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Ergonomic requirements for the design of displays and control actuators —

Part 3: Control actuators

Spécifications ergonomiques pour la conception des dispositifs de signalisation et des organes de service —

Partie 3: Organes de service

Reference number
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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 9355-3 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

ISO 9355 consists of the following parts, under the general title *Ergonomic requirements for the design of displays and control actuators*:

— *Part 1: Human interactions with displays and control actuators*

— *Part 2: Displays*

— *Part 3: Control actuators*

— *Part 4: Location and arrangement of displays and control actuators*

Ergonomic requirements for the design of displays and control actuators —

Part 3: Control actuators

SAFETY PRECAUTIONS — It is particularly important that the provisions of this part of ISO 9355 be observed wherever the operation of a control actuator could lead to injury or damage to health, either directly or as a result of human error.

1 Scope

This part of ISO 9355 gives ergonomic requirements for, and guidance on, the selection, design and location of control actuators adapted to the needs of the operator, suitable for the control task in question and taking account of the circumstances of their use. It is applicable to manual control actuators used in equipment for both occupational and private use.

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 447, *Machine tools — Direction of operation of controls*

ISO 9355-1:1999, *Ergonomic requirements for the design of displays and control actuators — Part 1: Human interactions with displays and control actuators*

ISO 9355-2, *Ergonomic requirements for the design of displays and control actuators — Part 2: Displays*

IEC 60447, *Basic and safety principles for man-machine interface, marking and identification — Actuating principles*

3 Terms and definitions

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

3.1
control actuator
part of the control actuating system that is directly actuated by the operator, e.g. by applying pressure

[ISO 9355-1:1999, 3.1]

3.2
manual control actuator
control actuator adjusted or manipulated by the human hand to effect change in a system

EXAMPLE Push-button, knob, steering wheel.

NOTE Touch-sensitive actuation is not included.

3.3
control type
range of control actuators with the same movement and grip characteristics, and fulfilling similar task requirements

3.4
control family
group of control types

3.5
operator
person given the task of installing, operating, adjusting, maintaining, cleaning, repairing or transporting machinery

[EN 894-3:2000, 3.5]

3.6
task
work task
activity or activities required to achieve an intended outcome of the work system

[EN 894-3:2000, 3.6]

3.7
control task
activity where a control actuator is used to achieve a task goal

4 Selection procedure — General

Many types of manual control actuators are available — from push-buttons to hand wheels. Each type is suited to particular task requirements and certain operator capabilities. Environmental factors (e.g. illumination, vibration) and organizational factors (e.g. team work, workstation separation) also have to be considered.

To ensure safe and efficient operation, the correct selection of control actuators is most important. The following clauses specify a systematic selection procedure that will enable designers and manufacturers to select manual control actuators to meet their specific requirements. Clause 5 describes the information required for selecting appropriate control actuators; Clauses 6 and 7 then specify how this information is to be used in order to make the selection.

The selection procedure involves three main steps, carried out in an iterative manner:

— task evaluation and information collection (Clause 5);

— intermediate selection of control families (Clause 6);

— identification of suitable control types (Clause 7).

Figure 1 shows the selection procedure overall.

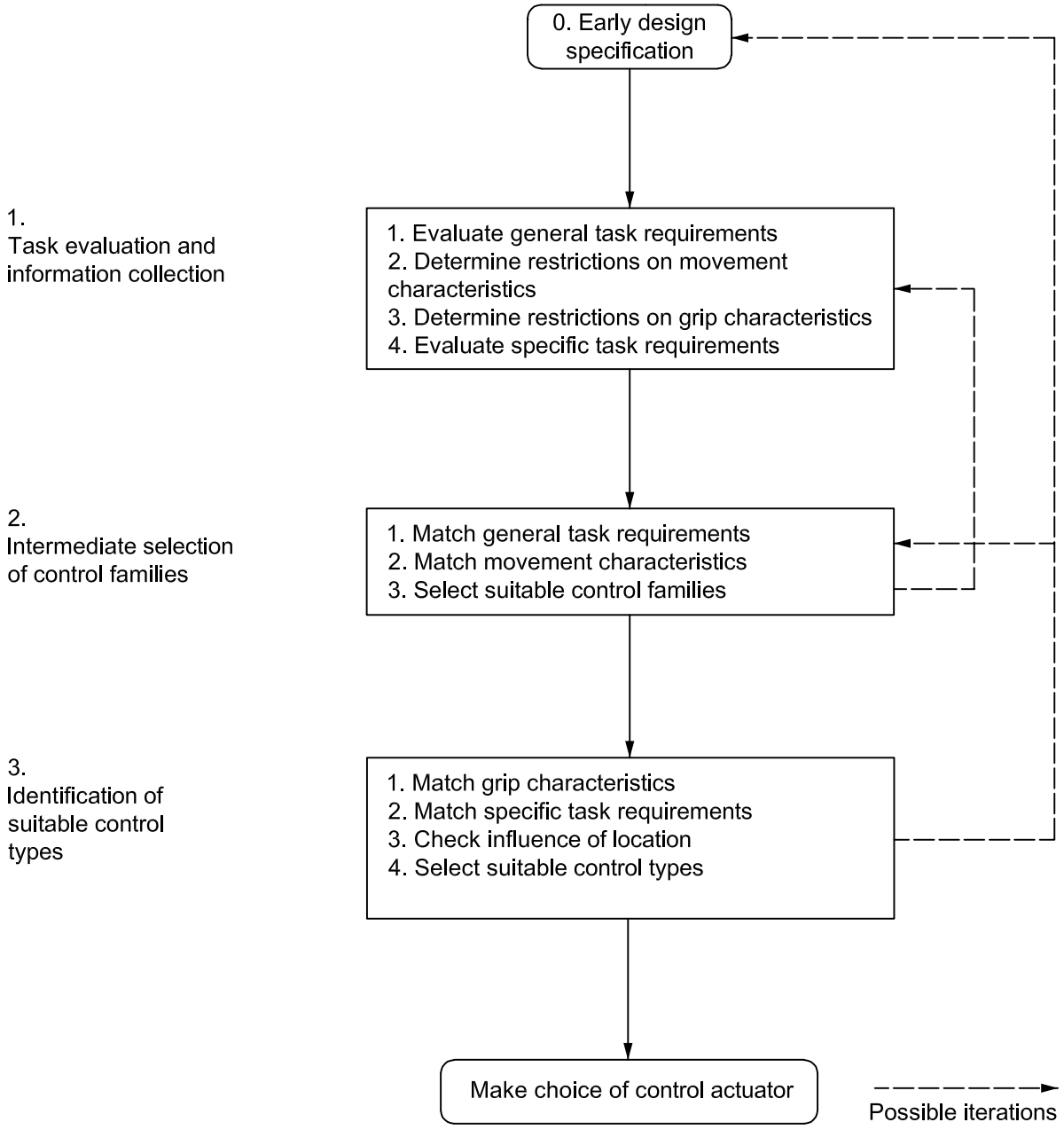


Figure 1 — Overall procedure for selecting manual control actuators

5 Task evaluation and information collection

5.1 Task requirements and characteristics

The division of tasks between the operator and the equipment should have been determined early in the design process according to the recommendations given in EN 614-1 and ISO 9355-1.

There are general and specific requirements imposed by a task which normally cannot be changed. If it is not possible to find a suitable control actuator for a specified task, then the allocation of this task or the task itself has to be reconsidered.

The task requirements considered in this International Standard are ones that experience has shown to be the most important in selecting manual control actuators. They are as follows.

General task requirements:

a) accuracy required in positioning the manual control actuator (**accuracy**);

b) speed of setting required (**speed**);

c) force/torque requirements (**force**).

Specific task requirements:

d) need for visual checking of manual control actuator setting (**visual check**);

e) need for tactile checking of setting (**tactile check**);

f) need to avoid inadvertent operation (**inadvertent operation**);

g) need to avoid hand slipping from manual control actuator (**friction**);

h) need for operator to wear gloves (**use with gloves**);

i) need for easy cleaning (**ease of cleaning**).

The general task requirements are used to identify classes of suitable control actuators. The specific task requirements are used in selecting individual control actuators within these classes. In evaluating the task requirements, the classification scheme according to Table 1 should be used. This differentiates between five different levels, from 0 to 4.

Table 1 — Classification scheme for evaluating task requirements

Code	Symbol	Degree of requirements
0	○	Negligible
1	◔	Low
2	◑	Average
3	◕	High
4	●	Very high

The task requirements do not need to be evaluated precisely; therefore, the detailed evaluation procedure given in 5.2 and 5.3 presents classification systems that have been found to be sufficiently accurate.

The characteristics of the various types of control actuator need to be considered, in order to determine the available selection options. This part of ISO 9355 gives information on both movement characteristics and grip characteristics. In many cases, some of these characteristics will have been predetermined by the task requirements.

Movement characteristics:

j) type of movement;

k) axis of movement;

l) direction of movement;

m) continuity of movement;

n) angle of rotation for continuous rotary movements $>180°$.

Grip characteristics:

o) type of grip;

p) part of hand applying force;

q) method of applying force.

The above categories, a) to q), are used throughout this part of ISO 9355.

NOTE The shorter descriptions given between parentheses for the task requirements [a) to i)] are used in table headings where space is limited.

See Figure 2 for an example of the form to be used for recording the results of the evaluation. The following subclauses (5.2 to 5.5) give the procedure for completing the recording form of Figure 2. The method for assigning each general task requirement to a class in Table 1 is also given. All acceptable task requirements should be entered on the recording form.

Description of information	Related subclause of ISO 9355-3	Degree of requirement (Classification)					Remark
		0	1	2	3	4	
		○	◔	◑	◕	●	
General task requirements:	5.2						
a) Accuracy	5.2.1						
b) Speed	5.2.2						
c) Force	5.2.3						
Specific task requirements:	5.3						
d) Visual check	5.3.1						
e) Tactile check	5.3.2						
f) Inadvertent operation	5.3.3						
g) Friction	5.3.4						
h) Use with gloves	5.3.5						
i) Ease of cleaning	5.3.6						
Movement characteristics:	5.4						
j) Type of movement	5.4.2	Linear			Rotary		
k) Axis of movement	5.4.3	X	Y	Z	X	Y	Z
l) Direction of movement	5.4.4	+/–	+/–	+/–	+/–	+/–	+/–
m) Continuity of movement	5.4.5	Continuous			Discrete		
n) Angle of rotation for continuous rotary movement > 180°	5.4.6	Yes			No		
Grip characteristics:	5.5						
o) Type of grip (see Figure 4)	5.5.1	Contact		Pinch		Clench	
p) Part of hand applying force	5.5.2	Finger			Hand		
q) Method of applying force	5.5.3	Normal			Tangential		

Figure 2 — Form for recording information used in manual control actuator selection procedure — Example

5.2 Determination of general task requirements [5.1 a) to c)]

5.2.1 Task requirement a) — Classification of accuracy (accuracy)

The accuracy required shall be assigned to a class in accordance with Table 1.

The accuracy required in the operation of a manual control actuator is determined by the task that has to be performed. Accuracy is influenced by a number of factors, the most important of which is continuity of movement required, i.e. whether action of a manual control actuator takes place in discrete steps or continuously.

Adequate feedback of information to the operator is necessary to minimize mistakes in positioning.

High accuracy is inconsistent with high force application and the selection procedure takes this into account. Thus, a requirement for high force and high accuracy together will not lead to the successful selection of a suitable manual control actuator.

Where control actuators are used frequently or for long durations, accuracy requirements are increased.

Accuracy in positioning relates to the accuracy of positioning a manual control actuator itself. Accuracy in the positioning of the controlled component may be increased by mechanical means, e.g. gears. In this case, a high accuracy of positioning of the controlled component can be achieved by use of a manual control actuator capable of only low accuracy.

5.2.1.1 Discrete manual control actuator movements

A discrete manual control actuator movement is one where the manual control actuator can only be moved to a number of fixed positions e.g. rotary switch, on/off switch. The error in selecting the correct position increases with the number of discrete positions. Thus, two positions shall be rated as “negligible” requirements, while 24 positions shall be rated as “high” requirements. Manual control actuators with more than 24 discrete positions should be avoided.

Accuracy can be improved by, for example, feedback to the operator of information on the current value of the controlled variable, by clear labelling of manual control actuator positions, and/or by placing the manual control actuator where it can be easily seen and moved.

For manual control actuators, a visual indication of the function of each position should be provided either by labels or a display.

Positions should not be indicated by numbers (“1”, “2”, etc.) or letters (“A”, “B”, etc.) to indicate a function, since this requires the operator to remember the related functions and leads to mistakes. Labels 1, 2... may be used where the value of the variable controlled varies from position to position at least on an ordinal scale. This becomes more important as the number of discrete positions increases. Labels and displays shall be designed in accordance with ISO 9355-2.

When selecting control actuators whose functions are critical to avoiding injury or damage to health, it is especially important that these requirements are followed.

5.2.1.2 Continuous manual control actuator movements

Where movement of a manual control actuator corresponds to a continuous change in a controlled variable, the extent to which the variable deviates from the required value is a measure of error. The probability of making an error depends mainly on the time allowed to complete the task (speed), availability of feedback of information to the operator, and operating force.

For continuous control actuator movements, appropriate feedback of information to the operator shall be provided, for example, by indicating the direction and speed of the component controlled. This may be

achieved by a display, by movements of other objects relative to the operator (e.g. movement of the surroundings when driving a vehicle, movement of a lathe tool), or by other suitable means.

Where tasks have to be completed at speed, e.g. continuous tracking of a target, high accuracy can only be achieved by provision of low force demands as well as visual feedback of information. For continuous tracking tasks, the requirements for accuracy in positioning the manual control actuator shall be rated as “very high” requirements.

The direction of movement of manual control actuators relative to the controlled component shall be in accordance with ISO 447 for machine tools, IEC 60447 for electrical equipment, and ISO 9355-2.

5.2.2 Task requirement b) — Classification of speed (speed)

The speed of operation required shall be assigned to a class in accordance with Table 1.

The time to complete a manual control actuator movement is composed of two components: time to reach and grasp the manual control actuator, and time to make the control movement. The former of these depends on the position of the manual control actuator relative to the operator and the type of grip necessary for its operation. In general, manual control actuators requiring contact grip are quicker to operate than manual control actuators requiring pinch grip, which in turn are quicker than manual control actuators requiring clench grip (see 5.5.2). For emergency situations it is essential for actuation to be as quick as possible. A mushroom-shaped actuator operated by hand contact is therefore recommended for emergency stop functions on machinery.

High speed of operation is inconsistent with a high force requirement, and the highest speeds can only be obtained when the force is lowest. Thus for continuous tasks, such as keyboard operation, where high speed is necessary, the operating force should be kept low. The specification of high speed and high force requirements together will not lead to the successful selection of a suitable manual control actuator.

5.2.3 Task requirement c) — Classification of force/torque (force)

Control actuators can be used to move parts of a machine. In some circumstances, large forces are needed to move these parts. Some machine designs allow mechanical or power assistance to minimize the load on the operator when using the control actuator. Where this is not possible, the magnitude of the force or torque required to operate the manual control actuator shall be assigned to a class in accordance with Table 2. The symbols in this table are used later in the evaluation process, therefore it is recommended that the appropriate symbol be recorded. Where control actuators are used frequently or for long durations force requirements are increased.

Table 2 — Classification of force/torque for selection of manual control actuators

Code	Symbol	Force N	Torque N · m	Degree of requirements
0		< 10 N	< 0,5	Negligible
1		⩾ 10 to < 25	⩾ 0,5 to < 1,50	Low
2		⩾ 25 to < 50	⩾ 1,50 to < 3,0	Average
3		⩾ 50 to < 80	⩾ 3,0 to < 5,0	High
4		⩾ 80 to < 120	⩾ 5,0 to < 50	Very high

5.3 Determination of specific task requirements [5.1 d) to i)]

Some of these may have been specified earlier in the design process. The designer should note on the recording form those which have been predetermined. Any which have to be excluded because of decisions earlier in the design process should also be noted on the form.

Assigning a high classification to some requirements may prevent high classifications being achieved for others, e.g. a “very high” requirement for *friction* might not be compatible with “very high” for *ease of cleaning*. Because of this, it is important to ensure that the requirements that are most critical from a safety point of view are met before considering less crucial aspects.

Where incompatible requirements are identified, it will be necessary to reconsider the task design or, where this is not possible, to reduce the requirements for the less important aspects.

All acceptable degrees of requirements should be entered on the recording form shown in Figure 2.

5.3.1 Task requirement d) — Need for visual checking of manual control actuator setting (visual check)

In the operation of manual control actuators it is important to have feedback to the operator that the correct control action has been performed. This may be accomplished, for example, by a change in reading of a display, a visual or audible change in the process being controlled, etc. It is often advantageous to ensure that the setting of the manual control actuator can be visually checked, particularly where movement is in discrete steps and no other form of feedback is provided.

The need for visual checking of the manual control actuator setting shall be assigned to a class in accordance with Table 1.

5.3.2 Task requirement e) — Need for tactile checking of setting (tactile check)

In some situations where the operator’s vision is fully occupied or the control actuator is located away from the operator’s field of vision, it is important for the position of manual control actuators to be readily identified by touch. Identification by touch can also be useful in reinforcing other forms of information feedback to the operator where safety critical functions are involved.

The need for tactile checking of the manual control actuator setting shall be assigned to a class in accordance with Table 1.

5.3.3 Task requirement f) — Need to avoid inadvertent operation

The importance of avoiding inadvertent operation of a manual control actuator depends on the consequences of such accidental operation. It is particularly important where injury or damage to health could result. This part of ISO 9355 gives information on the degree of difficulty in inadvertently operating a control actuator itself. In some circumstances, where very high risks are present, this may not be considered sufficient. In such cases, the following measures should be considered:

— location of manual control actuator in a recess;

— shrouding the manual control actuator (e.g. cover to prevent access of parts of body larger than the hand, surround manual control actuator with a collar);

— use of manual control actuators that are operated in two movements at right angles to each other;

— use of a lock-out system;

— use of two-hand controls (for details, see EN 574).

The need to avoid inadvertent operation shall be assigned to a class in accordance with Table 1.

5.3.4 Task requirement g) — Need to avoid hand slipping from manual control actuator (friction)

Where manual control actuators are used continuously or frequently, it is important, for reliable operation and safety, to ensure that the operator's hand does not slip on the manual control actuator's surface. This will be particularly important where a requirement for high force application has been identified.

The need to avoid slippage of the hand on the manual control actuator shall be assigned to a class in accordance with Table 1.

5.3.5 Task requirement h) — Need for operator to wear gloves

Whether or not an operator needs to wear gloves depends on the process. The need for gloves shall be assigned to a class in accordance with Table 1.

Where no gloves are required, this may be classified as "negligible" (see Table 1). Where thick gloves need to be worn continuously, for example, where metal components have to be handled frequently or for long durations, it should be classed as "very high".

5.3.6 Task requirement i) — Need for easy cleaning

In some applications, for example on machinery for food processing, it is important to ensure that all parts — including manual control actuators — are easy to clean.

The need for ease of cleaning shall be assigned to a class in accordance with Table 1. Where hygiene needs to be considered, this may be classified as a "high" to "very high" requirement, depending on its importance.

5.4 Specification of movement characteristics [5.1 j) to n)]

5.4.1 General

A manual control actuator could be located in many positions relative to the operator. For equipment to be used by a standing operator there will be a series of normal operating positions, any one of which may be assumed in making the evaluations described in this part of ISO 9355. For a seated operator, the evaluation should be made relative to the preferred seat position.

The recommendations given in this part of ISO 9355 are valid for control actuators placed in the space immediately in front of the operator. Caution should be exercised in applying this part of ISO 9355 outside these limits. Where doubt exists, user trials should be conducted (see EN 614-1).

The right-angled axis system to be used in the evaluation is shown in Figure 3.

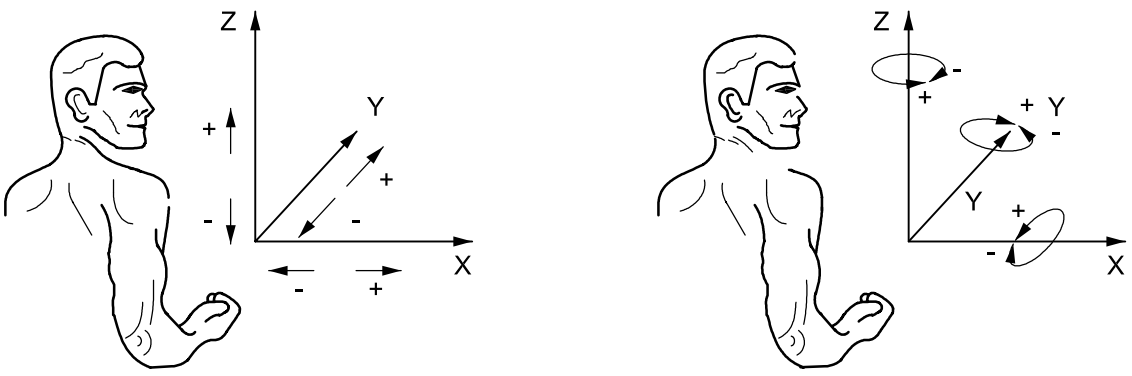


Figure 3 — Axis systems for linear and rotary movements

Five characteristics (j, k, l, m, n) relate to the determination of movement. Their evaluation requires description of the location of movement in space. Only those restrictions on movement characteristics that are imposed by the initial design specification should be entered on the recording form (see Figure 2).

All acceptable characteristics should be entered on the recording form.

5.4.2 Movement characteristic j) — Type of movement (linear or rotary)

The type of movement required from the manual control actuator is in one of two groups according to whether the movement is essentially linear or rotary over the distance the hand will move. In this sense, long levers are classified as linear. Where earlier specifications or consideration of postural constraints restrict the type of movement, either 'linear' or 'rotary' should be entered on the recording form (see Figure 2).

5.4.3 Movement characteristic k) — Axis of movement

The axis of movement is the axis, along or around which movement takes place relative to the operator (see Figure 3). It is necessary to consider the possible postures the operator may adopt and the movements of the operator's upper body when using the manual control actuator. Where earlier specification or consideration of postural constraints restricts the axes of movement, the possible movement axes should be entered on the recording form. The predominant movement should be classified as X, Y or Z relative to one of the three axes shown in Figure 3.

5.4.4 Movement characteristic l) — Direction of movement

The direction of movement is the direction to actuate the control relative to the axis as shown in Figure 3. "+" and "–" directions are indicated for both linear and rotary movements. Where earlier specification or consideration of postural constraints restricts the direction of movement, the possible movement directions should be entered on the recording form. Where the operator is required to move the manual control actuator in both directions "+/–" should be recorded.

5.4.5 Movement characteristic m) — Continuity of movement

Continuity of movement describes whether the operation is continuous or takes place in discrete steps e.g. a multi-position switch. Where earlier specification restricts whether either continuously variable controls or controls which operate in discrete steps are used then this should be indicated on the recording form.

NOTE Normally this will have been determined when classifying the general task requirements, accuracy and speed.

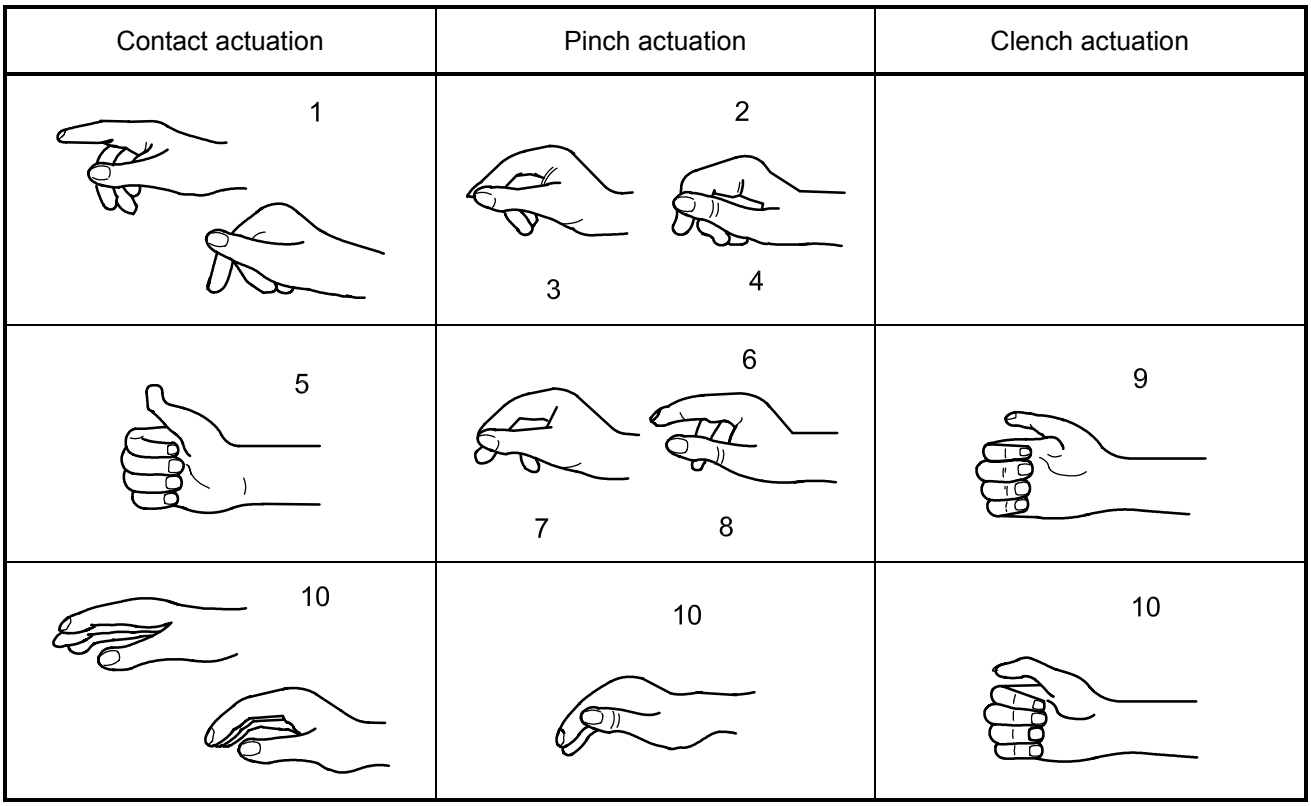
Where the operation of a manual control actuator is linked to a visual display, its movement shall be compatible with the movement of the display (see ISO 9355-1 and ISO 9355-2).

5.4.6 Movement characteristic n) — Angle of rotation for continuous rotary movement > 180°

For rotary manual control actuators, this describes whether rotation is continuous for more than 180° (Yes) or not (No). Where earlier specification or consideration of postural constraints restricts whether more than a half turn is required for a rotary control actuator, then this restriction should be entered on the recording form.

5.5 Specification of grip characteristics [5.1 o) to q)]

Grip characteristics address the interaction between the hand and the control actuator: three types of characteristic are described. Only those restrictions on grip characteristics that are imposed by the initial design specification should be entered on the recording form.



Key

1	finger	6	three fingers
2	two fingers	7	evenly spaced
3	thumb opposed	8	thumb opposed
4	thumb at right angle	9	fingers
5	thumb	10	hand

Figure 4 — Types of grip (see 5.5.2)

5.5.1 Grip characteristic o) — Type of grip

There are three types of grip between the operator's hand and the manual control actuator (see Figure 4):

— contact grip, where a unidirectional force is applied by a finger, thumb or hand to a control actuator;

— pinch grip, where the manual control actuator is held by fingers and/or thumb without clenching the fist;

— clench grip, where all the fingers are wrapped around the manual control actuator (see Figure 4).

Where earlier specification or consideration of postural constraints restricts the grip, then the possible grip characteristics should be entered on the recording form.

5.5.2 Grip characteristic p) — Part of hand applying force

This is the part of the hand, whether one finger, several fingers or the whole hand, used to operate the control actuator. Where earlier specification or consideration of postural constraints restricts the part of the hand that can apply the force, then the possible parts of the hand should be entered on the recording form.

5.5.3 Grip characteristic q) — Method of applying force

This refers to whether the force is applied normal or tangential to the surface of the manual control actuator. The former relies primarily on the shape of the actuator and the finger or hand interlocking, whereas the latter relies primarily on the friction between the actuator surface and the skin. Where earlier specification or consideration of postural constraints restricts the method of applying force, then either normal or tangential should be entered on the recording form.

5.6 Recording the information

The form in Figure 2 is given as a means of recording the preceding information. The form should be completed as far as is possible up to this stage. It is useful to record those requirements which are the most important or critical or which cannot be changed: the remarks column can be used for this purpose.

6 Intermediate selection of control families

In order to be able to proceed with the selection process, the information collated on the recording form is used as follows.

Figures 5 and 6 allow the selection of control families for linear and rotary control actuators, respectively. The first column provides a number for each row, L1...L41 and R1...R33. The next three columns denote possible combinations of accuracy, speed and force using the classification scheme from Clause 5. The fifth column denotes those axes and directions of movement for which the combinations of accuracy, speed and force in the previous three columns can be met. The final two columns denote control families, designated by numbers, which meet the criteria in each row. One column is used for discrete movement control actuators, the other continuous movement. Figure 6 has a further column which allows selection of control families which require more than a half turn.

If earlier design specification has stipulated whether a linear or a rotary control actuator should be used, then it will only be necessary to use one or the other of Figure 5 or Figure 6.

Using Figures 5 and/or 6:

— take the acceptable combinations of speed, accuracy and force from the recording form (see Figure 2);

— compare these with the combinations given in the corresponding columns in Figures 5 and 6;

— select all those rows in Figures 5 and 6 which fulfil these requirements;

— for the selected rows, compare the movement characteristics (k, l, m, n) with those specified in the recording form;

— select all control families which meet these requirements.

The movement characteristics can now be checked. Where particular movement characteristics have already been determined, it is possible to compare these with the available movement characteristics on the rows that have been identified as meeting the general task requirements. Rows which contain the required axis (k) and direction (l) of movement are used to select possible control families from the last two columns. Where discrete or continuous movement (m) has already been specified, then the appropriate column should be used.

For each row which meets the above requirements the number of the control family in the appropriate final column should be recorded.

If no row complies with all the general task requirements, then a suitable manual control actuator will not be able to be identified, and it will then be necessary to reconsider the general task requirements. The above procedure should then be repeated until at least one row in Figure 5 or 6 matches all imposed requirements.

Row number	Available degree of requirements			Movement characteristics		Control family number	
	a) Accuracy	b) Speed	c) Force	k) and l) Axis and direction of movement		m) Discreet movement	m) Continuous movement
L1	◑	◑	◔	X + Y –		6	14
L2	◑	◑	○	X +		4	12
L3	◑	◕	○	X +		1	10
L4	◑	◔	◔	X +		7	—
L5	◑	◕	○	X +		2	11
L6	◑	◔	○	X +		5	13
L7	◔	◔	◑	X + and Z +		8	15
L8	◑	◔	◑	X +		9	16
L9	◑	○	○	X –		1	10
L10	◑	◑	◔	X –		4	12
L11	◕	◑	○	X –		5	13
L12	◕	◕	○	X –		2	11
L13	◕	◕	◑	X –		3	—
L14	◑	◑	◔	X –		8	15
L15	◑	◑	◔	X –		9	16
L16	◕	◕	◔	Y +/–		4	12
L17	◕	◕	○	Y +/–		1	10
L18	◑	◑	●	Y +/–		7	—
L19	●	◕	○	Y +		2	11
L20	◑	◑	◑	Y +		6	14
L21	◕	◕	◕	Y +		8	15
L22	◑	◑	◕	Y +		9	16
L23	◕	◑	◕	Y –		7	—
L24	●	●	○	Y – and Z –		2	11
L25	●	◕	○	Y –		5	13
L26	◕	◕	○	Y –		3	—
L27	◑	◕	◑	Y –		6	14

Figure 5 — Selection of control families — Linear

Row number	Available degree of requirements			Movement characteristics		Control family number	
	a) Accuracy	b) Speed	c) Force	k) and l) Axis and direction of movement		m) Discreet movement	m) Continuous movement
L28				Y –		9	16
L29				Z +/–		1	10
L30				Z +		4	12
L31				Z +		5	13
L32				Z +		6	14
L33				Z +		3	—
L34				Z +		9	16
L35				Z –		7	—
L36				Z –		4	12
L37				Z –		5	13
L38				Z –		8	15
L39				Z –		6	14
L40				Z –		3	—
L41				Z –		9	16

Figure 5 — Selection of control families — Linear *(continued)*

Row number	Available degree of requirements			Movement characteristics		Control family number		
	a) Accuracy	b) Speed	c) Force	k) and l) Axis and direction of movement		m) Discreet movement	m) Continuous movement	n) Suitable for rotation > 180°
R1	●	◕	○	X+/–Z+/–		21	30	
R2	◕	◑	◔	X+/–Z+/–		20	29	
R3	◕	◕	○	Y+/–		18	27	
R4	◑	●	◔	X+/–Y+Z+/–		23	33	
R5	◑	◑	◔	X+/–Y+Z–		25	36	
R6	◑	◔	◔	X+/–		24	35	
R7	○	◕	◕	X+/–		19		
R8	◕	◕	◔	X+Y–		20	28	Yes
R9	◑	●	○	X+Y+/–		17	26	
R10	◑	◔	◑	X+Y–		22	32	
R11	◔	◑	◑	X+		22	31	Yes
R12	◔	◔	●	X+Y–		24	34	Yes
R13	◔	◑	◔	X–Y+		20	28	Yes
R14	◔	●	○	X–		17	26	
R15	◑	◑	◑	X–Y+Z–		22	31	Yes
R16	◑	◔	◕	X–		22	32	
R17	◔	◑	●	X–Y+Z–		24	34	Yes
R18	◕	◑	◕	Y+/–		21	30	
R19	◑	◑	○	Y+/–		20	29	
R20	◔	●	○	Y+/–		18	27	
R21	◑	◔	○	Y+		24	35	
R22	◑	◔	◑	Y+Z–		25	36	
R23	◑	◔	◕	Y–		24	35	
R24	◔	◑	◔	Y–		25	36	
R25	◔	◔	◑	Y–		22	31	Yes
R26	◕	◕	○	Z+/–		17	26	
R27	◑	◔	○	Z+/–		18	27	

Figure 6 — Selection of control families — Rotary

Row number	Available degree of requirements			Movement characteristics		Control family number		
	a) Accuracy	b) Speed	c) Force	k) and l) Axis and direction of movement		m) Discreet movement	m) Continuous movement	n) Suitable for rotation > 180°
R28	◑	◔	●	Z+/–		22	32	
R29	○	◑	◕	Z+/–		19		
R30	●	◕	◔	Z+		20	28	Yes
R31	◑	◔	●	Z+		24	34,35	Yes
R32	●	●	◔	Z–		20	28	Yes
R33	◔	◔	●	Z–		24	35	

Figure 6 — Selection of control families — Rotary *(continued)*

7 Identification of suitable control types

The final selection of control actuators involves comparing the specific task requirements and grip characteristics of those control families identified as being suitable in Clause 6. This requires the use of the remaining information entered in the recording form of Figure 2.

Figure 7 contains information on the characteristics of different types of control actuators, and is divided into four sections:

— linear control actuators — discrete movements;

— linear control actuators — continuous movements;

— rotary control actuators — discrete movements;

— rotary control actuators — continuous movements.

The number in the first column of each section identifies a group of similar control types; this number is used to cross-reference from Figures 5 and 6. The second column contains information on the grip characteristics for actuating controls of this type. This specifies the type of grip (o), the part of the hand applying the force (p), and the method of applying the force (q). The third column describes particular control types that are part of the control family. A typical example of such a type is illustrated in the column that follows. The next six columns describe the features of these control types in terms of the specific task requirements d), e), f), g), h) and i). The final column contains remarks which could help in the selection process.

7.1 Step 1 — Comparison of grip characteristics

Using Figure 7, take the numbers of all control families identified in Figures 5 and 6, then look up the corresponding numbers in the first column of Figure 7.

If any grip characteristics are specified in the recording form (see Figure 2), compare them with the grip characteristics associated with each selected control family.

Proceed to step 2 for those control families that have compatible grip characteristics.

7.2 Step 2 — Comparison of specific task requirements

For each control type in a suitable control family, compare the specific task requirements to the associated features d), e), f), g), h) and i) given in Figure 7.

If the classification of the features in Figure 7 matches the equivalent specific task requirements, then mark that control type as being suitable for further consideration.

If the classification of the features in Figure 7 does not match the equivalent specific task requirements then that control type is not suitable.

Each possible control family should be assessed in turn until a list of possible control types has been generated.

If it is not possible to find a match between the specific task requirements and the features of the control type then it will be necessary to re-evaluate the specific task requirements or determine if other aspects of the specification can be altered so as to allow a successful selection of a control type.

7.3 Check for influence of actuator position

If there is doubt as to the suitability of a particular location, then user trials should be conducted.

Where the requirement for visual check d) cannot be satisfied, consideration should first be given to providing additional feedback of information by labels, displays etc.

If no satisfactory manual control actuator is found after the above measures have been considered, then the task allocation has to be reconsidered.

Where many possible types of control actuator are identified it is recommended that the most important of the task requirements be identified and then those control actuators having the highest classification for that task requirement be selected.

Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
1	Contact finger normal	Paired push buttons		◑	◑	◑	◔	◑	◕	
		Singlepush button		○	○	●	◔	◑	◑	
		Rocker switch (2 positions)		◕	◕	◕	◔	◑	◑	e.g. room light switch
2	Contact finger tangential	Slide switch		○	○	◕	○	◔	◔	
		Inset slide switch		●	◕	●	○	○	○	e.g. emergency stop control
3	Contact hand normal	Shaped inset slide switch		●	●	●	○	○	○	
		Mushroom headed push switch		● a	● a	○	◕	●	◕	
		Hand push button		●	●	○ a	◕	●	◕	
		Flush mounted hand switch		○	○	○ a	◕	●	●	
4	Pinch finger normal	Rod lever type toggle		●	◕	○ a	◑	◕	◑	Inadvertent operation much less likely in some orientation
		Flat lever toggle		●	◕	○ a	◕	◕	◑	Inadvertent operation much less likely in some orientation
		Inset flat lever toggle		◕ a	◕	●	●	○	○	

Figure 7 — Identification of suitable control types

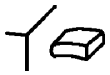
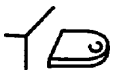
Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
5	Finger pinch tangential	Edge pinch push pull switch		◑	○	○ a	◔	◔	◕	Visual check depends mainly on the axis
		Top-bottom pinch, push pull switch		◑ a	○	○ a	○	◔	◕	Inadvertent operation depends mainly on positioning
		Ridged surface push pull		◑ a	○	○ a	○	◔	◔ a	
6	Hand pinch normal	Flanged pull, several fingers		◑ a	○	○ a	◕	◕	◑	e.g. drawer handle
		Recessed pull		○	○	●	●	◔	○	e.g. inset drawer handle
7	Finger Clench normal	Knob moveable in 2 directions		◑	○	○ a	◑	◔	●	
		Loop pull		◑ a	○	◔	●	◔	◔	
		Pull bar		◑ a	○	○	◔	●	◔	
		T handle		◑ a	○	○	●	●	◔	
8	Hand pinch normal	Smooth bent hand grip		◑ a	○	○	● a	●	●	
		Ridged bent hand grip		◑ a	○	○	●	●	●	
		Smooth hand bar		◑ a	○	◔	●	◔	◑	

Figure 7 — Identification of suitable control types *(continued)*

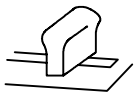
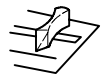
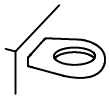
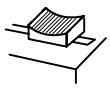
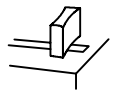
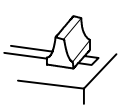
Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
9	Hand clench tangential	Smooth conical hand grip		◑	○	○ a	◔	●	●	Avoidance of inadvertent operation mainly depends on position
		Ridged hand grip		◑	○	○ a	◑	●	●	
		Stirrup type hand grip		◑	○	○ a	◔	◔	◑	
10	Finger contact normal	Slider with shaped edges		◑ a	○	○ a	◕	◔	◔	Visual checking dependent on orientation
		Slider with pointer		● a	○	○ a	◕	◔	◔	Visual checking dependent on orientation
		Ring pull		○	○	○ a	●	◔	◔	
11	Finger contact tangential	Flat ridged slider		◑ a	○	◕	○	○	○	Visual checking dependent on orientation
		Shaped ridged slider	 	◕ a	○	●	◔	○	○	
12	Finger pinch normal	Shaped ridged slider	 	◕ a	○	○ a	◕	◔	◔	Visual checking and avoiding inadvertent operation dependent on orientation
		Recessed slider		● a	◑	●	●	◔	○	Visual checking dependent on orientation

Figure 7 — Identification of suitable control types *(continued)*

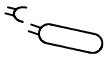
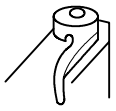
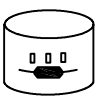
Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
13	Finger pinch tangential	Ball knob		◔	○	○	○	○	◑	Avoidance of inadvertent operation dependent on positioning
		Concave edged knob		◑ a	◕	◔ a	◔	○	◑	
14	Hand pinch normal	Ball knob slider		◑ a	○	○ a	◑	◑	◑	
		Oval T handle slider		◑ a	○	○ a	◔	◕	◑	
15	Hand clench normal	Hand grip sliders		◕ a	○	○	●	◕	◕	
		Hand grip slider with release		◕ a	○	●	●	◕	◕	
16	Finger clench tangential	Smooth cylindrical pull grip		◑ a	○	○ a	○	◕	◕	
		Smooth tapered pull grip		◑ a	○	○ a	◔	◕	◕	
		Smooth grip-profiled ends		◑ a	○	○ a	◑	◕	◕	
17	Finger contact normal	Finger lever		◕ a	◑	○ a	◔	◔	○	e.g. a bike gear selector
18	Finger contact tangential	Edge roller		○ a	○	◑ a	○	◔	○	
		Circumfer-ential slider		◕	◔	◑ a	○	◔	○	

Figure 7 — Identification of suitable control types *(continued)*

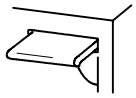
Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
19	Finger contact normal	Punch type handle		● a	◔	○	◔	●	●	e.g. board levers requiring a push to operate
		Flat type lever								
		Push in type flap		◕ a	●	○ a	◔	◕	◑	
20	Finger pinch normal	Recessed bar type knob		● a	◕	●	◕	◔	○	
		Pointer knob		● a	●	○ a	◕	●	◕	
		Key type actuation		● a	◕	◔ a	◕	●	◕	
21	Finger pinch tangential	Knurled round knob		◕ a	◔	◕	◑	◑	◔	
	Finger contact tangential	Smooth knob with skirt		◕ a	○	◕ a	◑	◑	◔	
		Ridged knob		○	○	◕	◕	◑	○	
22	Hand pinch normal	Lever with round knob		● a	●	◔	◑	●	●	
		T handle		● a	◕	◔ a	●	●	◕	
		Recessed hand knob		● a	◕	●	●	●	◑	Visual checking dependent on orientation

Figure 7 — Identification of suitable control types *(continued)*

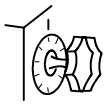
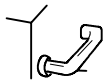
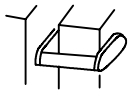
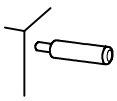
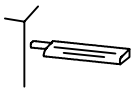
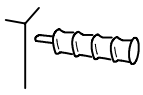
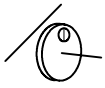
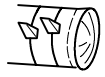
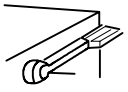
Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
23	Finger pinch normal	Ridged hand wheel		○	○	◑	◑	◕	○	Avoidance of inadvertent operation dependent on positioning
		Triangular knob		○	○	◑	◑	◕	◑	
		Hexagonal knob with skirt and scale		◑ a	○	◑	◑	◕	◑	
24	Hand clench normal	Lever handle selector		● a	●	◔	●	●	●	
		Door handle type		● a	◕	◔ a	●	●	●	
		Bar handle type		◕ a	◕	◔ a	●	●	●	
25	Finger pinch tangential	Smooth hand grip		○	○	◕	◑	○	●	
		Square section hand grip		○	○	◕	◕	○	●	
		Profiled hand grip		○	○	◕	◑	○	◕	
26	Finger contact normal	Finger recess knob		◕ a	○	◕	●	○	◑	
		Circumfer-encial slider		● a	◕	○ a	◔	○	◔	
		Pointer type knob		◔	◕	○ a	◔	◔	◔	

Figure 7 — Identification of suitable control types *(continued)*

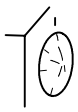
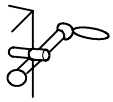
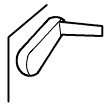
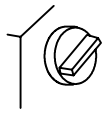
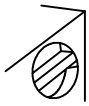
Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
27	Finger contact tangential	Thumb wheel		◕ a	○	◕	○	◔	◔	
		Finger spin wheel		◕ a	○	●	○	○	◔	
		Tracker ball		○	○	◕	○	○	◕	
28	Finger pinch normal, complete rotation (> 180°)	Finger operated crank		○	○	◔ a	◑	◑	◕	
		Cranked finger lever		○	○	◔	◕	◕	◕	
		Cranked round knob with scale		◕ a	○	◔ a	◑	◑	◕	
29	Finger pinch normal, rotation (> 180°)	Finger thumb rotary knob		◕ a	◕	◑	◑	◕	◕	
		Inset finger thumb knob		◑ a	◕	●	◕	◔	○	
		Wing nut type actuator		◑ a	◕	◑	◕	◕	◑	

Figure 7 — Identification of suitable control types *(continued)*

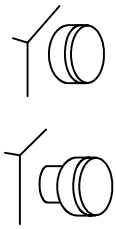
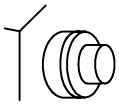
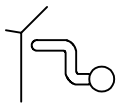
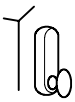
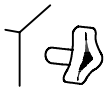
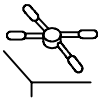
Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
30	Finger pinch tangential	Edge gripped finger knob		○	○	◕	◑	◑	◔	
		Ganged finger knob		○	○	◕ a	◑	◔	◔	
31	Hand pinch normal rotation (> 180°)	Small hand crank with knob		○	○	○ a	◑	◕	●	
		Winder type lever								
		Hand wheel with crank		○	○	○ a	◕	●	●	
32	Hand pinch normal rotation (> 180°)	Shaped T handle		● a	◕	◑ a	◕	◕	●	Visual checking depends on positioning of control
		Shaped 3-sided knob		◕ a	◔	◔ a	●	◕	◑	
		Shaped 4-sided knob								
33	Hand pinch tangential	Knurled edge gripped hand		○	○	◑	◑	◕	◑	
		Octagonal shaped knob		○	○	◑	◑	◕	◑	
		Shaped internal profile knob		○	○	◑	◑	◕	◑	

Figure 7 — Identification of suitable control types *(continued)*

Control family		Control type	Typical examples	Features (specific task requirements)						
No.	Grip			d)	e)	f)	g)	h)	i)	Remark
	Characteristics o) type of grip p) part of hand q) method of applying force			Visual check	Tactile check	Inadvertent operation	Friction	Use with gloves	Ease of cleaning	
34	Hand clench normal rotation > 180°	Hand crank wheel		○	○	○	●	●	●	
		Hand crank wheel		○	○	○	◕	●	●	Hand folds away
		Retratable crank		○	○	●	◕	●	●	Visual checking of position is poorer where control is mounted above chest height
35	Hand clench normal rotation > 180°	Stirrup hand grip		◕ a	◕	◑	●	◕	◕	
		Hand lever		● a	◕	○	◕	●	●	
		Capstan		◕ a	◔	○	◕	●	●	
36	Hand clench tangential	Smooth hand wheel		○	○	◔	◑	●	◕	
		Ridged hand wheel		○	○	◔	◔	●	◕	

a Classification of these features is particularly dependent on the specific location of a manual control actuator relative to the operator. For these control types it is necessary to carefully consider the location. Poor location will mean that the classification given here cannot be met.

Figure 7 — Identification of suitable control types *(continued)*

8 Additional information for design of manual control actuators

8.1 General

Where operator error in the use of a manual control actuator could lead to injury or damage to health, it is important to use manual control actuators that meet the recommendations given in this clause. The decision on whether this is necessary should be made on the basis of a risk assessment carried out in accordance with EN 1050.

In Clause 5, the manual control actuators are grouped according to the type of grip required for their operation; contact grip, pinch grip and clench grip. The same classification is used in the following.

8.2 Dimensions

The minimum recommended dimensions of manual control actuators are given in Table 3.

The dimensions shown for clench grip are smaller than those required for maximum human force application.

Table 3 — Minimum recommended dimensions of manual control actuators

Type of grip	**Part of hand applying force**	**Width or diameter of manual control actuator,** r mm	**Length of manual control actuator along axis of movement or axis of rotation,** s mm
1	**2**	**3**	**4**
Contact grip	Finger	$r = 7$	$s = 7$
	Thumb	$r = 20$	$s = 20$
	Hand (flat)	$r = 40$	$s = 40$
Pinch grip	Finger/thumb	$7 \leqslant r = 80$	$7 \leqslant s = 80$
	Hand/thumb	$15 \leqslant r = 60$	$60 \leqslant s = 100$
Clench grip	Finger/hand	$15 \leqslant r = 35$	$s = 100$

8.3 Actuation force or torque

The maximum recommended operating forces for linear manual control actuators and the maximum recommended operating torques for rotary manual control actuators are given in Table 4.

The values given are based on optimizing forces for ease of use. They take account of requirements for frequent or continuous use.

NOTE When determining operating forces or torques it is necessary to take account of velocity, frequency of use and duration of action (see EN 1005-3).

Where avoidance of inadvertent operation is necessary, the operating force should not be less than 5 N. However, resistance to operation alone is not a reliable means of avoiding inadvertent operation, so this measure should only be taken in conjunction with other measures (shrouding, correct location, correct selection, etc.).

Table 4 — Maximum recommended operating forces/torques for manual control actuators

Type of grip	Part of hand applying force	Other factors	Max. recommended linear actuating force N	Max. recommended linear actuating torque N·m
1	2	3	4	5
Contact grip	Finger	Any direction	10	0,5
	Thumb		10	0,5
	Hand		20	0,5
Pinch grip	Finger/one hand	Any direction	10	1
		X direction	10	2
		Y direction	20	2
		Z direction	10	2
Clench grip	One hand	X direction	35	—
		Y direction	55	—
		Z direction	35	—
		0,25 m radius	—	20
	Both hands	0,25 m radius	—	30

8.4 Position relative to operator

Each manual control actuator should be positioned so that the operator can operate it while maintaining a clear view of any associated information and without needing to overstretch or adopt an awkward posture. Where operators of varying body dimensions have to be accommodated, this could require provision of means of changing the operating position to suit each operator. This is particularly important where a manual control actuator is used frequently or continuously.

The recommendations in this International Standard apply particularly when manual control actuators are placed immediately in front of the operator. Where manual control actuators are positioned outside this space, the information given in the selection procedure may not be sufficient. In particular, the classification of the various manual control actuators shown in Figure 7 for visual check (d) and inadvertent operation (f) are likely to be inaccurate. Tactile check (e) may then assume a greater significance.

8.5 Position relative to visual displays

Where a manual control actuator is linked to a visual display of information, the recommendations given in ISO 9355-2 for the positioning and size of the visual display should be observed. The manual control actuator should be within easy reach of the operator.

Where manual control actuators are grouped according to their function or sequence of operation, their layout should be the same as the layout of their associated visual displays.

8.6 Compatibility and consistency

The relationship between the movement of a manual control actuator and its associated display shall follow the principles given in ISO 9355-1.

ISO 447, which gives requirements for controls on machine tools, and IEC 60447, which gives more general requirements for electrically operated controls on machines, should be followed as applicable.

Annex A
(informative)

Example of use of this part of ISO 9355

A.1 General

This annex describes how this part of ISO 9355 is applied to help select a suitable control actuator.

A.2 Task evaluation and information collection (Clause 5)

A control actuator is required for adjusting the sound output from an audiometer machine.

The control has to be operated accurately so that precise sound levels can be delivered to the subject. It is decided that there are only low requirements for speed and no requirements for force. These general requirements are entered on the recording form (see Figure 2).

Consideration of specific task requirements concludes that there are low requirements for visual checking and tactile checking, average requirements for avoiding inadvertent operation and no requirements for friction, use with gloves and ease of cleaning. These requirements are also entered on the recording form.

Because it is necessary to change the sound levels from both high-to-low and vice versa, movement in both + and – directions are needed. It is also necessary to change the sound level in a continuous manner. Both these aspects are entered on the recording form; the other aspects are left empty. The recording form is completed as shown in Figure A.1 (relevant remarks have been added).

Description of information	Related subclause of ISO 9355-3	Degree of requirement (Classification)					Remark
		0	1	2	3	4	
		○	◔	◑	◕	●	
General task requirements:	5.2						
a) Accuracy	5.2.1					●	Very high requirement
b) Speed	5.2.2		◔				Low requirement
c) Force	5.2.3	○					No requirement
Specific task requirements:	5.3						
d) Visual check	5.3.2		◔				Low requirement
e) Tactile check	5.3.3		◔				Low requirement
f) Inadvertent operation	5.3.4			◑			Average requirement
g) Friction	5.3.5	○					No requirement
h) Use with gloves	5.3.6	○					No requirement
i) Ease of cleaning	5.3.7	○					No requirement
Movement characteristics:	5.4						
j) Type of movement	5.4.2	Linear			Rotary		Either possible
k) Axis of movement	5.4.3	X	Y	Z	X	Y	Z	Any possible
l) Direction of movement	5.4.4	+/–	+/–	+/–	+/–	+/–	+/–	Both required
m) Continuity of movement	5.4.5	Continuous			Discrete			
n) Angle of rotation for continuous rotary movement > 180°	5.4.6	Yes			No			No requirement
Grip characteristics:	5.5						
o) Type of grip (see Figure 4)	5.5.2	Contact	Pinch		Clench		No requirement
p) Part of hand applying force	5.5.3	Finger			Hand		No requirement
q) Method of applying force	5.5.4	Normal			Tangential		No requirement

Figure A.1 — Completed recording form for selection of sound level control actuator

A.3 Intermediate selection of control family (Clause 6)

The values for a), b) and c) from the recording form are next compared with those in the equivalent columns of Figure 5 for linear control actuators and of Figure 6 for rotary control actuators:

Degree of requirement		
a) Accuracy	b) Speed	c) Force
●	◔	○

Rows from these figures are selected where they match or exceed the requirements given in the recording form. For this example, rows L19, L24, L25, R1, R30 and R32 meet these requirements; they are summarized in Figure A.2.

Row number	Available degree of requirement			Movement characteristics		Control family number		
	a) Accuracy	b) Speed	c) Force	k) and l) Axis and direction of movement		m) Discreet movement	m) Continuous movement	n) Suitable for rotation > 180°
L19	●	◕	○	Y+		2	11	
L24	●	●	○	Y– and Z–		2	11	
L25	●	◕	○	Y–		5	13	
R1	●	◕	○	X+/–Z+/–		21	30	
R30	●	◕	◔	Z+		20	28	Yes
R32	●	●	◔	Z–		20	28	Yes

Figure A.2 — Intermediate selection of control families

The rows shown in Figure A.2 all allow high accuracy and at least a low level of speed; any value of force is acceptable at this stage.

The movement characteristics are checked next. For the example considered in Figure A.1 the requirements are for movement in both "+" and "–" directions. There are no restrictions on the axis of movement. Our requirements are for continuous movement not discrete movement so we need only consider control families in the continuous movement column.

Study of Figure A.2 reveals that row R1 is suitable for both X and Z axes in both directions. The columns headed "Control family number" indicate that control family 30 is suitable for these requirements and for continuous movement.

Closer inspection shows that row L19 is suitable for movements in the Y+ direction but not Y–. However, L24 is suitable in Y– but not Y+. Nevertheless, they both lead to the selection of control family 11 for continuous movement. Thus taken together they show that control family 11 will meet the selection criteria for both directions on the Y axis.

Similarly, R30 and R32 together permit movement in the Z axis for both direction. These identify control family 28 as being suitable for continuous movement.

Row L25 is excluded from further consideration because it does not provide the level of requirements.

We can thus draw up a list of suitable control families: 11, 30, 28.

A.4 Identification of suitable control types (Clause 7)

Each of the control families is considered in turn using Figure 7. This allows us to examine the characteristics of the suitable control families and compare them with our specific task requirements (d, e, f, g, h, i) and the grip characteristics (o, p, q) which are summarized in Figure A.1.

Control family 11 contains linear sliders operated by finger contact.

Control family 30 contains rotary knobs operated by finger pinch grip.

Control family 28 contains small cranked knobs operated by finger pinch grip and which permit more than a half turn of rotation.

Consideration of the specific task requirements suggests that

— control family 11 (linear sliders) is suitable apart from the need for tactile checking of position,

— control family 30 is not suitable for either visual or tactile checking, and

— control family 28 is not suitable for tactile checking and only the control type “cranked knob with a scale” is suitable for visual checking.

This evaluation suggests that, in order to achieve a successful selection, either the tactile checking requirement has to be reduced and the sliders then used, or else some other way of increasing accuracy can be used (as suggested in 5.2.1.2) and a new evaluation carried out.

If the sliders from control family 11 are selected, they should be positioned so that movement is in the Y axis. This is the orientation which provides the required accuracy and is good for visual checking.

Figure 7, control family 11, further informs that sliders with a shaped top have better features for visual checking, inadvertent operation and friction than those with a flat top. It also warns that visual checking is dependent on orientation of the slider, so that care has to be taken in positioning the device.

Conclusion: Control family 11 provides the best compromise for providing a control actuator which matches the requirements for adjusting sound levels on an audiometer machine. Control family 28 provides a slightly less suitable alternative provided the cranked knob with a scale is selected.

Bibliography

[1] ISO 12100-1, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology*

[2] ISO 12100-2, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles*

[3] EN 574, *Safety of machinery — Two-hand control devices — Functional aspects — Principles for design*

[4] EN 614-1, *Safety of machinery — Ergonomic design principles — Part 1: Terminology and general principles*

[5] EN 894-3, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Part 3: Control actuators*

[6] EN 1005-3, *Safety of machinery — Human physical performance — Part 3: Recommended force limits for machinery operation*

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