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Remote-handling devices for radioactive materials —

Part 2: Mechanical master-slave manipulators

Dispositifs de manipulation à distance pour matériaux radioactifs —

Partie 2: Télémanipulateurs maître-esclave mécaniques

Reference number
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Contents

Page

Foreword ... iv

Introduction ... v

1 Scope ... 1

2 Normative references ... 1

3 Terms and definitions ... 1

4 General architecture and classification ... 3
4.1 General architecture ... 3
4.2 Classification ... 4
4.3 Kinematics ... 7

5 Basic considerations for the choice of a manipulator ... 9
5.1 General criteria ... 9
5.2 Particular criteria ... 10
5.3 Mounting of the master-slave manipulators ... 12
5.4 Leak-tightness and protection against contamination ... 13

6 Different manipulator mounting methods and associated requirements ... 15
6.1 Unsealed connection tube, with a gaiter ... 15
6.2 Unsealed connection tube, without gaiter ... 21
6.3 Sealed connection tube ... 21
6.4 Design of the lower end of the gaiters ... 22
6.5 Special case of double gaiters ... 25
6.6 Replacement of manipulator gaiters ... 26
6.7 Attachment of leak-tight manipulator gaiters ... 29

7 Accessories ... 29
7.1 Connection tubes with shielding ... 29
7.2 Balancing ... 29
7.3 Terminations ... 30
7.4 Electricity supply ... 31
7.5 Various ... 31

Annex A (normative) **Method of measurement of no-load forces and torques, flexures and backlashes** ... 33

Annex B (informative) **Typical disconnection stations** ... 45

Bibliography ... 48

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17874-2 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

ISO 17874 consists of the following parts, under the general title *Remote-handling devices for radioactive materials*:

— *Part 1: General requirements*

— *Part 2: Mechanical master-slave manipulators*

— *Part 3: Electrical master-slave manipulators*

— *Part 4: Power manipulators*

— *Part 5: Remote-handling tongs*

Introduction

This part of ISO 17874 deals with mechanical master-slave manipulators used for nuclear applications.

These devices replace the hands and arms of the operators in areas inaccessible to personnel (mostly behind shielding walls).

Mechanical master-slave manipulators were originally developed for hot cells, which were designed for research and development for nuclear power reactor-fuel elements. They are now also in use in other nuclear installations, such as fabrication or reprocessing plants for fuel elements, waste-treatment stations and decommissioning of nuclear facilities.

This part of ISO 17874 should be of assistance to designers of nuclear plants, as well as to manufacturers, users and license authorities.

Remote-handling devices for radioactive materials —

Part 2:
Mechanical master-slave manipulators

1 Scope

This part of ISO 17874 specifies the criteria for the selection, installation and use of a mechanical master-slave manipulator, for remote handling of radiaoactive materials in a nuclear facility.

This part of ISO 17874 deals only with the technical aspects related to the manipulator and its interface with the nuclear facility in which it is intended to be installed.

In particular, the process apparatus and the manipulator features need to be studied in parallel in order to optimize all the functionalities of the manipulator.

However, this part of ISO 17874 does not cover the fundamental design criteria of the nuclear facility (e.g. the process involved, maintenance of the process equipment, intervention for other purposes).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11933-1:1997, *Components for containment enclosures — Part 1: Glove/bag ports, bungs for glove/bag ports, enclosure rings and interchangeable units*

ISO 11933-2:1997, *Components for containment enclosures — Part 2: Gloves, welded bags, gaiters for remote-handling tongs and for manipulators*

ISO 10648-2:1994, *Containment enclosures — Part 2: Classification according to leak tightness and associated checking methods*

ISO 17874-1:2004, *Remote-handling devices for radioactive materials — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
mechanical master-slave manipulator
manipulator reproducing the effects of the hand and arm movements of the operator by means of mechanical transmission elements, installed in a shielding or a containment wall

3.2
arm
effectively reproduces the functions of a human arm, respecting in most cases the same distribution and corresponding articulations

NOTE 1 The corresponding articulations are shoulder, upper arm, elbow, forearm, wrist joint, etc.

NOTE 2 The motions of a manipulator master arm and its associated slave arm are generally parallel.

3.3
master arm
arm located outside a hot cell and equipped with a handle on which the operator acts

3.4
slave arm
arm located inside a hot cell and equipped with tongs to grip the work-piece

3.5
axis
directions of a Cartesian coordinate system defined from the operator's standing point, considered as the origin of this system

NOTE The following axes are considered: Axis X: from right to left along the shielding wall; Axis Y: forward into the shielded cell; Axis Z: up towards the ceiling of the shielded cell.

3.6
balancing
characteristic allowing the manipulator to be maintained with negligible forces applied by the operator in stable positions throughout the whole operating volume by mechanical means (e.g. counterweights)

3.7
connection tube
component mounted inside the through-wall tube, which transmits the motions of the master arm to the slave arm by rotation and by internal mechanical elements

NOTE The connection tube can be withdrawn into the operating room.

3.8
disconnection
mechanical operation allowing the separation of two assembled elements, such as the disconnection of a slave arm or a master arm from the connection tube

3.9
extended reach (*Z*-motion)
a motorized mechanical extension of the slave arm, by a double telescope, serving to adjust the working length and hence to extend the reach across the working volume

3.10
gaiter of a manipulator
booting US
specially profiled flexible sleeve designed to protect the mechanical parts of the slave arms of a manipulator from contamination or to provide continuity of the leak-tightness of a hot cell

3.11
handle
component fixed at the end of the master arm and gripped by the operator, facilitating the control of the movement of the manipulator

3.12
indexing motions (X- and Y-motion)
an adjustable mechanical or electrical displacement between the slave arm position and the corresponding master-arm position, to enlarge the working volume and minimize operator strain

3.13
jaws
components fixed on the end of the tongs which facilitate the handling of an object

NOTE The jaws can be disconnectable.

3.14
joint
articulation
assembly of several pieces allowing one or more rotational motions

3.15
operating volume
space in which the operation of a tong is possible, considering all the positions in which the different components of the slave arm of a manipulator can be moved

3.16
operator side removal
operation consisting of extracting a part or the whole of a manipulator from the operator side of the hot cell

3.17
orientation motion
rotation motions around certain axes of the manipulator

NOTE 1 According to the axis considered, the three following motions are distinguished: tilt (α), twist (β) and swivel or azimuth motion (γ).

NOTE 2 In articulated manipulators, the orientation motion can be accomplished around the forearm axis or around the arm axis.

3.18
tong
gripping device fixed at the slave-arm end of the manipulator and consisting of an actuator assembly and jaws

3.19
through-wall tube
cylindrical piece mounted in the wall of a hot cell and allowing the passage of the mechanical linking elements between the different parts of a manipulator from the outside to the inside of the hot cell

NOTE The through-wall tube contains the connection tube.

3.20
positioning motion
motion effecting a displacement of the tongs (or end-effector)

NOTE According to the axis considered, three different motions are distinguished: X, Y and Z.

4 General architecture and classification

4.1 General architecture

A mechanical master-slave manipulator is a fixed assembly mounted on a shielded enclosure wall. It comprises three main components, a master arm, a slave arm and a connection tube equipped with mechanical elements ensuring the connection between the master arm and the slave arm.

The connection tube is generally installed horizontally through the enclosure wall. It shall be constructed in such a manner that the motions, forces, and torques, executed by the hand of the operator on the handle of the master arm, are transmitted respectively to the slave arm and the tongs.

The manipulator shall ensure force reflection from the slave arm to the master arm. The transmission elements shall be reversible in motion and communicate forces and torques reversibly, in all positions.

Depending on the final use (mounting on $\beta\gamma$ hot cells or α-$\beta\gamma$ hot cells), the connection tube can be unsealed or sealed. In addition, the slave arm can be equipped with a gaiter, the aim of which is to realize the protection or the leak-tightness of the manipulator slave arm. The jaws of the tongs or the complete tongs assembly can be exchanged by remote control.

The master arm and slave arm are arranged to have identical kinematics. Additional components are provided on the master arm, in particular, counter-weights balancing the arms of the master-slave manipulators and, where necessary, lockable brakes and/or the control elements for motorized relative motions or off-sets between the slave arm and the master arm (i.e. indexing).

4.2 Classification

4.2.1 Introduction

As defined in ISO 17874-1, mechanical master-slave manipulators are classified into two categories (see Figure 1):

— mechanical master-slave manipulator with telescopic arms;

— mechanical master-slave manipulator with articulated arms.

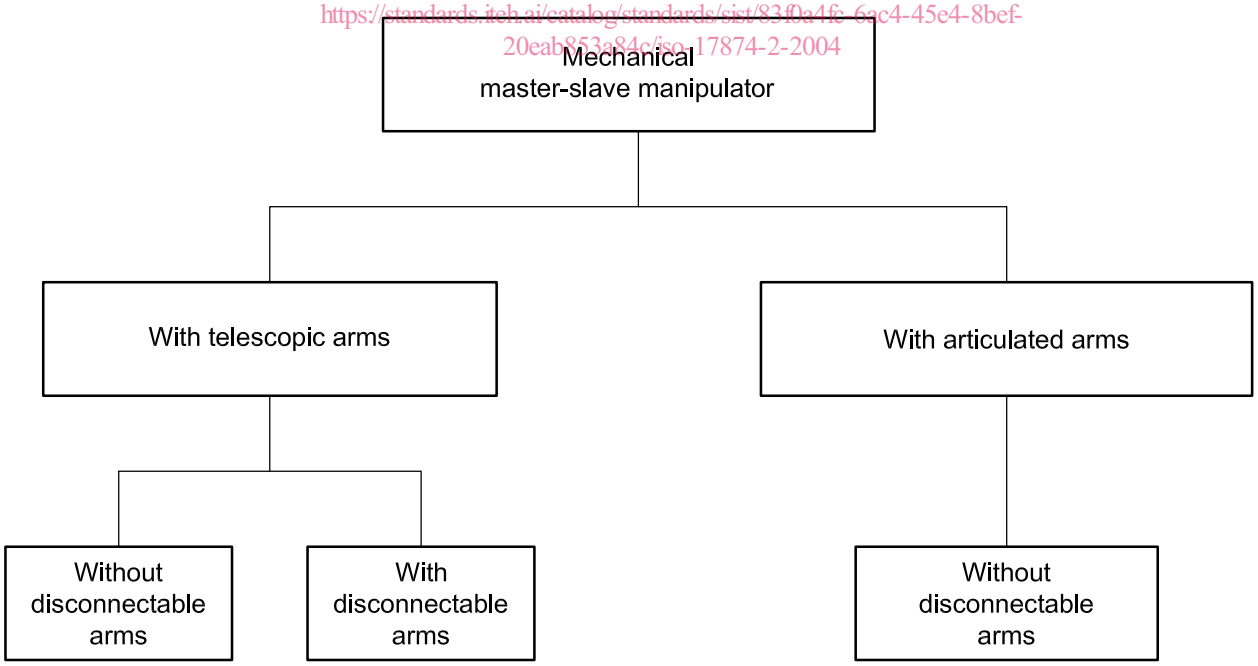


Figure 1 — Classification of mechanical master-slave manipulators

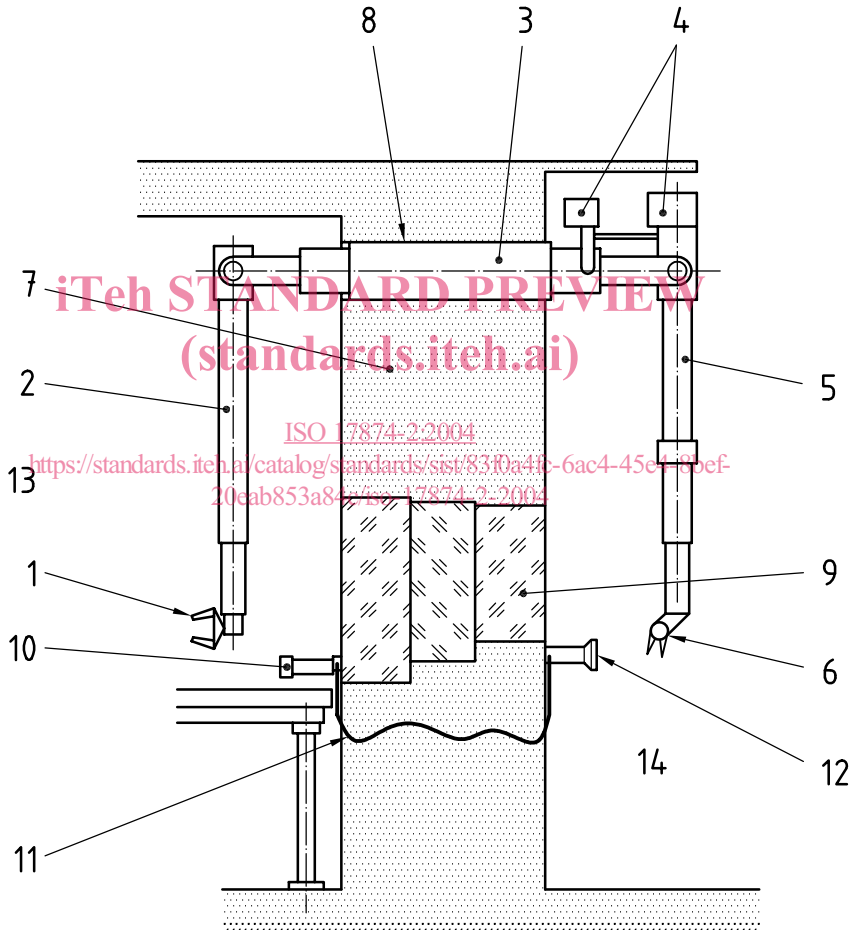
4.2.2 Mechanical master-slave manipulators with telescopic arms

Depending on the type, this kind of mechanical master-slave manipulator (see Figure 2) permits the transmission of forces up to the maximum magnitude that an operator would employ in unaided manual activity. They are suitable for complicated tasks, and are usually installed in pairs on a working station.

Manipulators with telescopic arms are designed for hot cells of all sizes with shielding walls made mainly of concrete or even of lead. They constitute the main working devices in such types of cells, which are generally of large dimensions.

A version with short arms is available, if higher forces must be executed than are possible with mechanical master-slave manipulators with articulated arms.

There are also compact manipulators with a double telescope in the slave arm, available for hot cells with a restricted height.



Key

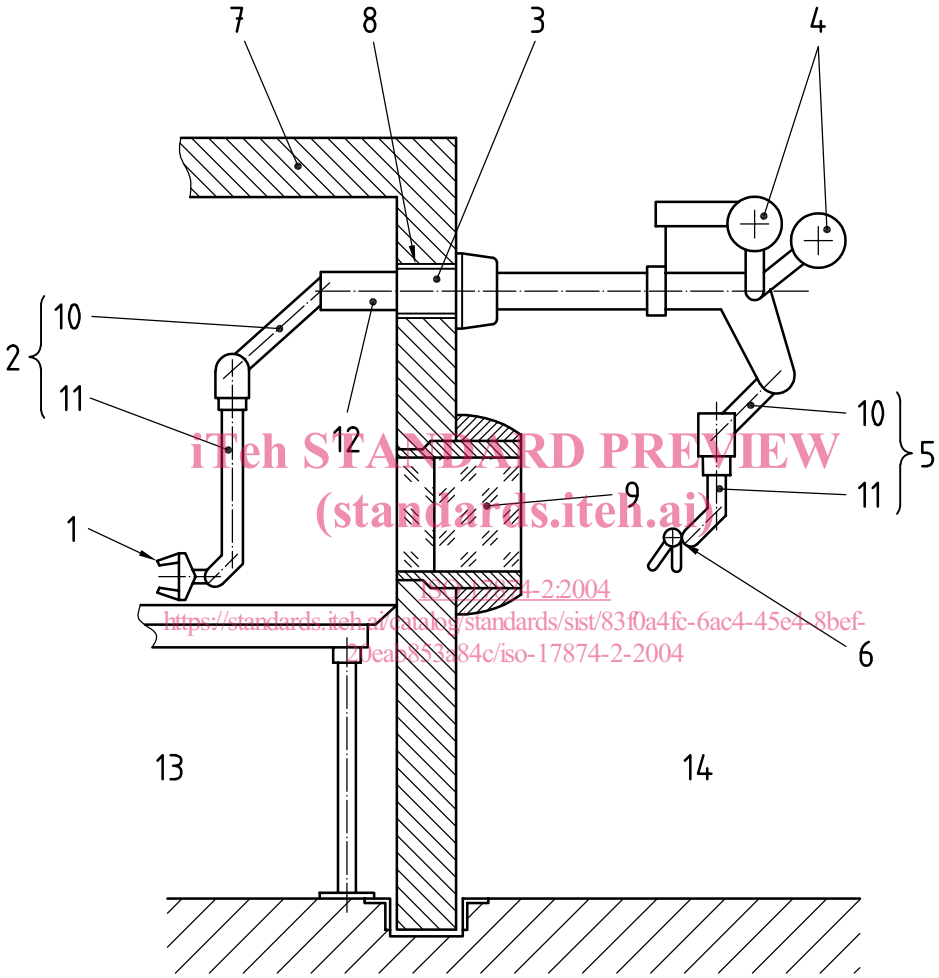
1 tong with parallel jaws
2 slave arm
3 connection tube
4 counter-weights
5 master arm
6 handle
7 shielding wall
8 through-wall tube
9 shielding window
10 microphone
11 sound-transmission cable
12 loudspeaker
13 hot cell
14 operating room

Figure 2 — Mechanical master-slave manipulator with telescopic arms

4.2.3 Mechanical master-slave manipulators with articulated arms

This kind of mechanical master-slave manipulator (see Figure 3) permits the transmission of forces up to a medium level such as an operator could easily employ repeatedly in unaided manual activity. They are suitable for complicated tasks, and are usually installed in pairs on a working station. They are designed for hot cells of all sizes, with shielding walls typically of lead, or even steel.

They are also often used in containment enclosures with thick concrete shielding walls. They have small dimensions and therefore provide a relatively small working volume. They are used instead of remote-handling tongs, if a larger working volume is available or/and more dexterity is needed.



Key

1 tong with parallel jaws
2 slave arm
3 connection tube
4 counter-weights
5 master arm
6 handle
7 shielding wall
8 through-wall tube
9 shielding window
10 upper arm
11 forearm
12 overhang
13 hot cell
14 operating room

Figure 3 — Mechanical master-slave manipulator with articulated arms

4.3 Kinematics

4.3.1 General

The manipulator shall have seven motions, three positioning motions (see Figure 4), three orientation motions (see Figure 5) and one gripping motion, according to the definitions given in ISO 17874-1.

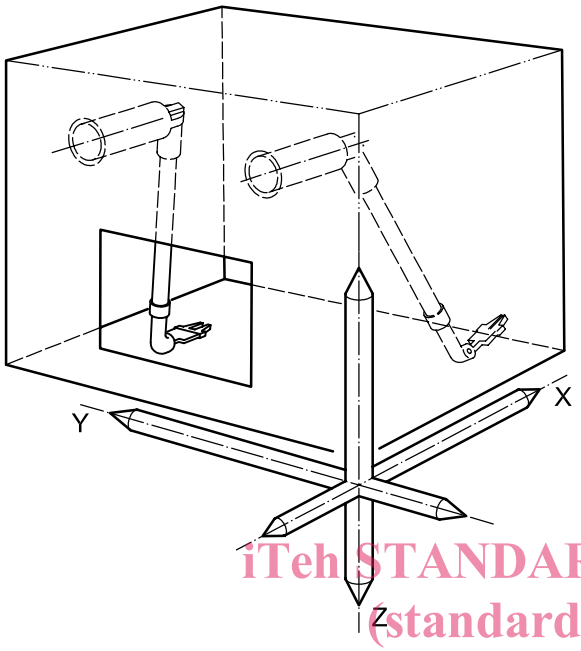


Figure 4 — Positioning motions

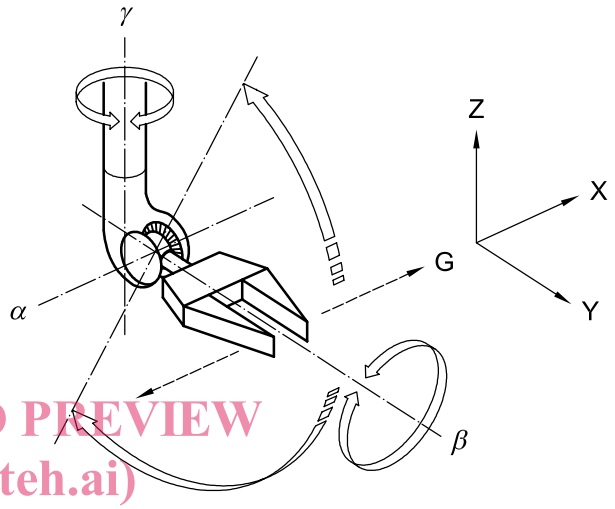
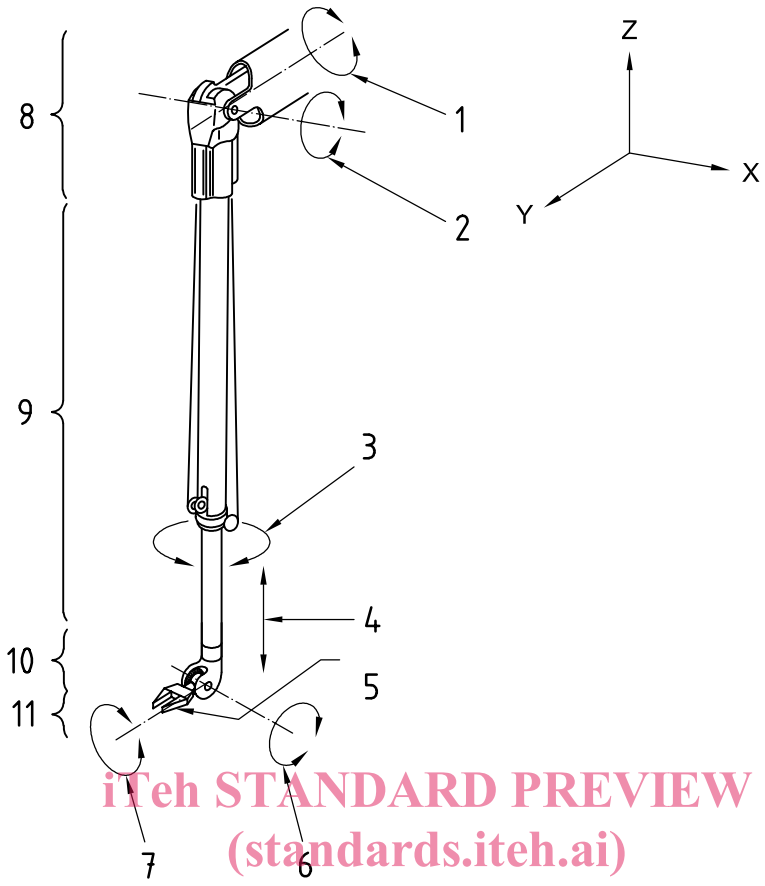


Figure 5 — Orientation and gripping

4.3.2 Manipulators with telescopic arms

For manipulators with telescopic arms, for which the motion along the Z axis is performed by translation of the tubes (see Figure 6).



Key

1 right-left motion (around the Y axis)
2 forward-backward motion (around the X axis)
3 arm rotation (around the Z axis) (swivel or azimuth motion)
4 up-down motion (along the Z axis)
5 gripping motion
6 wrist rotation (around the X axis) (tilt motion)
7 tongs rotation (around the Y axis) (twist motion)
8 shoulder
9 telescopic arm
10 wrist joint
11 handle (master side)/tongs (slave side)

Figure 6 — Mechanical master-slave manipulator with telescopic arms

This kind of manipulator shall be equipped with an electrical indexing of the Y-motion (forward-backward) and X-motion (right-left). It may also include an electrical extension of the Z-motion (up and down), consisting of a double telescopic arm. The latter is called extended reach.

The indexing allows the range of action of the slave arm to be increased, while keeping the master arm in a good ergonomic position.

Mechanical master-slave manipulators with telescopic arms are differentiated in the following way.

— Manipulators without disconnectable arms. In this case, the functional links between the master arm and the slave arm are directly realized by cables or tapes.

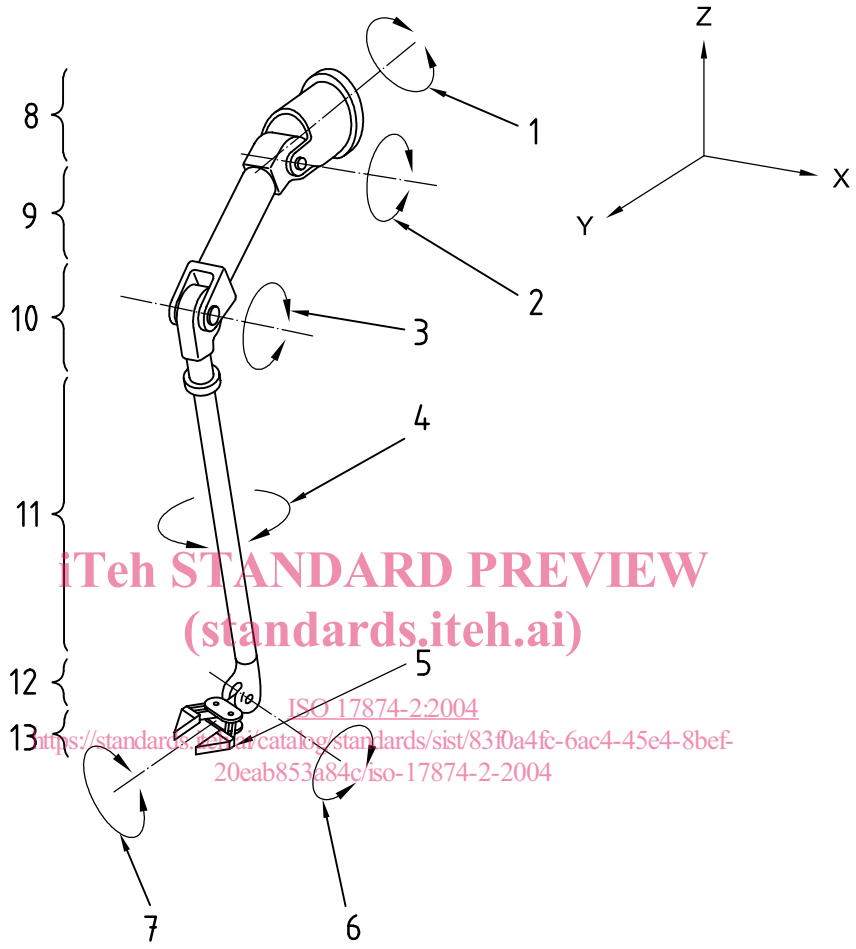
— Manipulators with disconnectable arms. In this case, the links by cables or tapes are interrupted at the level of the connection tube, where the motion transmissions are performed by rotating shafts and gears.

This solution consequently allows the disconnection of the slave arm. In many cases, the disconnection of the master arm is also possible.

4.3.3 Manipulators with articulated arms

For manipulators with articulated arms, the motion along the Z axis is performed by a combination of two rotations around the shoulder axis and the elbow axis (see Figure 7).

This kind of manipulator can be equipped with electrical or mechanical indexing of the upper arm.



Key

1 right-left motion (around the Y axis)
2 forward-backward motion (around the X axis)
3 arm rotation (around the Z axis) (swivel or azimuth motion)
4 up-down motion (along the Z axis)
5 gripping motion
6 wrist rotation (around the X axis) (tilt motion)
7 tongs rotation (around the Y axis) (twist motion)
8 shoulder
9 upper arm
10 elbow
11 forearm
12 wrist joint
13 handle (master side)/tongs (slave side)

Figure 7 — Mechanical master-slave manipulator with articulated arms

5 Basic considerations for the choice of a manipulator

5.1 General criteria

The design constraints of the manipulator determine the field of use offered by the two categories of manipulators.