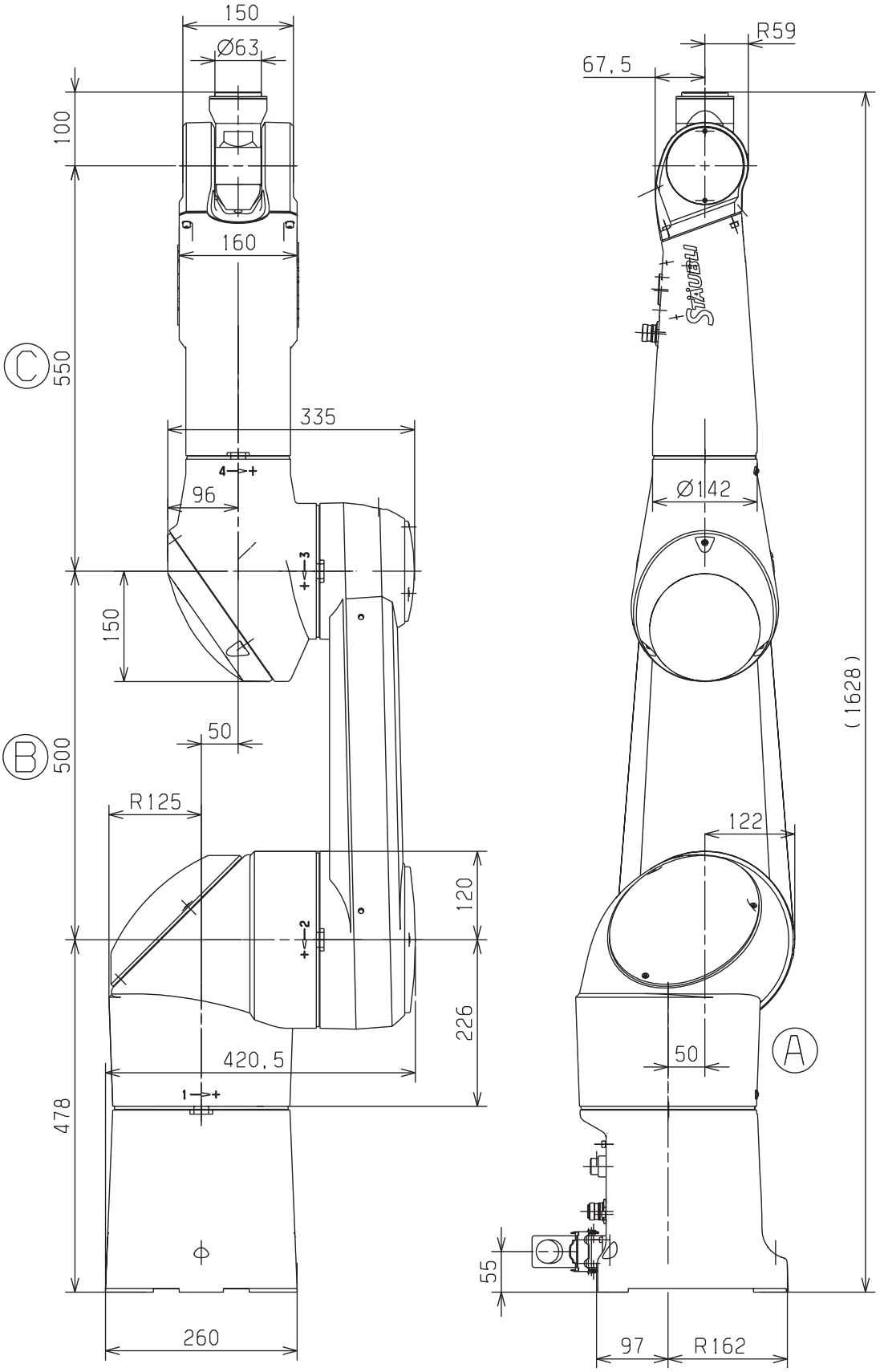

Figure 1.4 - Long arm

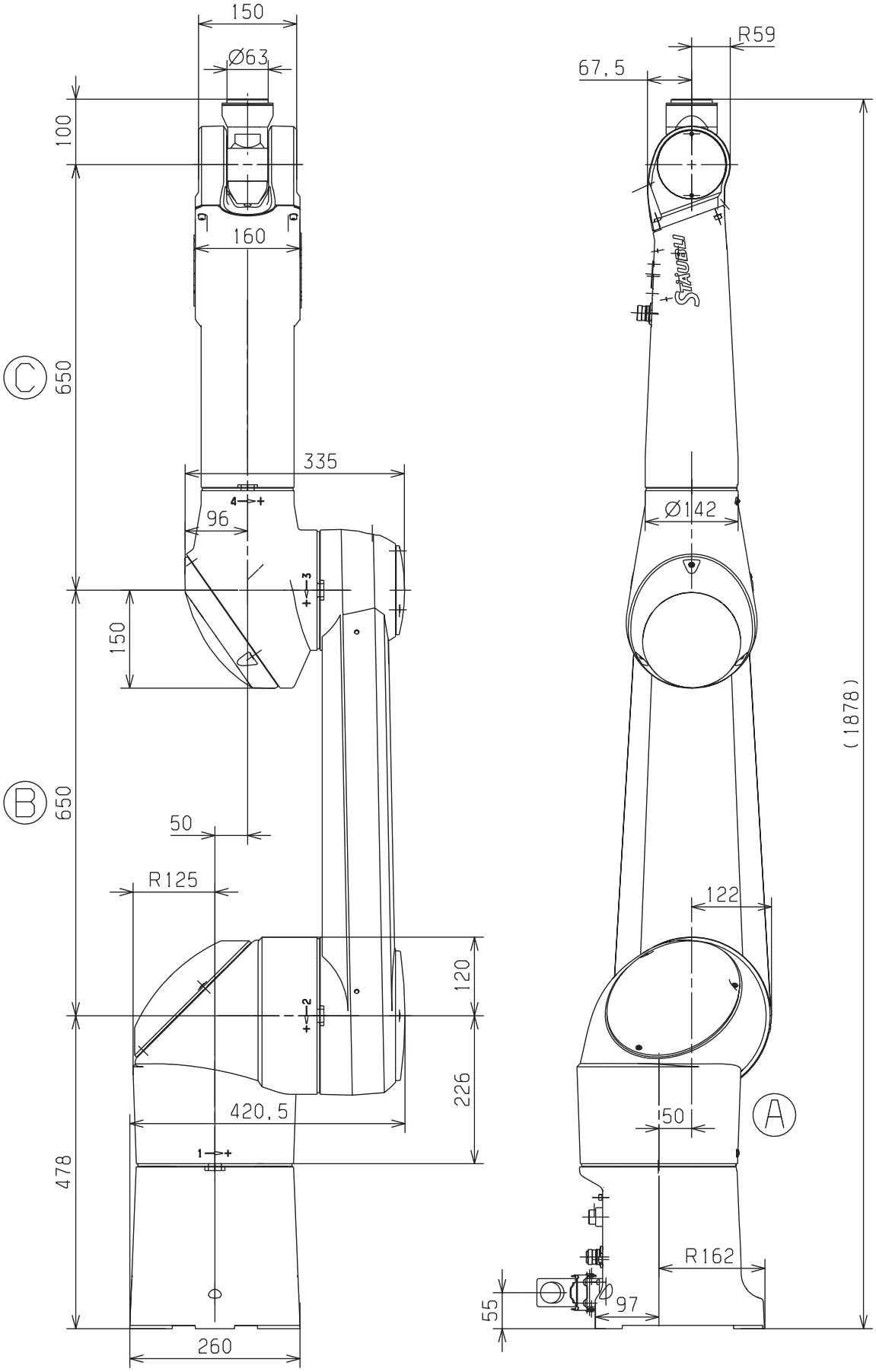

Figure 1.5 - Arm XL

1.3. DESIGNATION OF ROBOTS OF THE TX SERIES 90 FAMILY

TX	9	0		CR
(1)	(2)	(3)		(4)

(1) TX family arm

(2) Maximum reach between joints 1 and 5 expressed in decimeters:
dimension Ⓐ + dimension Ⓑ + dimension Ⓒ.

(3) Number of active joints:
- 0 = 6 active axis.

(4) Upper case letters to indicate an option.
- L = long version.
- XL = extra-long version.
- CR = clean room application.
- SCR = ultra-clean room application.

These letters can be combined.
Example: LCR = Long arm for clean room applications.

In the manual, the following terminology is used:

Standard arm: for arm with standard geometry **(figure 1.3)**.

Arm L: arm with a different shape where the forearm and the arm are longer **(figure 1.4)**.

Arm XL: extra long arm **(figure 1.5)**.

1.4. GENERAL CHARACTERISTICS

1.4.1. DIMENSIONS

See figures **1.3, 1.4** and **1.5**.

1.4.2. WORK ENVIRONMENT

- Working temperature: + 5°C to + 40°C (in accordance with standard directive NF EN 60 204-1).

> **CAUTION:**
> **It may be necessary to perform a warm-up cycle before nominal performances are obtained.**

- Humidity: 30% to 95% max. non-condensing (in accordance with standard directive NF EN 60 204-1).
- Altitude: 2000 m max.
- Vibrations: please consult us.

Clean room application:

- CR: cleanness class 4 in accordance with standard 14644-1.
- SCR: cleanness class 3 in accordance with standard 14644-1.

IP65 arm protection and IP67 wrist protection in accordance with standard NF EN 60529 with electric connectors or plugs in place.

> **CAUTION:**
> **If the robot is used in dusty surroundings or in the presence of spattered liquids, we strongly recommend use of the pressurization system as described in chapter 1.10, page 33.**

1.4.3. WEIGHT

Standard arm	Long arm	Arm XL
111 kg	114 kg	116 kg

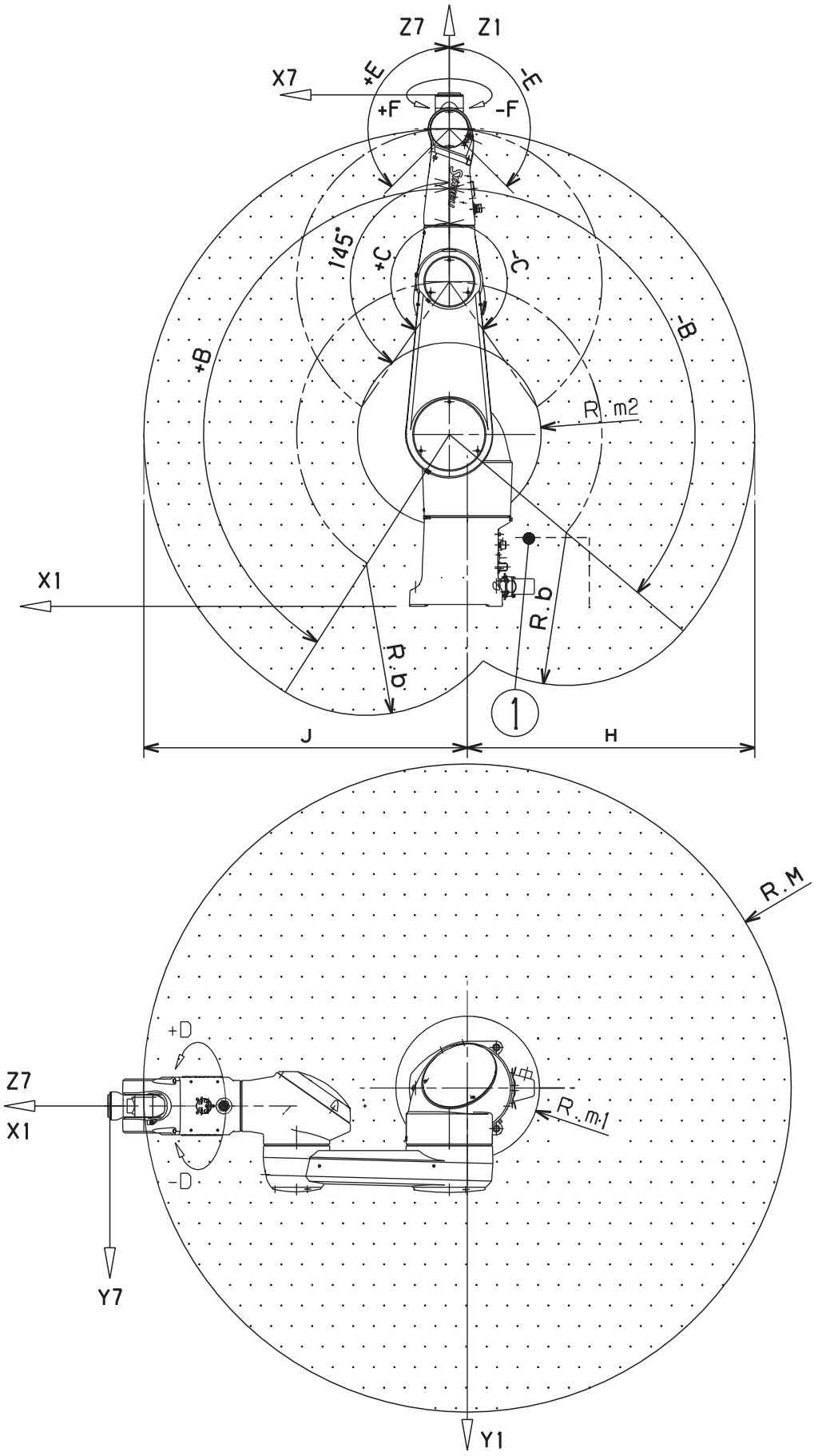

Figure 1.6

1.5. PERFORMANCE

See **figure 1.6** (1) Brake release access area

	Standard arm	Long arm	Arm XL
Work envelope			
R.M max. reach between axis 1 and 5	900 mm	1100 mm	1350 mm
R.M max. reach between axis 2 and 5	850 mm	1050 mm	1300 mm
R.m1 min. reach between axis 1 and 5	200 mm	272 mm	327 mm
R.m2 min. reach between axis 2 and 5	256 mm	320 mm	391 mm
R.b reach between axis 3 and 5	425 mm	525 mm	650 mm
Maximum speed at load center of gravity	10.42 m/s	10.54 m/s	11.09 m/s
Repeatability at constant temperature	± 0.03 mm	± 0.035 mm	± 0.040 mm

1.5.1. AMPLITUDE, SPEED, RESOLUTION, REPEATABILITY

Axis	1	2	3	4	5	6
Amplitude (°)	360	277.5	280	540	255	540 (1)
Working range distribution (°)	A ± 180	B + 147.5 - 130	C ± 145	D ± 270	E + 140 - 115	F ± 270
Nominal speed (°/s) TX90	250	200	300	430	350	600
Nominal speed (°/s) TX90 L	215	170	255	430	350	600
Nominal speed (°/s) TX90 XL	190	160	230	400	345	600
Maximum speed (°/s) (2)	400	400	400	500	450	720
Angular resolution ($°.10^{-3}$)	0.057	0.057	0.057	0.057	0.122	0.183

(1) Can be configured by software up to ±18 000°. See the "Software configuration" chapter in the "Controller" documentation

(2) Maximum speed for reduced conditions of load and inertia.

Low speed in manual mode: 250 mm/s at tool centre point and 45 °/s on each joint.

Maximum Cartesian speed: 2.5 m/s.

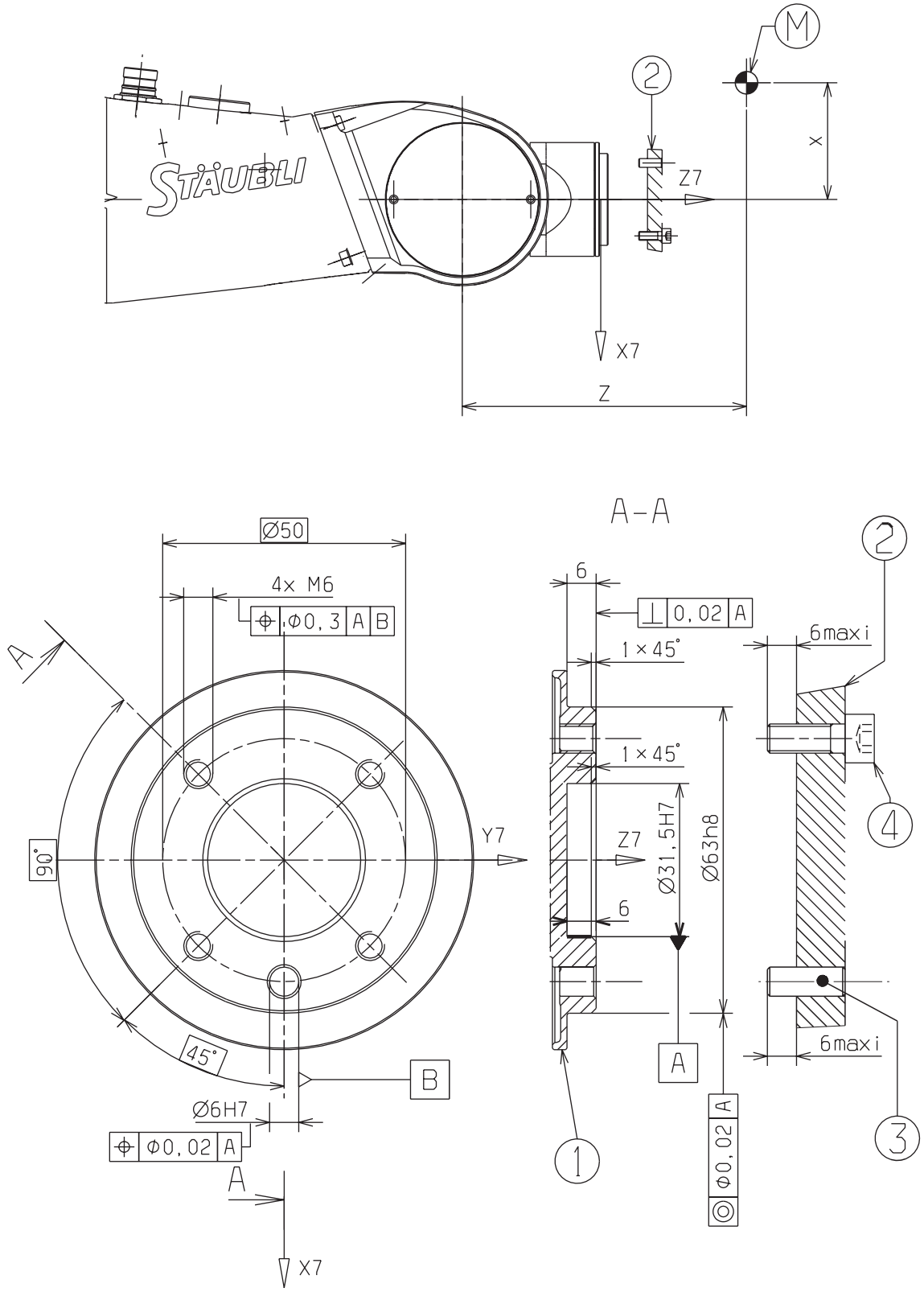

Figure 1.7

① Mechanical interface

② End-effector

1.6. LOAD CAPACITY – MECHANICAL INTERFACE

See **figure 1.7**.

The end-effector is not supplied with the robot arm assembly; its design depends on the robot's specific applications. All studies can be undertaken in cooperation with STÄUBLI to obtain optimum performance without exceeding the robot arm assembly load limits.

The end-effector is installed on the mechanical interface of the wrist dimensions of which are given on figure **1.7**.

Secured by 4 class 12-9 screws M6 **(4)**, tightening torque 16.7 Nm ± 1.2 Nm.

Indexing via pin **(3)**, diameter 6.

Mechanical interface designation:
ISO 9409 - 1 as per Standard ISO 9409 - 1 : 1996 (F)
(except the localization of the 4 M6 threaded holes)

CAUTION:
Length of end-effector attaching screws is limited to avoid all interference with the wrist (figure 1.7).

1.6.1. LOAD CAPACITY **(figure 1.7)**

Load characteristics:

(1) Load center of gravity position : z = 195 mm as compared with axis 5 and x = 80 mm.

(2) Load center of gravity position : z = 165 mm as compared with axis 5 and x = 75 mm.

Load capacity	Standard arm		Long arm		Arm XL	
	Floor or ceiling configuration	Wall configuration	Floor or ceiling configuration	Wall configuration	Floor or ceiling configuration	Wall configuration
At nominal speed (1)	6 kg		5 kg		4 kg	
(2)	7 kg		6 kg		5 kg	
At reduced speed (1)	14 kg		12 kg		9 kg	

(1) in all configurations and taking maximum inertias into account. See table below.

	Nominal inertias (kg.m²)			Maximal inertias (kg.m²) (2)		
	Standard arm	Long arm	Arm XL	Standard arm	Long arm	Arm XL
For joint 5	0.3	0.25	0.2	1.5	1.25	1
For joint 6	0.05	0.04	0.03	0.25	0.20	0.15

(2) under reduced speed and acceleration conditions.

Generally: VEL = 60%, ACC = 30%, DEC = 30% (consult us)

CAUTION:
The nominal values can be exceeded to a certain extent but imply a limitation to the speed and the acceleration of the arm. If these limits are to be exceeded, please consult STÄUBLI.

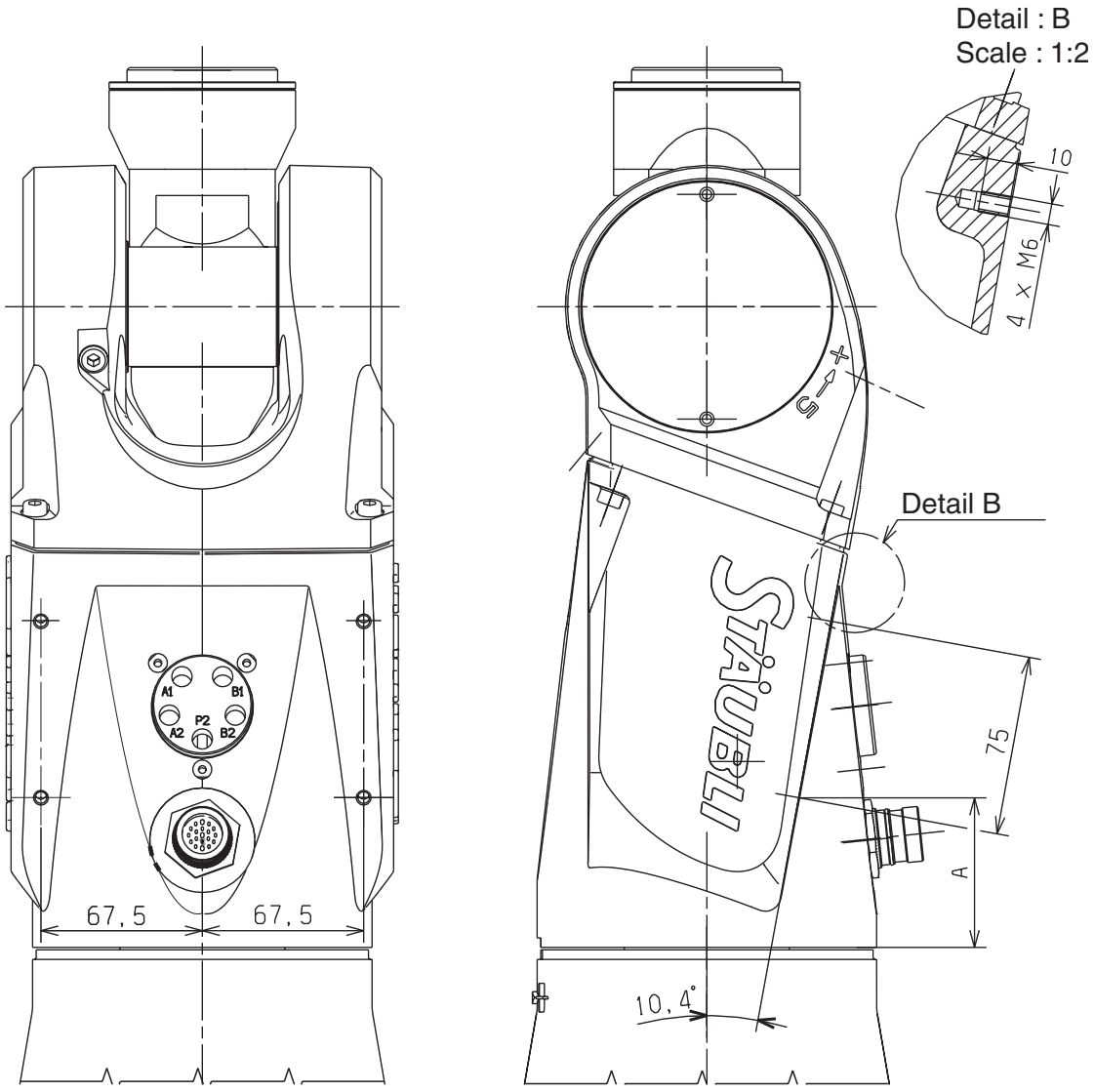
Detail : B
Scale : 1:2
10
4 x M6
S
Detail B
75
A
10,4°
67,5
67,5
A1
B1
A2
P2
B2

Figure 1.8

1.6.2. TORQUE LIMITS

	Reference axis		
	Axis 4	**Axis 5 (Z6)**	**Axis 6 (Z7)**
Static torque (Nm)	36	30	11

Note:
These pairs are available for a load carried equal to 0 kg.

1.6.3. ATTACHMENT OF ADDITIONAL LOAD ON FOREARM

See **figure 1.8**.

An additional load can be attached to the forearm using 4 M6 screws; maximum torque is 7 Nm.

Position of 4 M6 tapped holes: See **figure 1.8**.

Dimensions	**Standard arm**	**Long arm**	**Arm XL**
A	62.6 mm	187.6 mm	287.6 mm

CAUTION:
The additional load depends on nominal load (see next page). In all cases, do not exceed load characteristics.

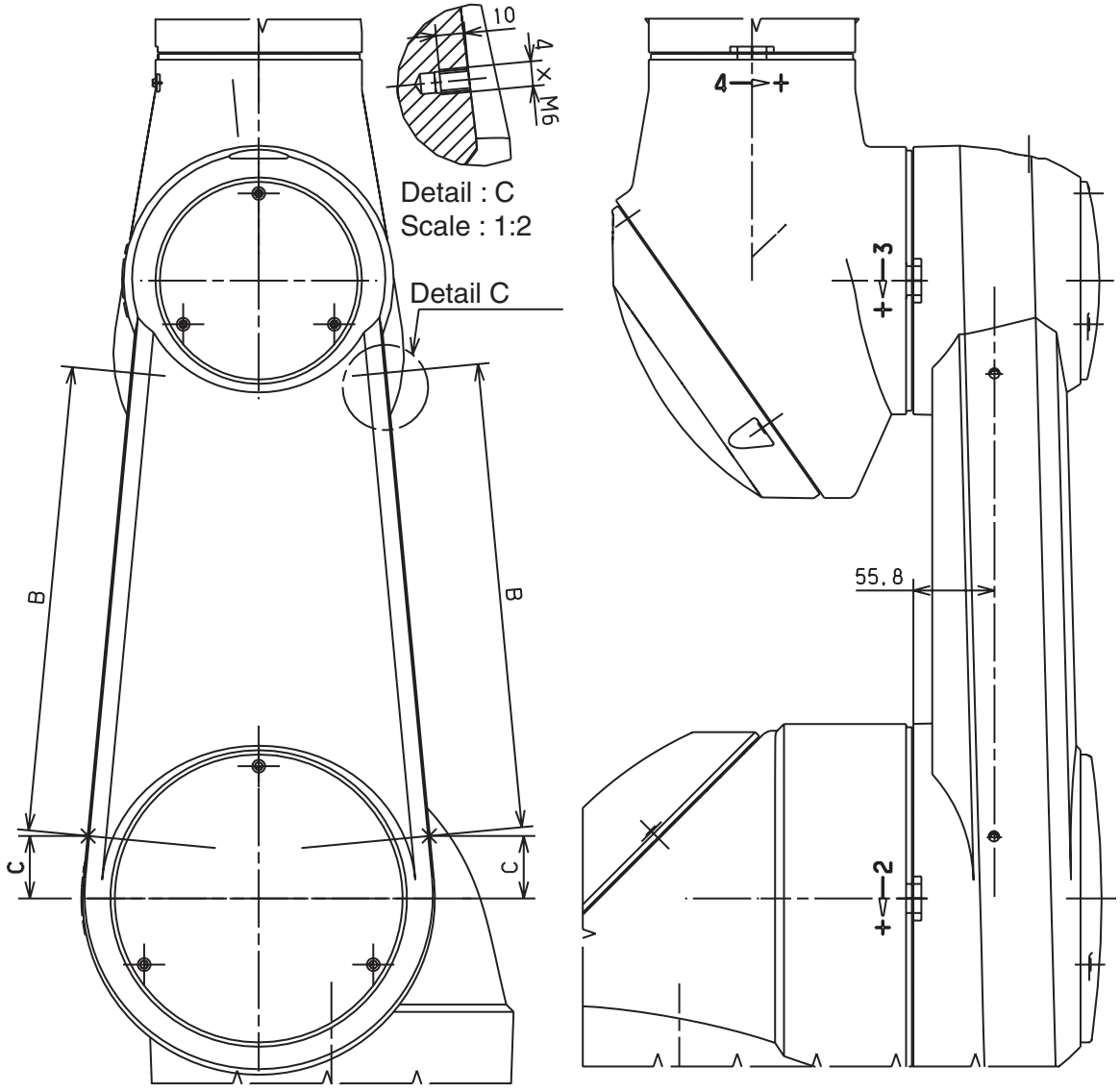

Figure 1.9

1.6.4. FIXING THE AUXILIARY HARNESS ON THE ARM CASING

See **figure 1.9**.

Dimensions	Standard arm	Long arm	Arm XL
B	320 mm	400 mm	550 mm
C	31.6 mm	30 mm	30 mm

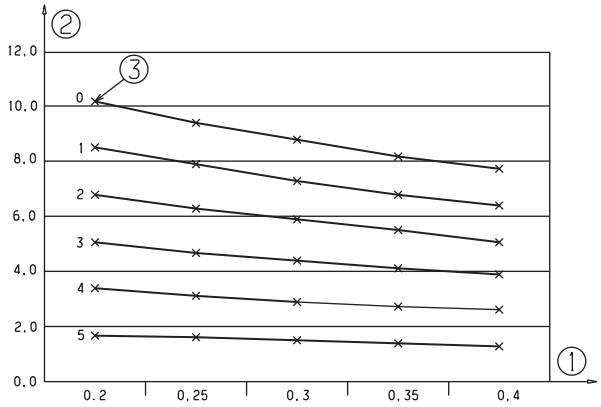

Figure 1.10

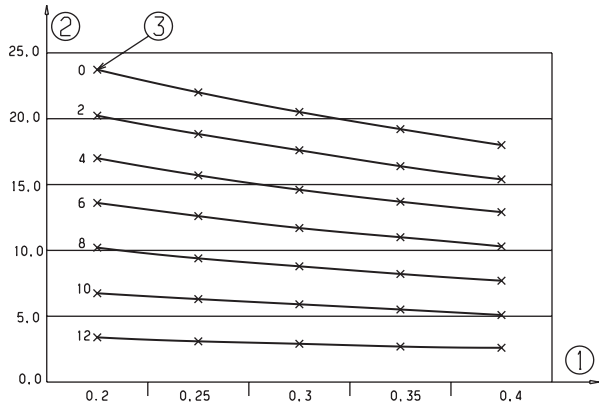

Figure 1.11

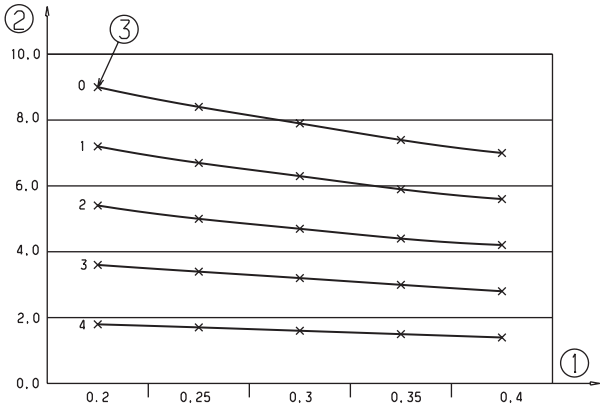

Figure 1.12

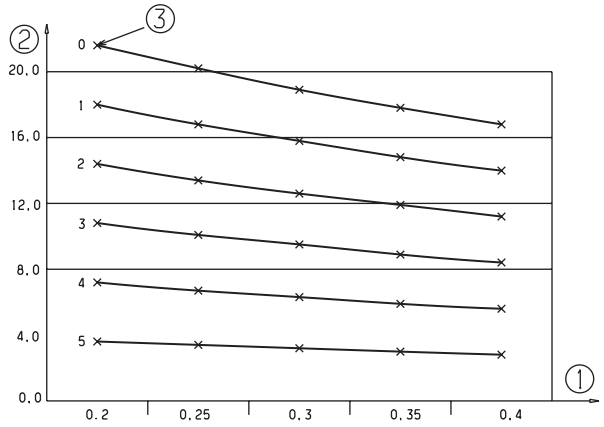

Figure 1.13

1.6.5. ADDITIONAL LOAD DIAGRAMS

See figures **1.10**, **1.11**, **1.12** and **1.13**.

These diagrams can be used to determine the additional load which can be attached to the forearm depending on its center of gravity position from joint 3 and the load attached to the mechanical interface of the wrist.

(1) Additional load center of gravity position (m) from centerline of joint 3.

(2) Additional load (kg).

(3) Load carried fixed on the mechanical interface of the wrist at a distance of 195 mm as compared with axis 5 and 80 mm as compared with axis 6.

Figure 1.10: for standard TX90
Figure 1.11: for standard TX90 with reduced speeds (1)
Figure 1.12: For TX90 L
Figure 1.13: For TX90 L at low speeds(1)

(1) Reduced speeds:
For CS8C: VEL = 60%, ACC = 30%, DEC = 30%

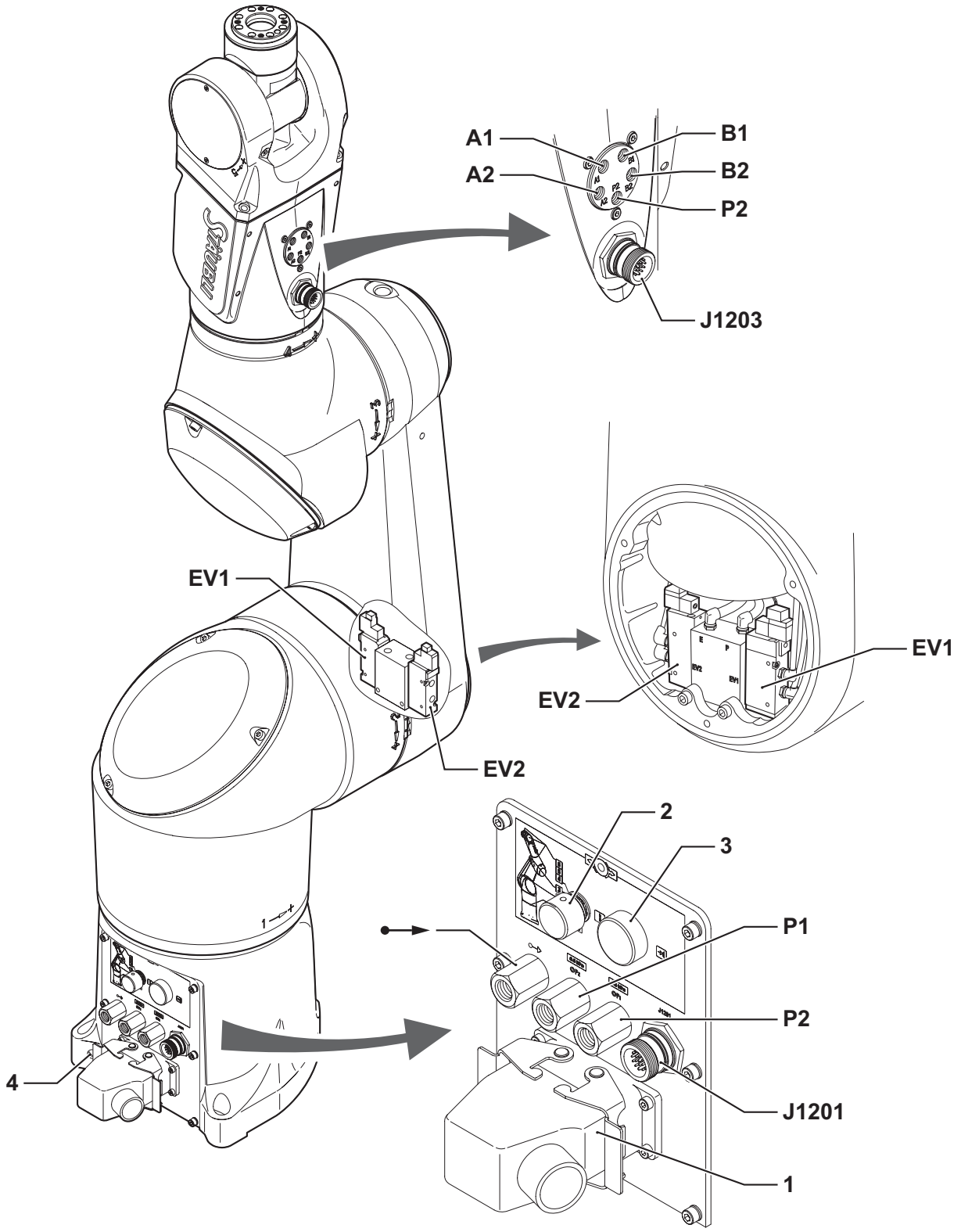

Figure 1.14

1.7. LOGIN USER

See **figure 1.14**.

The electric wiring of the arm is assembled into a harness including several cables supplying the motors (power, brakes, resolvers), the solenoid valves, the limit switches and login user. These components are connected by means of removable connectors.

The harness also includes pneumatic hoses which supply air to the solenoid valves (**EV1** and **EV2**).

The robot also has a pressure source (**P2**) close to the tool clamp.

The outlets of the solenoid valves **EV1** and **EV2** are on the forearm:

- **A1** and **B1** for solenoid valve **EV1**.
- **A2** and **B2** for solenoid valve **EV2**.

The wiring is inside the structure and routed through the centre of the joints. It is connected to the arm base on a plate which includes several electrical and pneumatic components such as (figure **1.14**) :

- Arm/**(1)** controller interconnection socket.
- R23 connector intended for the user for possible electrical connection of grip (**J1201**).
- Brake release selector **(2)**.
- Brake release pushbutton **(3)**.
- Pneumatic connections to the **P1** and **P2** compressed air networks.
- Pneumatic exhaust muffler ⟶ .
- Arm ground connection **(4)**.

CAUTION:

Do not add wires or cables to arm wiring as this may cause premature wear of the arm electrical wiring and lead to loss of the warranty.

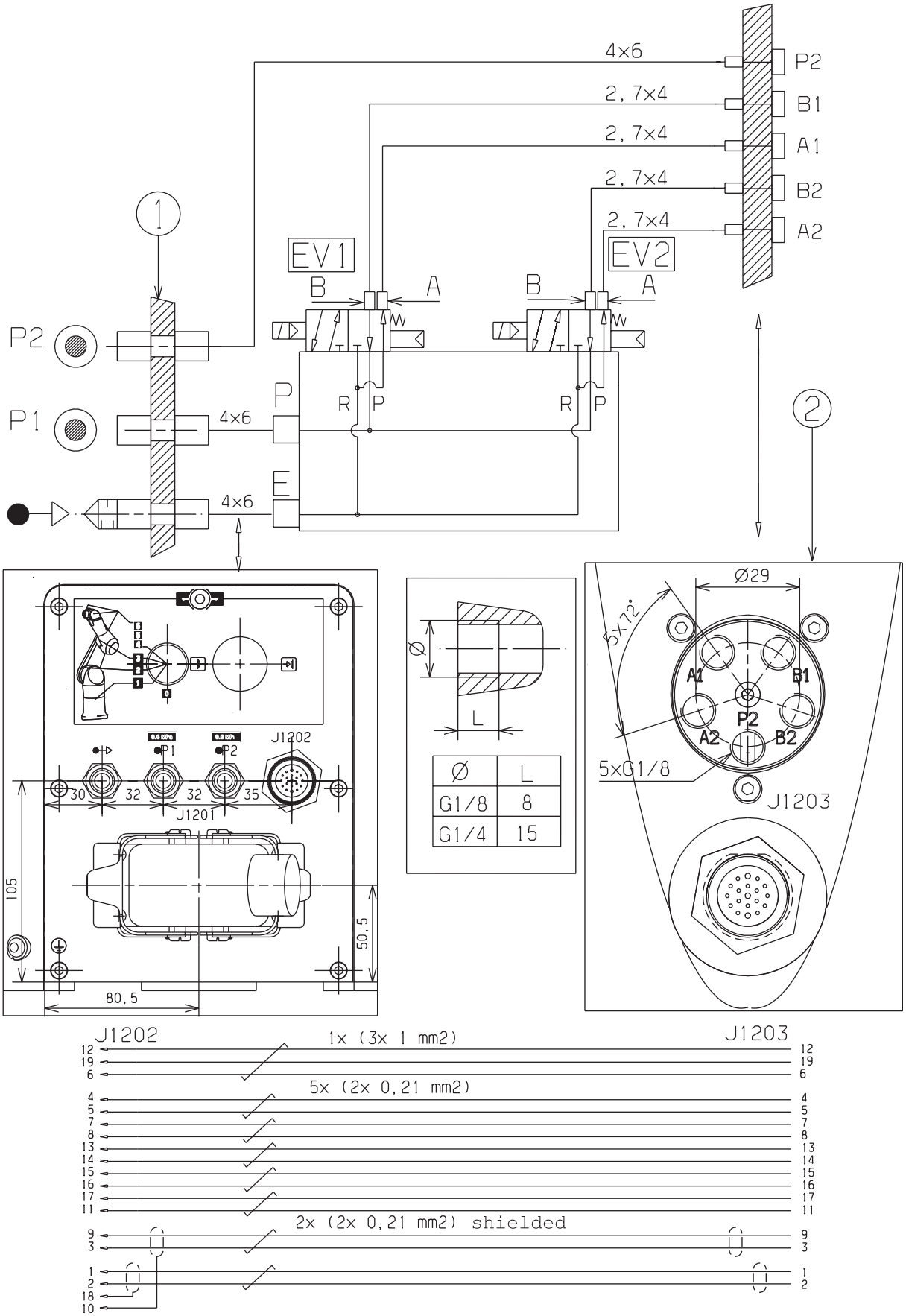
4×6
2, 7×4
2, 7×4
2, 7×4
2, 7×4
P2
B1
A1
B2
A2
1
EV1
EV2
B
A
B
A
P2
P1
4×6
4×6
P
R
P
R
P
E
2
J1202
P1
P2
30
32
32
35
J1201
105
50.5
80.5
Ø
L
Ø
L
G1/8
8
G1/4
15
Ø29
5×72°
A1
B1
P2
A2
B2
5×G1/8
J1203
J1202
1x (3x 1 mm2)
J1203
12
19
6
5x (2x 0,21 mm2)
4
5
7
8
13
14
15
16
17
11
2x (2x 0,21 mm2) shielded
9
3
1
2
18
10

Figure 1.15

1.8. PNEUMATIC CIRCUITS (USING COMPRESSED AIR) AND ELECTRIC CIRCUITS WITH STANDARD ROBOT EQUIPMENT (OR CLEAN ROOM AS AN OPTIONAL EXTRA)

1.8.1. PNEUMATIC CIRCUIT

(1) Plate attached to base

(2) Forearm

Solenoid valves (EV1 and EV2):

- 5/2-way monostable.
- Electrically controlled (24 VDC).
- Working pressure: 1.5 to 7 bar.
- Flow coefficient KV 8.6.
- Clip-on connector.
- Overvoltage protective circuit and indicator diode.

Description (figure 1.15):

- The arm is connected to the compressed air network (7 bars max., lubricated or not) via the base **P1**.

> **CAUTION:**
> **The air must be filtered by a 10 µm filter.**

- There is a direct line between the base and the forearm (**P2**).
- The centralized solenoid valve exhaust is directed to the base and through a muffler ⟶ .

1.8.2. ELECTRIC CIRCUIT

The electrical circuit consists of:
- A male 19-contact socket at the bottom of the arm.
- A female 19-contact socket on the forearm.

These 19 contacts include 3 power contacts and 16 command contacts.

The 3 power contacts in each socket are connected by a 3-wire conductor with cross-section AWG18 (contacts 6-12-19).
The 16 command contacts in each socket are connected in the following way:
- 2 shielded twisted pairs, cross-section AWG24 connecting contacts 3-9-10 and 1-2-18 in each socket.
- 5 twisted pairs, cross-section AWG24 for the other contacts.

Supply voltage: 60 VDC - 25 VAC.

Permissible current:
- 3-wire conductor AWG18: 4.5 A per contact.
- Pairs and shielded pairs AWG24: 2 A per contact.

> **CAUTION:**
> **Do not use the shields as a conductive cable.**

- Connection to forearm (**J1203**) by R23 elbow male cylindrical connector.
- Connection to base (**J1202**) by R23 straight female cylindrical connector.

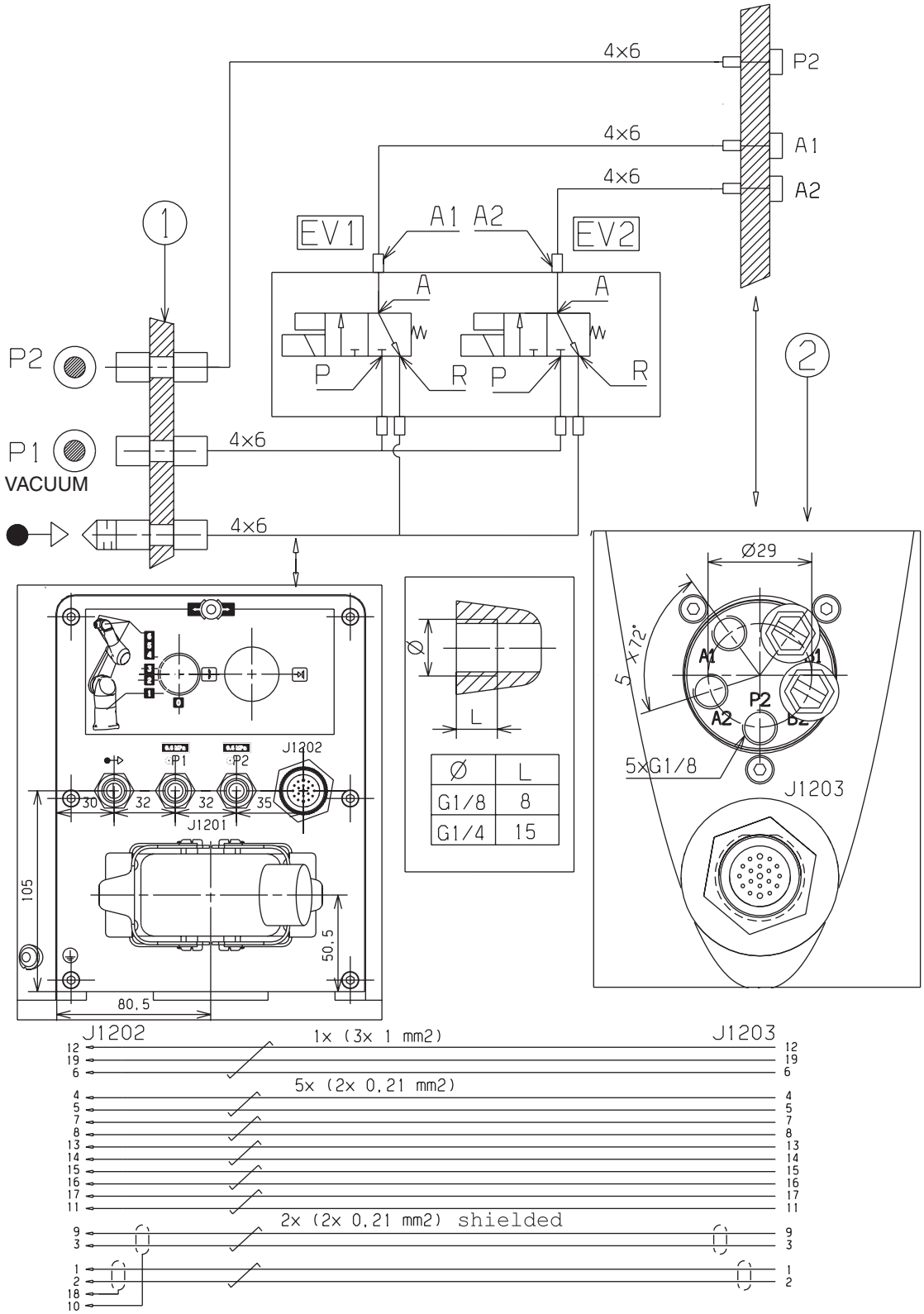
4×6
P2
4×6
A1
4×6
A2
EV1
A1 A2
EV2
A
A
P
R
P
R
1
2
P2
P1
VACUUM
4×6
4×6
J1202
P1
P2
30
32
32
35
J1201
105
50,5
80,5
Ø
L
Ø
L
G1/8
8
G1/4
15
Ø29
5 x 72°
A1
B1
P2
A2
B2
5xG1/8
J1203
J1202
1x (3x 1 mm2)
J1203
5x (2x 0,21 mm2)
2x (2x 0,21 mm2) shielded

Figure 1.16

1.9. PNEUMATIC CIRCUITS (USING VACUUM) AND ELECTRIC CIRCUITS WITH CLEAN ROOM ROBOT EQUIPMENT (OR STANDARD EQUIPMENT AS AN OPTION)

1.9.1. PNEUMATIC CIRCUIT

(1) Plate attached to base

(2) Forearm

Solenoid valves (EV1 and EV2):

- 3/2-way monostable.
- Electrically controlled (24 VDC).
- Max. working pressure: vacuum only ~ - 0.8 bar.
- Flow coefficient KV 12.6.
- Clip-on connector.

Description (figure 1.16):

- The arm is connected to the vacuum network via the base **(P1)**.
- There is a direct line between the base and the forearm **(P2)**.
- Max. working pressure: vacuum only.

> **CAUTION:**
> **Cleanliness of sucked in air must be equivalent to 10 µm filtered air.**

1.9.2. ELECTRIC CIRCUIT

The electrical circuit consists of:
- A male 19-contact socket at the bottom of the arm.
- A female 19-contact socket on the forearm.

These 19 contacts include 3 power contacts and 16 command contacts.

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- 5 twisted pairs, cross-section AWG24 for the other contacts.

Supply voltage: 60 VDC - 25 VAC.

Permissible current:
- 3-wire conductor AWG18: 4.5 A per contact.
- Pairs and shielded pairs AWG24: 2 A per contact.

> **CAUTION:**
> **Do not use the shields as a conductive cable.**

- Connection to forearm (**J1203**) by R23 elbow male cylindrical connector.
- Connection to base (**J1202**) by R23 straight female cylindrical connector.

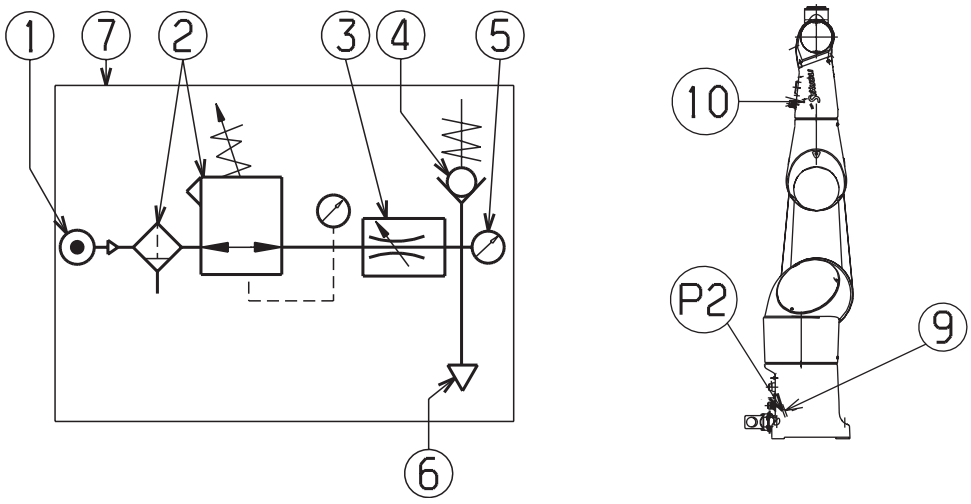

Figure 1.17

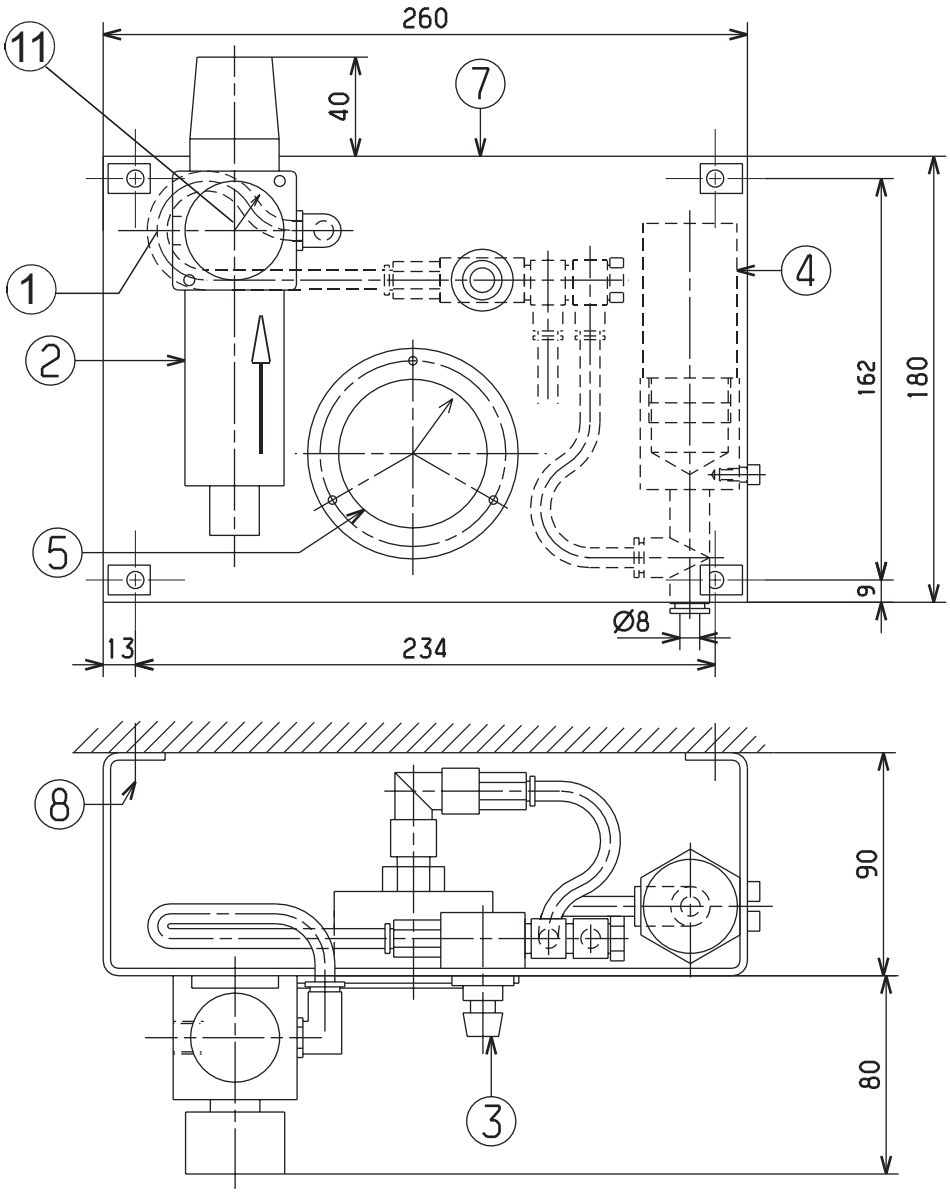

Figure 1.18

1.10. PRESSURIZATION SYSTEM FOR DUSTY SURROUNDINGS OR SPATTERING WITH LIQUIDS

1.10.1. PURPOSE

For very severe applications in dusty surroundings or with spattered liquids, the objective is to keep the pressure inside the arm above atmospheric pressure in order to avoid migration of dust and liquids.

> **CAUTION:**
> **The overpressure must never exceed 20 mbar.**

1.10.2. INSTALLATION (figures **1.17** and **1.18**)

- If the hose **(P2)** between **(9)** and **(10)** is not used, cut the pipe **(P2)** at **(9)** and plug **(P2)** at **(10)**.
- If **(P2)** is used for another function, add a pressure sealed union to the connector mount (black plate at base of arm to which the electrical connector is attached).
- Attach the unit with 4 screws (Ø 6 max.) at item **(8)** (screws not supplied) to a rigid vertical wall in direction shown by arrow; the air inlet **(1)** being to the left of the regulator **(2)**.
- Provide for air inlet at **(1)**, this is a G1/4 tapped hole; the air pressure is 10 bar maximum. Before the pressure arrives at **(1)**, make sure that the regulator **(2)** is completely screwed out and that the valve **(3)** is completely screwed in. Before pressurizing the arm, also make sure that the arm is correctly connected and correctly sealed (covers closed, plugs in hoisting ring tapped hole, pipe connected at **(6)** and at **(9)**, etc.).
- Install a pipe with an outside Ø 8 between the unit (output **6**) and the arm (input **P2**). Provide a male G1/4 union for the pipe with an outside Ø 8. At **(P2)**, the hole is a G1/4 tapped hole for the complete RX range.
- Pressurize the arm.

  1) Slowly screw in the regulator. First adjust the pressure to 1 bar max. (pressure shown on pressure gage **11**).

     Note:
     *At this stage, the low pressure gage **(5)** must remain at 0 mbar.*

  2) Very slowly screw out the valve **(3)**; the value on the pressure gage **(5)** must increase progressively. When this value reaches 5 to 10 mbar and remains stable, adjustment is considered as correct.

> **CAUTION:**
> **An excessive value (above 40 mbars) will make the pressure gage (5) unusable.**

- If however the valve **(3)** is completely screwed out and it is impossible to reach 5 mbar, check that:

  a) The circuit is tight (unit, arm, pipe, etc.).

  b) The pressure gage **(5)** is not unserviceable (damaged by a pressure greater than 40 mbar).

If the 2 points a and b are correct, the pressure can be increased by means of the **(2)** regulator without however exceeding 2 bar.

Note:
It is preferable for safety reasons (valve 4 opens between 15 and 25 mbars) and consumption reasons to work with minimum pressures (high and low pressures).

1.11. RELEASING JOINT BRAKE

CAUTION:
Make sure that the arm and load relevant to this joint are suitably supported.

The controller must be connected to the power supply.

Place the brake release selector in position corresponding to the joint to be released.

When the pushbutton is pressed to free the brakes, the brake on the joint under consideration is freed and the motor is put into short-circuit on the amplifier to brake the arm drop speed.

1.12. SAFETY

DANGER:
None of the joints are equipped with a balancing system. Short-circuiting of the motors is the only system used to limit the drop speed.

DANGER:

- **TX90L and TX90XL arms**

If the arm is kept immobile under full load while disconnected from the power supply, in certain configurations it is possible for the brake on joint 2 to slip under the external force thus applied, causing the arm to drop slowly.

CHAPTER 2

ON-SITE PREPARATION

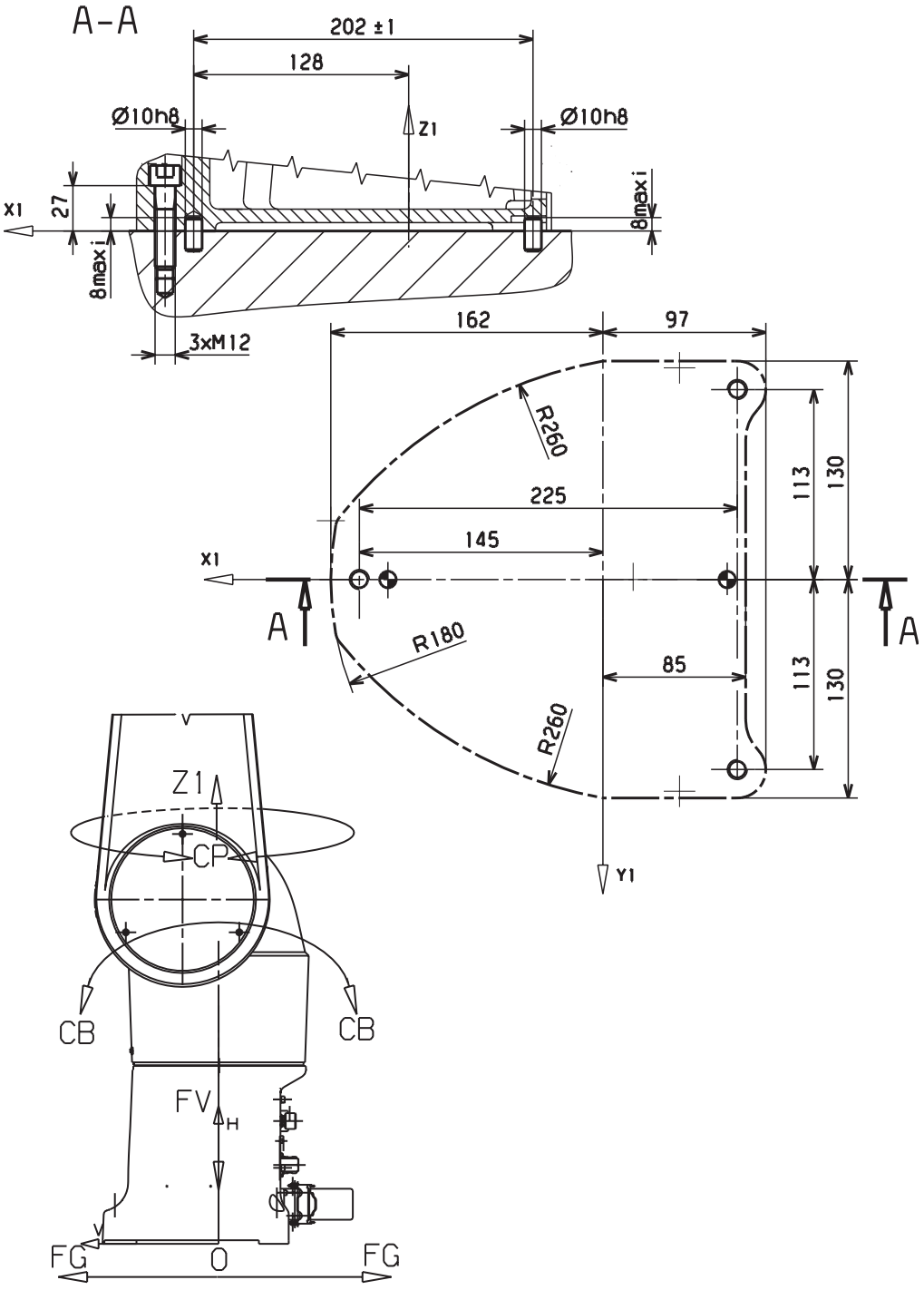
A-A
202 ±1
128
Ø10h8
Z1
Ø10h8
X1
27
8maxi
8maxi
3xM12
162
97
R260
225
145
113
130
X1
A
A
R180
85
113
130
R260
Y1
Z1
CP
CB
CB
FV
H
FG
0
FG

Figure 2.1

2.1. WORKING SPACE

The user is responsible for performing all preparatory work required to complete the on-site installation of the robot. Working space must be sufficient, installation surface appropriate; the power supplies must be available (for the electric power supplies, see the characteristics of the controller).

DANGER:

The arm's working area must be surrounded by a closed safety enclosure in compliance with the country's safety legislation preventing personnel accessing the dangerous area.

International standard: ISO 10218 (1992).

French standard: NF EN 775 (1993).

European Directive: machine directive CEE 89-392.

CAUTION:

There must be no obstacles within the robot work envelope.

2.2. ATTACHMENT (figure 2.1)

The arm must be installed vertically, with the base underneath (floor-mounted configuration), the base uppermost (ceiling-mounted configuration), or the base horizontal (wall-mounted configuration). In all cases, it must be securely attached by 3 class 12.9 M12 hex. socket head screws.

Attachment surface shall be flat and metallic. A deformable support will greatly reduce robot's performance in speed and accuracy.

When calculating the size of the support, it is necessary to take into account the maximum forces transmitted by the arm in movement at point 0, which are as follows for the standard arm:

Floor or ceiling mounted arm

- F_V = 1767 N
- F_G = 1144 N
- C_B = 1350 Nm
- C_P = 735 Nm

under following load conditions:

		Load position (mm)	
	Load (kg)	**Axis 5**	**Axis 6**
Standard arm	6	195	80
Long arm	5	195	80
Arm XL	4	195	80

The user can accurately position the robot by means of two 10h8 diameter centering pins (not supplied).

CHAPTER 3

STORAGE, TRANSPORT AND INSTALLATION

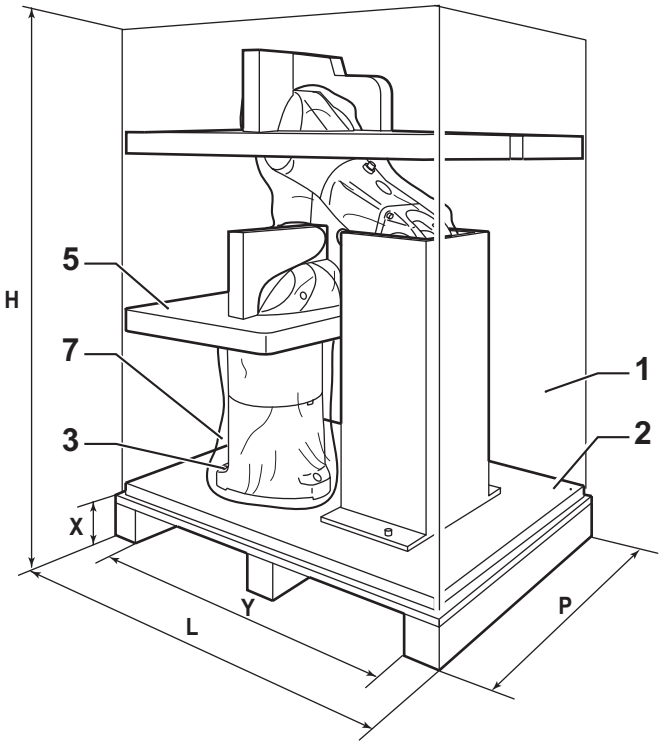

Figure 3.1

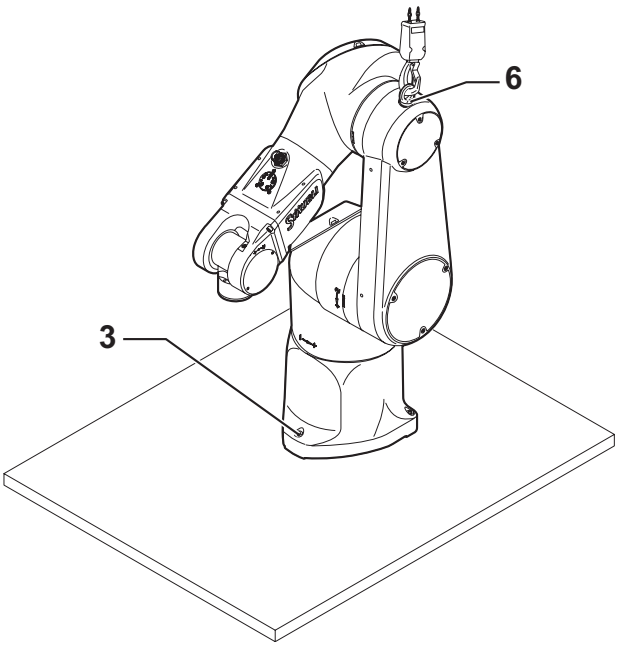

Figure 3.2

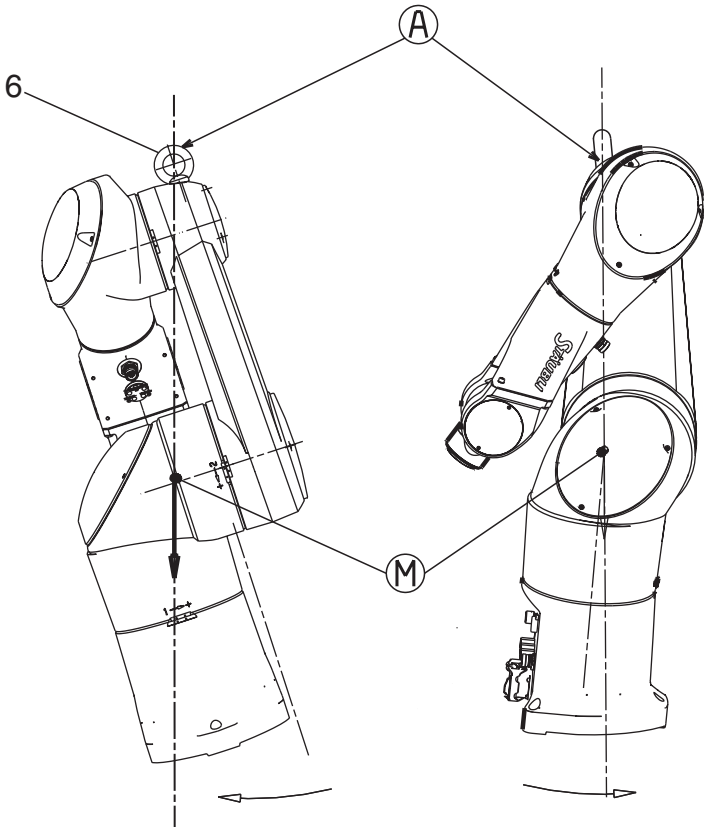

Figure 3.3

3.1. ARM PACKAGING (figure 3.1)

Standard packaging:

	Standard arm	Long arm	Arm XL
Case **(1)** L x H x D	1000 x 1520 x 800 mm		
Gross weight	156 kg	159 kg	161 kg

International packaging:

	Standard arm	Long arm	Arm XL
Case **(1)** L x H x D	1060 x 1520 x 830 mm		
Gross weight	171 kg	174 kg	176 kg

The arm is packed in the vertical position. It is attached to the pallet **(2)** by 3 M12 bolts.

3.1.1. CONDITIONS OF STORAGE AND TRANSPORT

- Temperature for storage and transport : -20°C to +60°C

3.2. HANDLING OF PACKING

By pallet truck under base **(2)**:
- X = 100 mm
- Y = 840 mm

3.3. UNPACKING AND INSTALLATION OF ARM

DANGER:

According to European Directive CEE 89-392, the hoisting ring's (6) threaded hole (M20) used for the robot hoisting is defined according to the ISO 262 standard.

- Move the packing case as near as possible to the installation site (figure 3.1).
- Remove the cardboard packaging **(1)**, remove the packing material **(5)** and the plastic cover **(7)** (figure 3.1).
- Pass the hook of the hoist through the hoisting ring **(6)** and hold slightly tensioned to stop the arm from tipping (figure 3.3).
- Remove the 3 M12 **(3)** bolts from the arm.
- Slowly raise the arm using the hoist.

CAUTION:

The robot will swing when raised and moved (figure 3.2).

Ⓐ Attachment point

Ⓜ Center of gravity

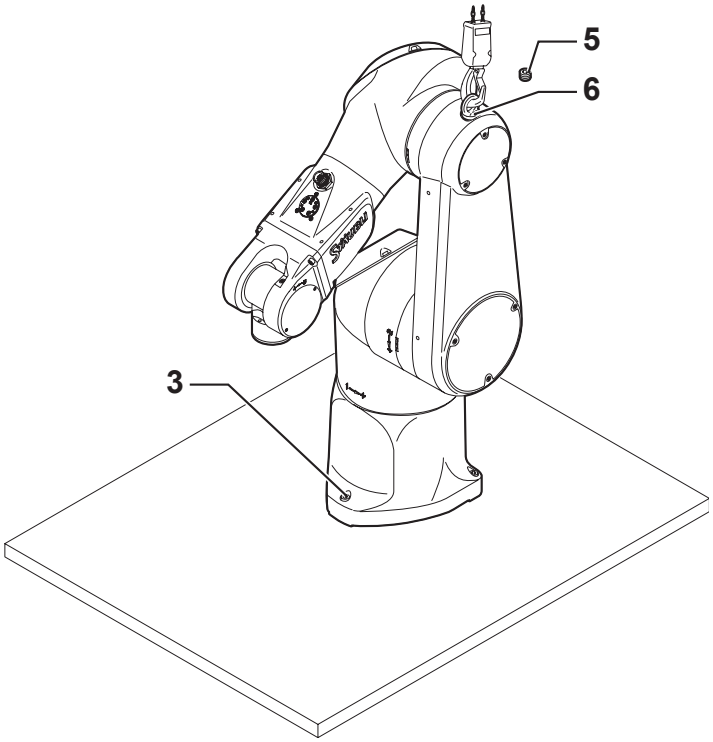

Figure 3.4

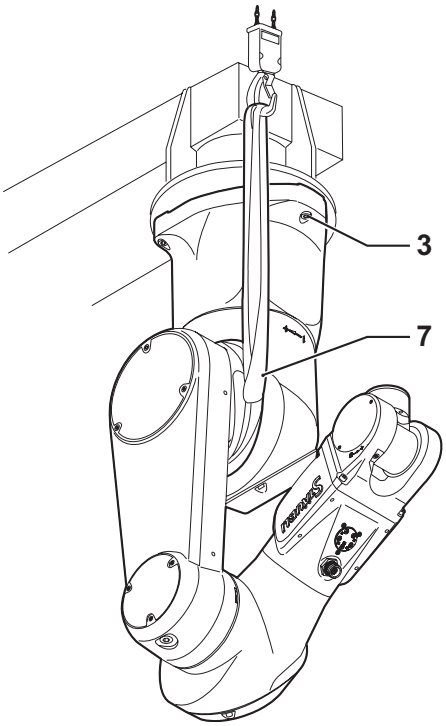

Figure 3.5

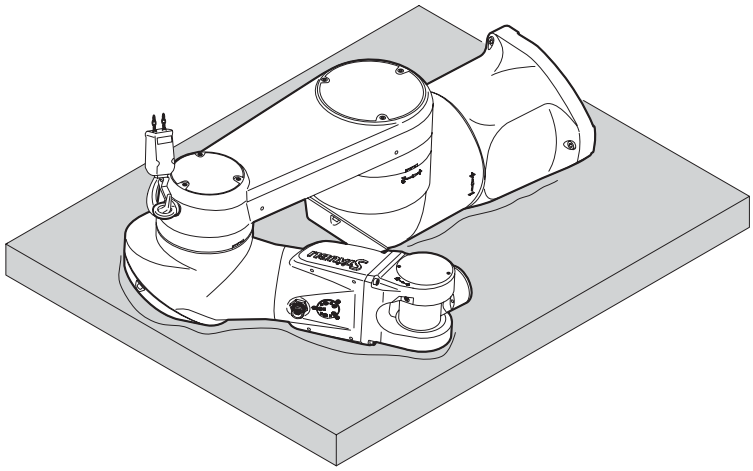

Figure 3.6

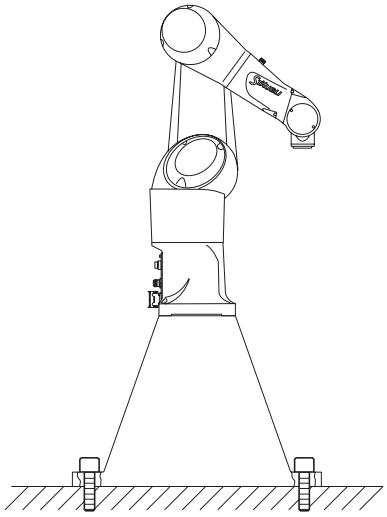

Figure 3.7

3.4. INSTALLATION OF ARM

CAUTION:

The arm can be fixed with its base facing downwards (floor-mounted version), upwards (ceiling-mounted version), or against a wall, without requiring any mechanical modifications. However, it is necessary to configure the controller accordingly. To do so, see the "Software configuration" chapter in the controller manual.

CAUTION:

Throughout all handling and installation operations concerning the arm, it is essential to keep the protection on the main connector at the foot of the robot in place at all times to avoid damaging and soiling the electrical and optical contacts.

3.4.1. INSTALLATION OF ARM ON FLOOR **(figure 3.4)**

- Position the arm on the support at its final attachment points.
- Attach the arm with 3 class 12.9 M12 hex. socket head screws **(3)**, tightened to 132 Nm ± 9 Nm.
- Unscrew the hoisting ring **(6)** and install the plug **(5)**.

DANGER:

For safety reasons, keep the sling slightly tensioned until the arm is securely attached to the floor.

3.4.2. INSTALLATION OF ARM ON CEILING **(figure 3.5)**

CAUTION:

Do not rotate joint 2.

- Carefully lay down the arm on a flexible support as shown on figure **3.6**.
- Place the fabric sling **(7)** around joint 2 as shown on figure **3.5**.

CAUTION:

500 kg fabric sling.

- Position the arm on the support at its final attachment points.
- Attach the arm with 3 class 12.9 M12 hex. socket head screws **(3)**, tightened to 132 Nm ± 9 Nm.

DANGER:

For safety reasons, hold the sling slightly tensioned until arm is securely attached to the ceiling.

3.4.3. MOUNTING FLOOR QUALITY

The user has to make sure that the mechanical caracteristics of the floor and the means of fixture allow to hold up the maximum forces caused by the moving arm *(see chapter **2**).*

CAUTION:

The height of the robot support can strongly influence the forces on the floor (figure 3.7).