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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

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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.

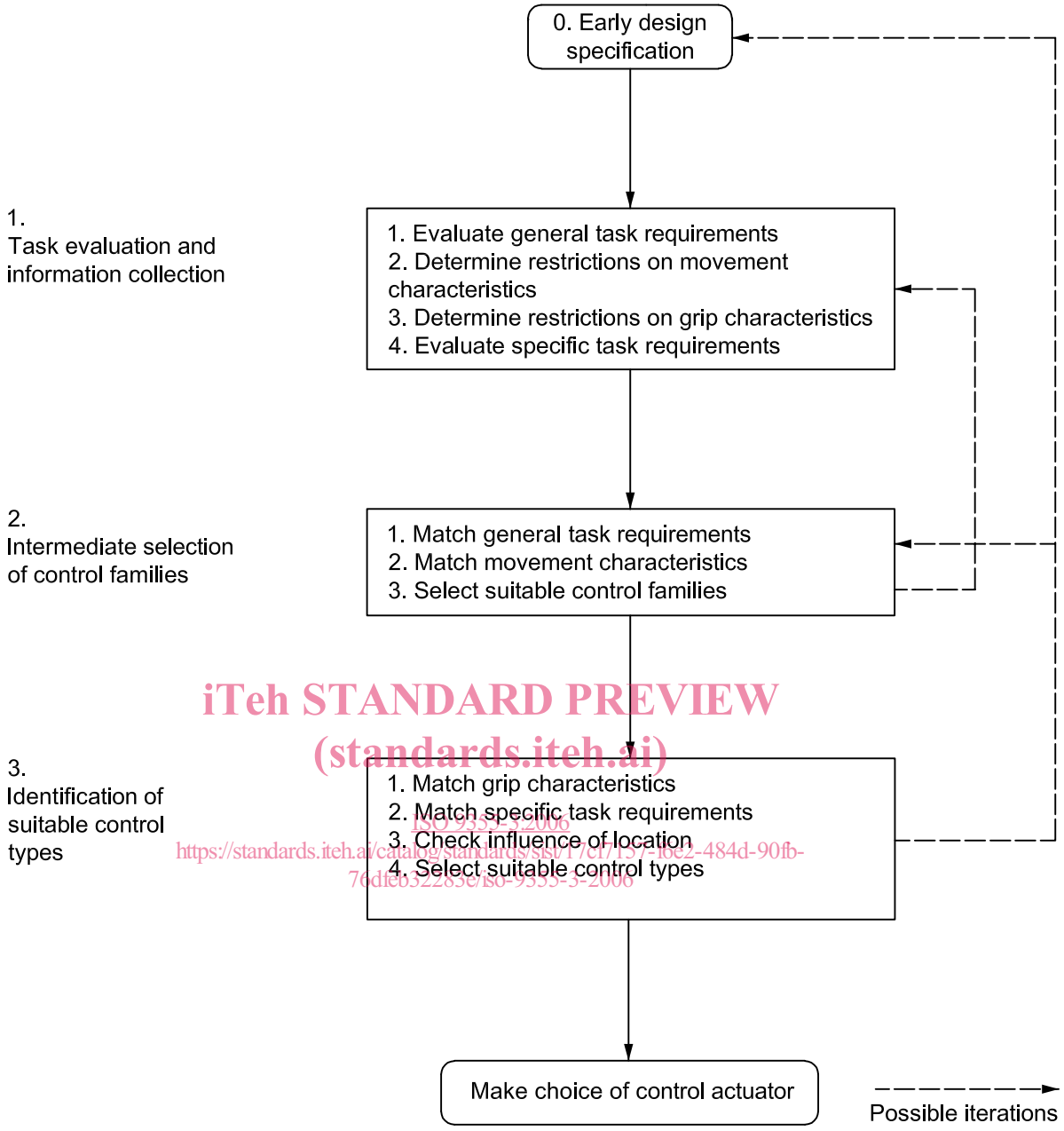

Figure 1 — Overall procedure for selecting manual control actuators

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.