UNIT 14 ERGONOMICS AND PRODUCT DESIGN

Structure

14.1 INTRODUCTION

The science of ergonomics is concerned with the design of human work.

Ergonomics is the scientific study of the work, the people who do it and the ways in which it is done. It is also concerned with the tools people use, the places they work in and the procedures and practices that they follow. In short, ergonomics is concerned with the design of working system.

Objectives

After studying this unit you should be able to

- define and explain the significance of the ergonomics in performing a job.
- explain the concept and objective of ergonomics,
- describe the advantages and applications of ergonomics,

- implement the work science,
- observe the natural laws of work in product design,
- build up a work culture that respects bioengineering, and
- define the principles and standards to observe while designing the product.

14.2 MEANING OF ERGONOMICS

The effect of health, safety and comfort are the core concepts of these studies and is given under a name Ergonomics.

Ergonomics is the word derived from Greek which means natural laws of work (ERGOS- means work and NOMOS- means natural law). In short it is an economics of work. The main aim of this study is to reduce the fatigue and strain of operator and hence, improving his efficiency on the whole. Thus ergonomics is defined as "the study of the relation between man and his occupation, equipment and environment, and particularly the application of anatomical, physiological and psychological knowledge to the problems arising there from".

It is found that many problems have been faced by ergonomic design of machine and controls due to poor design of work place layouts. The mere availability of tools and technology does not ensure its economic development unless the worker's efficiency is also favourable. To have the fruits of productivity, particularly of present developed technology, the people must be trained to apply these tools of science and technology effectively on a broad front of economic activities. At the same time the environmental conditions also should encourage him to submit full of his abilities.

Ergonomics brings out the best possible match between the physical and mental demand of work and the capabilities of individual members of the work force so as to optimize, both the productivity of the organization and the health, safety and well being of its people.

Ergonomics uncovers the new dimension of the relationships between man, machine and the environment to make man-machine systems more efficient and safer.

Therefore, ergonomics is the application of human biological sciences in conjunction with engineering sciences to the worker and his working environment in order to design the products for worker satisfaction and productivity improvement.

14.3 OBJECTIVES OF ERGONOMICS

Most of the recent researchers in this field are trying to explore various factors influencing the human efficiency while working on the machine. The scientific study of the relation between man, machine and his environment (in this context, the word environment includes tools, material, method of work, working culture, working environment, weather and working habits) is the main aim of ergonomics. Human body possesses lot of adaptability and flexibility so that the effect of bad working conditions may be apparent immediately but ultimately there will be its impact, which may affect the efficiency badly. The identification of such effects and hence establishment of optimum conditions so as to minimise these effects necessitate the ergonomic studies.

Thus by summing up the above, we can now list out the objectives of ergonomics as follows :

(a) To identify basic causes related to human factors by which the efficiency of man-machine is hampered.

(b) To provide better working conditions so as to improve productivity of the system.

(c) To create adequate facilities to reduce or eliminate the stresses, fatigue and failures in the performance of man-machine system.

(d) To provide comforts and make the job easy.

(e) To match the requirements of the task with the capabilities of a man and hence eliminate the loss in output.

Further, the field has become significant because the man in a man-machine system has some wrong notions about himself such as :

(a) Man has false notion that he knows all about himself and he thinks that he can work with same efficiency in all conditions. This in fact may become true once a while but in long run he fails or lacks to perform.

(b) A human has false idea that human body can take any amount of punishment or strain.

(c) Human tendency is to be reluctant in reporting. This is making a man to accept the poor design, but at the cost of efficiency, which he is unable to identify or recognise.

In every sphere of technology, the man is involved and therefore we come across many situations in which the characteristics of man may conflict with the characteristics of technical procedures. Matching these characteristics is not so simple since it is very difficult to trace the characteristics and their tolerances of human beings. These depend on many factors such as Geographic, Demographic, Economic and Environmental reasons on one hand and physiological, psychological and anatomical reasons on the other hand.

Sir Wilfred Le Gross Clask, in his address to the Ergonomic Research Society at its symposium on Human factors in Equipment Design, expressed "a man and his machine may be regarded as functional unit and the aim of ergonomics is to bring perfection in this unit so as to promote accuracy, speed of operation and at the same time to ensure minimum fatigue and thereby maximum efficiency". Therefore the productivity is not the primary objective of ergonomics but is only the end product. But the primary objective must be concentrated in establishing the most optimum working conditions such as lighting, climatic conditions, noise level, work loads, working posture, psycho sensorial functions, displays, handling of machine levers, controls, etc.

14.4 ADVANTAGES OF ERGONOMIC DESIGN

With the better ergonomic design there would be

(a) Higher output.

(b) Improved productivity.

(c) Minimum fatigue.

(d) Greater ease of working.

(e) Maximum satisfaction to worker.

(f) Good product design.

(g) Comfort and convenience.

(h) Congenial atmosphere.

14.5 APPROACHES ADOPTED BY ERGONOMICS

Better Product Design Approach

Design and implement scientific experiments and other research methodology to study human factors areas as they pertain to the operation of men, machines, products, weapons or any complex systems. This unit focuses on this approach.

Man-Machine System Approach

Evaluate existing or proposed man-machine systems and subsystems in terms of human physiological and psychological requirements so that optimum suitability and durability from human input standard is established. In the next unit, i.e. Unit 15 of this block, we present the Man-Machine System Approach and its features.

Environment and Human Productivity Approach

Consult with professional prior to, during and after design and development of system to ensure optimum operation in terms of human capabilities, limitations and variables with reference to environmental effects. We shall throw some light on the aspects of this approach in Unit 16 of this block.

SAQ 1

(a) What do you understand by term ergonomics? Discuss the meaning and its relevance.

(b) What are the objectives of ergonomic study?

(c) List out the advantages of applying ergonomics in the industries.

(d) Explicate the approaches to ergonomics in the industry.

Activity 1

Enquire the workmen of any company of your choice and record the areas or products or units which they are not feeling comfortable and convenient. Think any Modification if you can make to solve their problems and record as follows.

	Product	Problem	Modification I
(a)	....	....	....
	....	....	....
	....	....	....
(b)	....	....	....
	....	....	....
	....	....	....
(c)	....	....	....
	....	....	....
	....	....	....
(d)	....	....	....
	....	....	....
	....	....	....
(e)	....	....	....
	....	....	....
	....	....	....

14.6 FIELDS REFERRED IN ERGONOMICS

Ergonomics is a blend of various subjects of engineering, medical and other relevant fields or combinations of fields. All these are often referred and its constituent themes are given a due consideration while ergonomically designing any product. These are briefed out as follows :

(a) Engineering psychology

(b) Work physiology

(c) Environmental physiology

(d) Anthropometry

(e) Sport mechanics

(f) Orthodontics

(g) Orthopedics

(h) Surgery

(i) Functional anatomy

(j) Experimental psychology

(k) Physiological psychology

(l) Industrial safety and hygiene

(m) Industrial medicine

(n) Physics and engineering

(o) Biomechanics

(p) Bio Materials, and

(q) Engineering psychology engineering.

Engineering Psychology

It is concerned with perception, decision making, i.e. the way an operator receives and processes information. It uses the applications of behavioural science in the design of man-machine systems.

It is the study of the sensory and mental capacities of man in order to establish the conditions under which a man-machine system can most efficiently and safely operate. The importance of engineering psychology in equipment design can be realized most strikingly in the design of cockpits and space capsule where the magnitude of controls and displays and the high risks are involved.

Work Physiology

This is concerned with the whole field of body activity particularly with reference to many different types of environments.

Environmental Physiology

This links up the study of the inter-relation of the living organisms with the physical factors of environment.

Anthropometry

It establishes the principles and standards for the design of equipments, work place, motion patterns for different operations to bring them into harmony with size, shape, mobility and structure of the human body.

Biomechanics

It is the science that deals with the internal and external forces and the effects of those forces produced by actions of human body.

Biomechanics of motion covers various aspects of physical movements of the body and its parts. For example, the operation of the body member can be characterized in terms of science of motion (Mechanics) such as bones connected at their joints in combination with the muscles serve as levers.

Further, it provides a strong scientific basis for the analysis of human movements, which is common to mechanics, materials, psychology, medicine, surgery, pathology, prosthesis, patient care, dentistry, athletes, sports, environmental studies, safety and mechanics of human tolerance to fatigue and injury.

Sport Mechanics

This focuses on analysis of various styles of movements of body as well as the sports equipment for best results through equipment design, injury prevention, energy optimisation, etc.

Orthopedics

This deals with the design and analysis of prosthetic and orthopedic devices, analysis of surgical procedures, comparison of treatment and heating pattern, design of surgical instruments, physical therapy techniques, etc.

Orthodontics

It is science concerned with the design of braces, materials for dentistry, treatment procedures, etc.

Surgery

This subject is connected with the ergonomics in designing of instruments, analysis of optional individualism orientation, skin heating properties, etc.

Biomaterials

This subject is referred in while studying ergonomics for testing of bio-compatibility, life cycle, etc.

Functional Anatomy and Physiology

These are concerned with the body frame work posture and the use of muscles. Therefore, they provide sound knowledge of the best ways in which forces can be applied or an object is lifted and also about the limits of joint movement.

Industrial Hygiene

This subject concentrates on reduction of toxic and other health hazard.

Physiological Psychology

This is a specialized course to study functioning of the brain and of the nervous system often referred by the ergonomics.

Experimental Psychology

This is the practical study of human behaviour that helps in ergonomic studies.

Industrial Medicine

This science helps in deciding those conditions of work which may prove harmful or harmless to the human structure.

Physics and Engineering

These are the core subjects for ergonomic studies to define the condition of work.

14.7 WORK SCIENCE

The work science has brought the relation between the engineering and medicine into light. The need for knowing human performance- limitations and capabilities made the anatomists psychologists, physiologists, industrialists, economists, industrial engineers, industrial designers, machine/equipment designers and manufacturers under one roof to think of laying down a bridge between social, human and engineering sciences.

The extensive research programmes undertaken in UK and other countries resulted in the formation of ERGONOMICS RESEARCH SOCIETY in 1949, and later known as ERGONOMICS SOCIETY. This society has identified some principles and laid down the scientific norms for doing certain work.

The work science can be classified under two heads :

(a) Techniques of work, and

(b) Organisation of work.

14.7.1 Techniques of Work

The work techniques are again divided into two sections :

(a) Biological techniques, and

(b) Mechanical techniques.

The biological techniques deal with hygiene of work based on work psychology and work Pedagogies (Science of training and instructions). The mechanical techniques deal with time and motion study.

14.7.2 Organisation of Work

This deals with the disposition of work and the evaluation of work based on output. It concerns with the 'amount of work' to be assigned to a man, 'the rest allowances' and 'working environment' around the worker.

The work science and ergonomics can be regarded as link of bioengineering and management. This has taken into account of biological, engineering and management aspects in the work culture and laid down some principles. A few of these basic principles and norms evolved by ergonomists and considered by every designer and discussed in the following Section 14.5.

SAQ 2

(a) What are the fields referred in ergonomics? With suitable examples, discus how they are consulted during product design.

(b) What is work science? How do you classify work science and what it speaks about?

Activity 2

Think of the relationship between various subjects and ergonomics. Write at least one example to represent the relationship

	Subject	Relationship	Example
(a)	....	....	....
	....	....	....
	....	....	....
(b)	....	....	....
	....	....	....
	....	....	....

(c) ....

....

....

(d) ....

....

....

(e) ....

....

....

14.8 DESIGN FACTORS

The design factors play a significant role in not only designing seats and work-tables, but also in working area and the plant and equipment lay out. While designing the equipment also, the operator cannot be ignored. Even while designing the equipment also the manufacturer will not overlook the operator and he designs and manufactures in such a way that its controls can be operated with a great ease, fast and effective. While laying out and positioning (erection) of these controls of equipment, unfortunately sometimes are not located at relevant positions. This causes subjection of undue stresses and thereby operational breakdown or some fault in operation. In such cases the industrial engineers have to take initiative and look back to study the positioning of such controls through the parameters of work-study design factors to make necessary modifications.

The design factors and recommended dimensions of various positions of human beings which are in common use are explained through figures and tables in the subsequent units (also Refer Unit 15, Man-Machine Systems and Unit 16, Environment and Human productivity of this Block 4). The design factors of the equipment and machine parts such as optimum size, positioning, allowable force, etc. so that they can be operated with ease and speed are covered here in this unit. These can be considered as the guidelines for an engineer in designing the equipment and working area.

14.9 ERGONOMIC DESIGN OF DISPLAY INSTRUMENTS

While designing any product, a designer has to incorporate the principles of ergonomics, in additions to the technical and managerial features. The application of the ergonomic features mainly is associated with the sub-units or components or sub-products of the main products where the humans are directly connected with them. These sub-units or components (in some cases main products also) include the display devices and controlling devices. Thus the ergonomic design of display and controlling units will automatically ensure ergonomic design of entire product.

We shall now discuss about the design factors for display devices.

There are three main types of commercially produced display instruments :

(a) Analogue Display system (Type-I) – Round dial with movable pointer.

(b) Analogue Display system (Type-II) – Fixed pointer with movable dial.

(c) Digital Display system – Open window in which the numerical value can be read directly.

Each of these has merits in certain situations. If the object displays figures, then digital display system is the most suitable provided that the required number is visible. In case, in a sequence of a process a change in value is to be observed, then moving pointer on a round dial is the better option. If a process has to be carried out directly by setting a control at a definite value (setting the steam value or setting the desired voltage or current), a movable pointer is useful. If such a setting is carried out slowly then movable dial may be preferred (Figures 14.1(a), (b) and (c)).

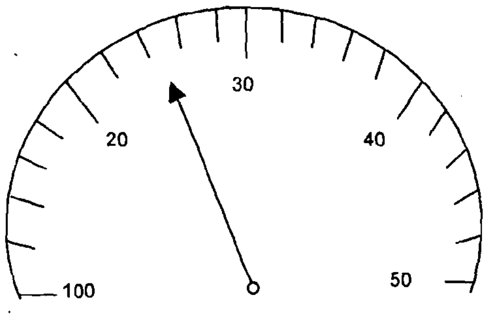


Figure 14.1(a) : Dial with Movable Pointer

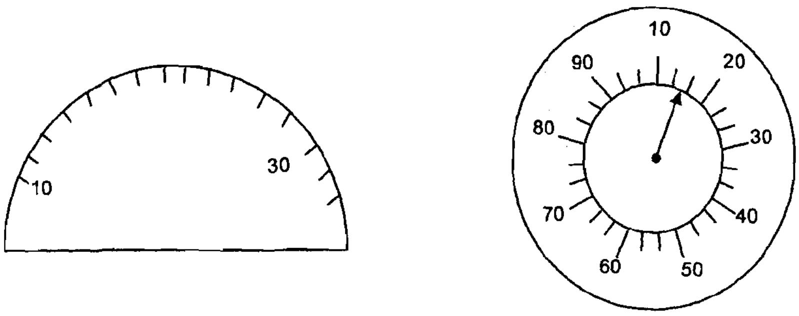


Figure 14.1(b) : Movable Dials with Fixed Pointer

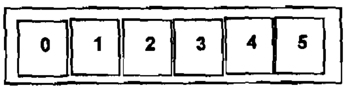


Figure 14.1(c) : Counter (Digital)

Table 14.1 : Common Display Instruments and their Utility

Type of Dial	Utility of Display Systems		
Type of display	**Type-I Analogue**	**Type-II Analogue**	**Type-III Analogue**
Reading absolute values	Fair	Fair	Very good
Observing rates of change	Very good	Fair	Useless
Setting a definite value directing a process	Very good	Fair	Fair

The effective utility of these display instruments could further be directed by distinctive colour, font, shape and size of numbers and letters, etc. matching the accuracy of display to the desired accuracy. Certain rules are recommended in order to have effective use of display on the basis of research carried out by various investigators. Researches indicate that the shape of the dial may influence reading accuracy. The frequency of error with very short reading times is shown in Figure 14.2. In such cases a digital display system may be preferred.

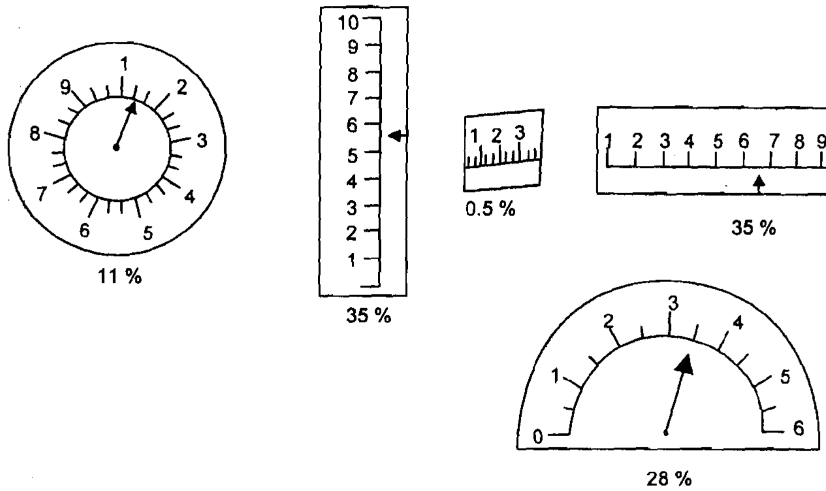


Figure 14.2 : Effect of Different Types of Information Display on Reading Precision

14.9.1 General Guidelines for Designing the Display Devices

(a) The degree of accuracy shown on the dial must be in accordance with the required accuracy. If a dial gives accuracy greater than the required makes reading more difficult and leads to reading error.

(b) The dial should give the correct and needed information to the operator while working on the machine. Superfluous information may cause error.

(c) As far as possible, sub-division should be in multiples of 1, 2 or 5, since other sub-divisions may raise difficulties in putting the correct information.

(d) Figures should be attached to the large scale markings which may be after 1, 2 or 5 sub-divisions. These numerical figures should be tangential on a moving scale and upright on a fixed scale.

(e) The pointer must have a sharp arrow or tipped point to show the correct numerical value. It should neither cover the scale nor the numbers. The pointer should move in the same plane so that the parallax can be avoided.

(f) The sizes of letters and figures must be adjusted to the Expected distance between the eye and the information display. For this, the following formula may be used :

Height of letters or figures in mm. = visual distance in mm/200

SAQ 3

(a) What do you understand by ergonomic design of products? What are the advantages of ergonomic designing?

(b) Describe different types of display units that often are associated with the products. Discuss the design factors that are to be considered while designing these display units.

(c) Enumerate the general guidelines in designing the display units ergonomically.

(d) Discuss the design aspects of the following display units with reference to the ergonomics :

(i) Analogue type display instruments

(ii) Digital type display instruments

Activity 3

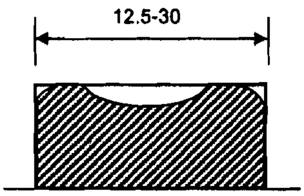
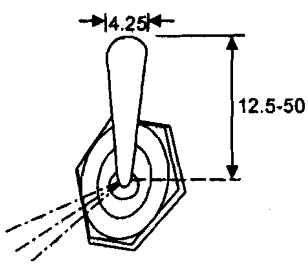
In a company of your choice list out and record the status of the various display units available. Check if there is ergonomic design. If not can it be modified or improved?

	Device	Status	Improvement I
(a)	....	....	....
	....	....	....
	....	....	....
(b)	....	....	....
	....	....	....
	....	....	....
(c)	....	....	....
	....	....	....
	....	....	....
(d)	....	....	....
	....	....	....
	....	....	....
(e)	....	....	....
	....	....	....
	....	....	....

14.10 ERGONOMIC DESIGN OF CONTROLLING DEVICES

The design of knobs, levers, push buttons, switches, steering and handles should provide ease so as to control efficiently. The dimensions and forces that can be applied on them should be optimum such that the operator will not be strained. These optimum dimensions are shown in the following Tables 14.2 and 14.3.

Table 14.2 : Optimum Dimensions for Controlling Devices

Control	Type of Use	Optimum Size (mm)	Separation (Inside Edge to Inside Edge)		Allowable Force, kg
			Minimum (mm)	Optimum (mm)	
Push Button	One finger (at random) One finger (by sequence) Different fingers (at random or by sequence)		12.5 6.5 12.5	50 6.5 12.5	0.5-1.5
Toggle Switch	One finger (at random) One finger (by sequence) Different fingers (at random or by sequence)		19 1.25 16	50 25 19	0.25-1.5

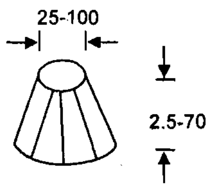
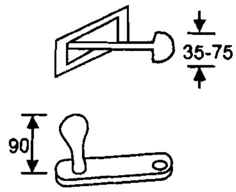
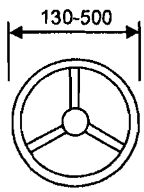
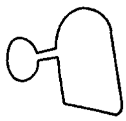
Knobs	One hand (at random) Two hands (simultaneously)		25	50	0.5-1.0
Crank and Lever	One hand Two hands (simultaneously)		50 75	100 125	15 Upto 4 for radius 125 upto 6 for radius 250
Hand Wheels	One hand Two hands (simultaneously)				1-15 for One Hand 1-25 for Two Hands
Pedals	One foot (at random) One foot (sequentially)		100 50	150 100	5-100

Table 14.3 : Selected Structural Body Dimensions

Sl. No.	Body Feature	Dimensions : Centimetres					
		Male, Percentile			Female, Percentile		
		5th	50th	95th	5th	50th	95th
1.	Height	162	173	185	150	160	170
2.	Sitting height, erect	84	91	97	79	85	91
3.	Sitting height, normal	80	87	93	75	82	88
4.	Knee height	49	54	59	46	50	55
5.	Popliteal height	39	44	49	36	40	45
6.	Elbow rest height	19	24	30	18	23	28
7.	Thigh – clearance height	11	15	18	10	14	18
8.	Buttock-knee length	54	59	64	52	57	63
9.	Buttock-Popliteal length	44	50	55	43	48	53
10.	Elbow to elbow breadth	35	42	51	31	38	49
11.	Seat breadth	31	36	40	31	36	43
12.	Weight*	58	75	98	47	62	90

*Weight given in kilograms.

Centimetre value is rounded to whole numbers.

Source : From weight, height and selected body dimensions of adults : data from National Health Survey, USPHS PUBLICATION 1000, SERIES 11, No. 8 (survey conducted on 6672 adult males and females which cover ages from 18 to 79 years).

Some Mile Stones in the History of Ergonomics

1940 : World War-II

1949 : U.K. Ergonomic Research Society

1970 : Germany Ergonomics Standard Committee

1973 : International Ergonomic Standard Organisation

1975 : ISO Technical Committee

These are some more points note worthy in designing the controlling devices.

14.10.1 General Guidelines for Designing the Controlling Devices

(a) Location of the controlling devices such as hand grips, levers, switches, dials, knobs, etc. is to be in such a position that they are clearly and easily readable and comfortably and conveniently operable because any manipulation of the machine deserves the full attention on these controlling devices.

(b) The designer should adhere to the principle of consistency of motion. For example, if turning increases the input to the machine the knobs or head wheel clock wise, then the needle of the meter indicating the reading of increase should also move clockwise.

(c) As far as possible the scales and knobs meant for the same function should placed together. Two methods are found to be most convenient in these designs are :

   (i) Scales on upper side and controls down, and

   (ii) Scales on left-hand side and controls on right hand side.

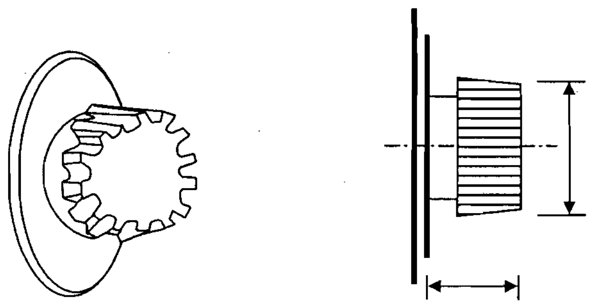


Figure 14.3 : Knobs and Switches for Controlling Function

(d) The motion of pointer of the scale or dial should be consistent.

(e) The sub divisions and numerals on dials or scales should not strain the eyes and should clearly be visible without causing much mental effort for reading.

(f) A control device should be marked with its function, indications of 'on' and 'off' positions and the speed levels or feed levels or steps of inputs, etc. If possible, it is better to use colour codes or sound tones also so as to make them distinctive. For instance, the speedometer now-a-days is designed with different colour codes on the dial. We can observe different sound on telephones, tones for dial tone, phone engaged, line engaged/out of order, cradle, ringing, local or STD call identification, etc. These are all the outcome of the ergonomic studies only.

(g) Shapes or alignment distinctions should be made wherever possible to avoid confusions. The computer central processing unit (CPU) will have many points to be connected such as power cord, monitor connection, mouse attachment, server connection, keyboard connection, etc. All these will have different shapes and distinct in their pin positions by which one will not suit the other except in its correct point. Such designs will enable the user to identify soon and be free from misalignments and confusions.

(h) Symbols and icons should be used for controls where ever possible. For example, each function on a computer especially in Windows is now-a-days symbolized and kept as icons on menu bar/task bar to make it user friendly.

(i) The control devices should be conventional and in the standard sizes which makes a new man also to operate without any confusion and makes accident free. During late seventies and early eighties most of the road accidents due to motor bikes have been registered due to confusion in break and gear control positions.

(j) The control positions should be designed in a logical sequence to prevent erroneous operations. If the operations are sequential but of random in nature, it is preferable to discover the related group of functions so that there is a set pattern of information, though there is no set pattern of operation. This enables the operator to locate particular control readily.

14.11 FACTORS FOR SELECTION OF CONTROLLING DEVICES

Most industrial processes operated by humans generally need to be controlled by knobs, levers, hand wheels, pedals etc. Correct type of control is to be selected with the due consideration of the safety and operational requirements. The correct choice could be based following factors :

Fit to the Functions

The controls should be so selected as to fit the functions and anatomy of limbs. For instance fast and precise operations should be performed by fingers or hands and those requiring force by arms or feet.

Easy Grasping/Gripping

Hand operated controls must be placed within easy grasping distances between elbow and shoulder height and be clearly visible. For example the types of gripping by hand are shown in the Figure 14.4.

Anatomic Considerations

Distances between the controls must match anatomic considerations. For example, if a control is to be operated by finger, the knob of at least 15 mm diameter is ergonomic while for hand control at least 50 mm diameter is necessary.

Need low Energy

For operations needing low energy expenditure and step or continuous adjustments for high precision, can be suitably done by manually operated push buttons, toggle switches, knobs. Whereas operations needing high energy expenditure, moving an element to great amplitude with less precision, can be carried out by levers, long arms, cranks, hand wheels and pedals, etc.

14.12 CONTROLS FOR HIGH PRECISION WORK

14.12.1 Push Buttons

They should be reasonably small. The design of push buttons has the following distinguished features :

(a) Surface should be slightly concave, so that the finger force may be transmitted more effectively.

(b) Diameter should be able to accommodate the finger tip without slipping.

(c) Recommended design range is as follows :

Diameter	:	12-15 mm
Movement	:	3-10 mm
Resistance	:	200-500 grams

(d) It is to be made of such a material which is easily distinguishable and preferably can shine even in the dark (luminescent colour may be used) so that there should be no problem in locating it.

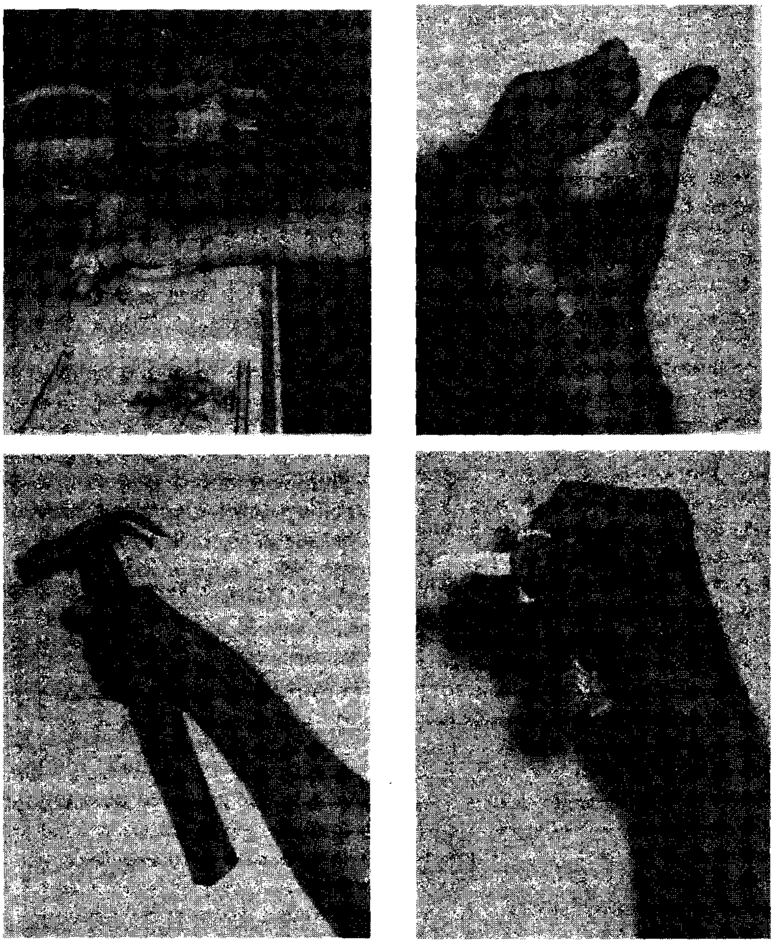


Figure 14.4 : Types of Grips by Hands

14.12.2 Toggle Switches

They should be able to be easily identified as they are miniature levers used as switches or selectors and guarantee high frequency of precision control. The general design guidelines are given below.

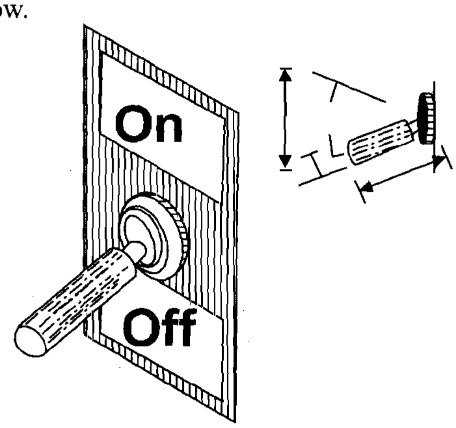


Figure 14.5 : Toggle Switch

(a) The toggle switches have only two positions 'ON' and 'OFF'. These two positions should be clearly written on the top and bottom, respectively.

(b) Recommended dimensions for general (simple) toggle switch L = 50 mm and d = 25 mm if weight applied (approx) is in the range of 200 – 400 grams.

(c) Movement should be vertical.

(d) Sometimes they are used for three positions, then the angle of movement in vertical direction between the two sequential positions should be between 30° to 40°, and meaning of each position should be clearly marked.

14.12.3 Knobs

These are rotary controls that can be operated freely by gripping it on both sides with the fingers of one hand. They are available in different shapes such as circular, bar-shaped, pointed and so forth. The general design guidelines for these products are given below.

(a) The shape should be in such a manner that must be easy to feel and provide a reliable grip.

(b) Any movement required must be clearly visible.

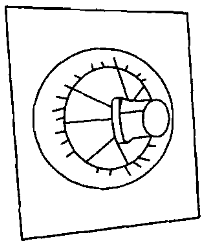
(c) They may be used for making fine adjustment when loads are light upto 22 in-lb [Sometimes they may be in continuous or discrete function and as rotary selector switches for switching operations. See Figures 14.6 (a) and (b)].

(d) Thicker knob allows two or three fingers for more grip and more ease. [Figures 14.4 and 14.6(a) shows a side knob which gives better view of pointer and scale].

(e) The gear ratio should be such that it should minimise the force required to operate.

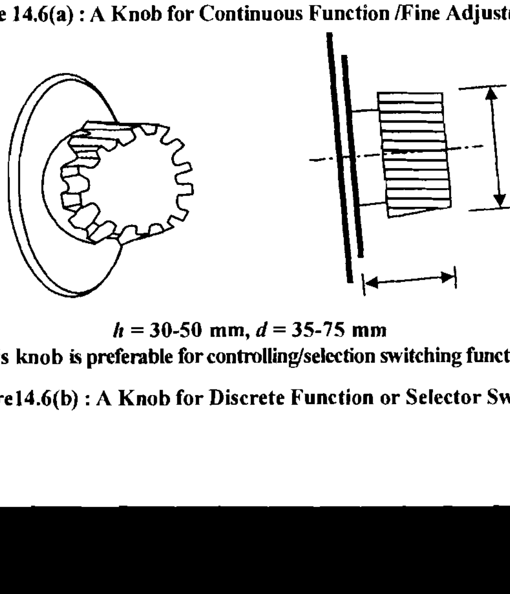
(f) Protection of scale against scratching is essential. An arc of 120 degrees can be obtained on a single rotation. For greater angle grasps have to be changed but this should be avoided.

(g) When several knobs are attached to an instrument panel, pointed knobs as shown in Figure14.6(c) are preferable as the adjusted position readily obtained.



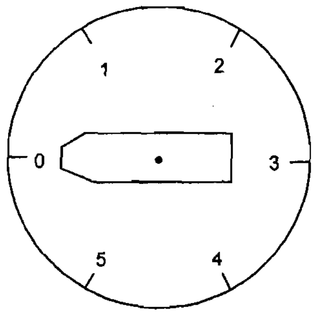
d = 10-30 mm; h =12-25 mm; Torque Required = 450 cm-gram
(Suitable for continuous function or fine adjustments)

Figure 14.6(a) : A Knob for Continuous Function /Fine Adjustment



h = 30-50 mm, d = 35-75 mm
(This knob is preferable for controlling/selection switching function)

Figure14.6(b) : A Knob for Discrete Function or Selector Switch



Pointer Dimensions : L **= 25 mm (min);** b **=25 mm (max);** h **=10-70 mm**

Figure 14.6 (c) : Pointed Knobs used for Selectors

14.13 CONTROLS THAT REQUIRE CONSIDERABLE FORCE

14.13.1 Cranks

It is a control parallel to the shaft in which the handle is offset from the shaft. This is suitable for setting or continuous movements which cover a wide range. It can also be used when high turning speeds are required upto 200 rpm. Further, different gear ratios can be selected to have desired speed. For fast movement, the handle must be set free to turn on its own axis, while fixed handles are more appropriate for precise movements or adjustments.

The Preferred Position for a Crank

(a) facing the operator,

(b) along a horizontal line at elbow height from the centre line of the body to the width of the shoulder of the operating hand, and

(c) along vertical line to shoulder height.

Design Data

– Lever arm length for low torque upto 200 cm-gram and low rpm
= at elbow, i.e. 60 – 120mm

– Lever arm length at high torque upto 160 cm-gram and high rpm
= 150 – 220 mm

– Lever arm length for quick movements and torques between 0.9 – 2.5 kg-cm
= upto 120 mm

– Lever arm length for exact positioning and torques between 1 to 3.5 kg-cm
= between 120 – 200 mm.

14.13.2 Hand Wheel

It is a circular control gripped at the rim preferably with both hands. It is recommended when large forces have to be exerted as the use of two hands and relatively long lever arms should be employed. It is useful for low turning speeds (1 rpm or low). Hand wheels are best when the amount of turn required does not exceed 90° for fine positioning.

Table 14.4 : Design Data for Hand Wheel

Torque (in-lb)	Diameter of Wheel at 38″-48″ from Floor	Wheels Diameter Below 38″ or above 48″
20-48	6″ (150 mm)	10″ (250 mm)
40-60	10″ (250 mm)	16″ (400 mm)
60-90	10″ (250 mm)	16″ (400 mm)
90 upwards	16″ (400 mm)	16″ (400 mm)

14.13.3 Pedals

A pedal is a reciprocating control operated by foot acting independently. When pedals are used for heavy energy expenditure, it is advised that a high back rest and horizontal position of the legs have to be adopted.

Flexion at the knee joint : 105°—130°

Flexion at the ankle joint : 90°

Generally, pedals are used without heavy expenditure of energy; the recommended arrangement is given in the Figure 14.7.

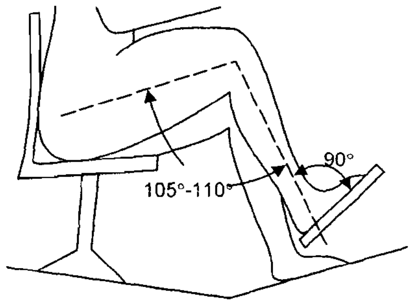


Figure 14.7 : Pedal and Recommended Angles

When using pedals in standing positions, it is advantageous if such pedals are at floor level so that the operator can change from one leg to the other. However, the use of pedals in standing position is highly undesirable from the fatigue point view.

14.14 RELATIONSHIP BETWEEN CONTROLS AND DISPLAY INSTRUMENTS

It is recommended that the controls (knobs, hand wheels, pushbuttons, etc.) are always used in conjunction with some type of display instruments. This helps in knowing the direction of movement of control that produces its result in a display. For example, the bed of milling machine moving from left to right; the movement of tracked vehicle when levers are used to turn it; the turning to knob alters the dial setting, etc. In equipment design, it happens occasionally that the designer has given very little thought to the importance of having the control movements compatible with the effects which they produce.

However, in early stages of development, unsatisfactory control-display relationship had been observed either for mechanical reasons or because of micro-conceptions in early stages of development. But the compatibility of controls with displays plays an important role in the operating efficiency of the equipments. It is therefore desired to arrange the controls and displays in the most simplified and distinctive way so that risk of error in reading the displays may be reduced to minimum.

A pioneering experimental study was carried out in this direction (to establish relationship between the controls and displays) by Worwick (1947) who used five boxes where display unit is shown by a row of five small bulbs and the control is shown by a rotary knob (Figure 14.8).

Figure 14.8 : Arrangement of Control and Display with Strongest Preferred Relationship

In this experiment, turning the knob (direction shown in the figure) causes a light signal to move from one end to another end as shown by the straight arrows in the figure in sequence. Fifty subjects were required to move the light to the centre from various positions (right or left of the centre) by turning the knob in any direction. The light would lit whichever way the knob was turned and the experimenter recorded whether the initial movement of the knob was made clockwise or anti-clockwise direction. With arrangements (1), (2) and (3) in which the control knob is in the same plane as the display unit, 70%-95% of the subject moved the control knob clockwise to produce a left-right movement of light in arrangement (1); an up movement of light in arrangement (2); and a down movement of light in arrangement (3).

However, when the control unit and display unit were in different planes as shown in (4) and (5), the preference shown by the subjects was not very clear. It can be concluded from this experiment that :

(a) The display unit and the control should be in the same plane.

(b) The display pointer should move in the same direction as the control itself i.e. as shown in the figure by arrangement (1), (2) and (3).

A second experiment was conducted with the same taking another group of subjects to determine which arrangement would produce the greatest speed and least error. It could again be concluded that the arrangements (4) and (5) could not show the effect on efficiency; however, the greatest degree of compatibility is achieved with a rotary control when the part of nearest to the index of a display moves in the same direction as does the index.

In this experiment the effect of expected and unexpected direction of movement on the performance was also considered because it is useful in tracking system. In tracking system, the subject has to follow a moving index with an index under his control. In target acquisition also, the subject has to move a marker under his control until it lies over a target. In order to carry out this experiment, two control systems (positional control and velocity control) with different dynamics have also been compared from the efficiency and accuracy points of view. The conclusions are :

(a) In positional control, the marker and the joystick have a relationship where left to right movement of the joystick will give a left to right movement of the marker.

(b) In velocity control, the speed of movement of the marker depends on the extent to which the joystick is displaced from its central position so that if a movement of the marker is being made from left to right, the initial movement of the joystick will be stationary, whilst the marker is moving at a constant speed and it will be moved from right to left while the marker is deceleration.

(c) Thus, in positional control, the relationship between the joystick and the index will be compatible for the whole of the time, but with velocity control, the movement between the joystick and the index will be compatible while the index is accelerating. So position control is superior.

(d) In the case of tracking, though the subjects were given using both operation control and velocity control, it was observed that the initial performance with velocity control was substantially inferior.

The consistency in the direction of movement of control between electrical and pressure controls was also tested on the same setup. Generally electrical control turns clockwise to increase and pressure control turns anti-clockwise to open the valve or to increase and it was concluded that the clock wise-clockwise arrangement is compatible, hence if the pressure control has to be mounted in the same panel where electrical control is fitted, then the pressure control should be fitted with left hand thread. It will further decrease the accidents also.

Some important points to be considered are, therefore, given below :

(a) The display pointer should move in the same direction as the control itself i.e. a knob, hand wheel, lever, crank etc. should revolve to the right to control the process, if the pointer of display moves to the right on a circular scale.

(b) A clockwise turn of a control should mean an increase in the control process and anticlockwise turn should mean decreased in flow.

(c) Concerned scales and knobs with a given/specified function should be placed together. The best arrangement would be scale above, knob below. All the display instruments and control instruments should preferably be on the same control board. If the display panel is separate from the switch board, then the arrangement of the knobs or switches must match that of the dials.

(d) The correct Symbols or icons must be specified at appropriate place wherever necessary. See Figure 14.9 for various symbols.

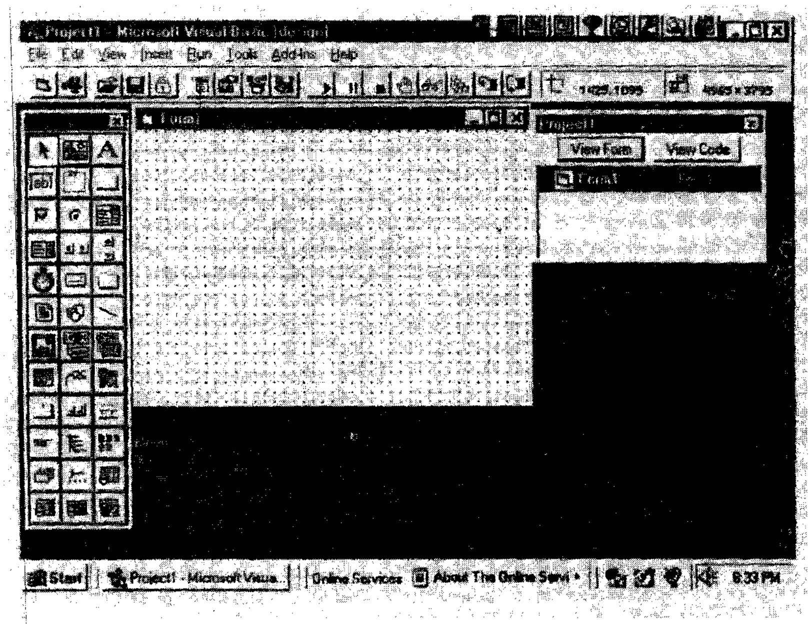


Figure 14.9 : Various Symbols of Controls

SAQ 4

(a) Describe different types of control units that often are associated with the products. Discuss the design factors that are to be considered while designing these control units.

(b) Discuss the design aspects of the following controlling devices with reference to the ergonomics :

(i) Push Buttons

(ii) Toggle Switches

(iii) Knobs

(c) Discuss the design aspects of the following control devices with reference to the ergonomics :

(i) Cranks

(ii) Hand Wheels or Steering

(iii) Pedals

(d) Enumerate the general guidelines in designing the control devices ergonomically.

(e) Discuss the factors influencing the selection of controlling units while designing a product.

(f) Discuss the relationship between the display devices and control devices.

Activity 4

In a company of your choice, list out and record the status of the various control units available. Check if there is ergonomic design. If not, can it be modified or improved?

	Device	Status	Improvement
(a)	....	....	....
	....	....	....
	....	....	....
(b)	....	....	....
	....	....	....
	....	....	....
(c)	....	....	....
	....	....	....
	....	....	....
(d)	....	....	....
	....	....	....
	....	....	....
(e)	....	....	....
	....	....	....
	....	....	....

Activity 5

Observe the bikes – Yamaha, Suzuki, Rajdoot, Bajaj and Hero Honda. Do you find the standardisation in them in all respects of systems such as breaking, gears, clutch etc, and spare parts? List out your findings.

....

....

....

Activity 6

Observe some products and write the design considerations involved in them with reference to ergonomics. An example is shown below.

(a) **A Pen :** Its radius is around 6 to 10 mm, which is most convenient size for holding between fingers comfortably.

(b) **A Mouse used in Personal Computer :** the width is around 50 to 70mm and length is 100 to 120 mm, which is as same size as of a human palm, thus makes so convenient.

(c) **Computer Table:** ....
....

(d) **Handle of a Suitcase:** ....
....

(e) **Cellular Phone or/and Telephone Hand Set:** ....
....

(f) **Peddles and Handles of a Bicycle:** ....
....

(g) **Steering and Seat Design in a Car :** ....
....

(h) **Knobs and Control Switches of a Power Press :** ....
....

(i) **Hand Stick for an Old Man/Blind Man :** ....
....

(j) **Fitter's Table/Inspection Table :** ....
....

(k) **A Television Characteristics and Features :** ....
....

14.15 MAN-MACHINE SYSTEM

A man-machine system is defined as an operating combination of one or more men with one or more machines interacting to bring about from given inputs to the desired outputs through a specified process or procedure with in the constraints of the environment.

A driver with his vehicle, operator on a lathe, a typist on a type machine, a programmer on a personal computer is a few to quote as examples of a simple man-machine system. A server based computer based systems in LAN (Local area network) is an example for several people with several machines, while many men working on rolling mill is many men to one machine system and operator if operates more than one automatic machines is an example of one man to many machines system.

Now we look into the system clearly, we find the following essential features or characteristics :

(a) Specific purpose and objective

(b) Information input

(c) Information processing and decision making unit

(d) Output

(e) Feed back unit

(f) Environmental constraints

Objective

A specific aim of the system is objective

Input

Input may be in the form of physical objects, materials, energy, skill or information. In a computer system the input is information while in a saw-mill, wood-log is an input and on lathe the input is skill and energy of the operator in terms of speed and feed, etc.

Processing and Decision

This is composed of three components, viz., sensing (receiving information), memory (storage) and decision (action). The sensing elements such as eyes, ears, skin, tongue and nose (the five senses) through sight, hearing, touch, taste and smell respectively for human beings and electronic/mechanical devices for machines receive the information and send to memory or storage unit (mind in the case of human beings). Based on the available information a decision will come out to perform the operation (programmed operation in the case of some machines like CNC/Computers, etc.).

Output

The result expected to come out of the system is output after making necessary changes and modifications on the input. Obviously this output also may be in any form like those of inputs.

Feed Back

It is treated as controlling component of the system. This is necessary to take corrective actions, but in some systems this is missed. The system in which output is not linked with input (feed back is missing) is said to be 'open loop system' and if it is linked, it is 'closed loop system'.

Environmental Constraints

The barriers often posed by the environment in the form of thermal discomfort, noise, bad lighting, wrong gestures and postures etc., cause the reduction in the input and hence the efficiency gets lowered. These are to be identified in time and prevented or corrected accordingly.

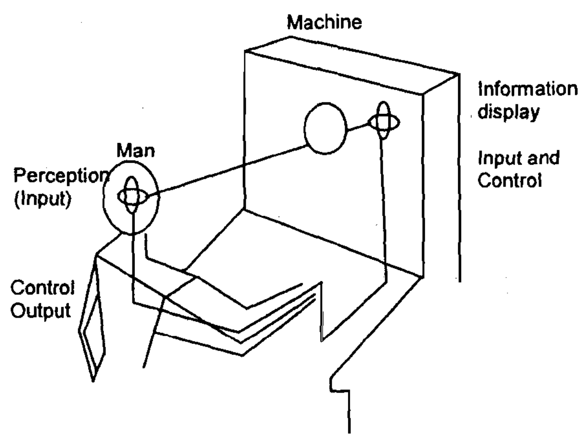


Figure 14.10 : A Simple Model of Man-Machine System

A simple model of this system is shown in the above Figure14.10.

Summarily, we can conclude that the man-machine system will have some purpose composed of system components, sub systems either in parallel of in series so as to suit the man with distinguished input-process- output- feed back model in certain environmental constraints. A detailed discussion is made in the next unit.

SAQ 5

(a) What is a man-machine system? Discuss a man-machine model with example. Give its significance in ergonomic design.

(b) Why do people overlook the importance of ergonomics in some cases? What are the wrong notions that a man has in man-machine system?

14.16 SUMMARY

This unit focuses mainly on ergonomic product design. Therefore, at the outset the meaning and objectives and the advantages of ergonomic design are discussed. Various approaches adopted by ergonomics and the constituents of ergonomics to consider while designing a product is narrated. The work science comprising of the techniques and organisation of work are explained. Then some light is thrown on aspects of the product design and process design factors. In any product or process while designing, the ergonomics is more concerned with the design of display instruments. Therefore, the general guidelines for designing the display devices and controlling devices and the factors for selection of controlling devices are described. The controls for high precision work and need little effort, such as push buttons, toggle switches, knobs, etc. and controls that require considerable force like cranks, hand wheel, steering, pedals are illustrated with figures and their design aspects. The relationship between controls and display instruments is established through this unit.

14.17 KEY WORDS

Bio Mechanics : It is the science that deals with the internal and external forces and the effect of the forces produced by actions of human body.

Bio-materials : Bio-materials are used for testing of bio compatibility, life cycle while studying ergonomics.

Biological Techniques : It deals with hygiene of work based on work psychology and work pedagogies.

Mechanical Techniques : It deals with time and motion study.

Knobs : Rotary controls that can be operated freely by gripping it on both sides with fingers of one hand.

Hand Wheel : It is a circular control gripped at the rim preferably with both hands.

Pedal : Pedal is a reciprocating control operated by foot acting independently.

Toggle Switches : Toggle switches are miniature levers used as switches and guarantee high frequency of precision control.

Crank : Crank is a control parallel to the shaft in which the handle is offset from the shaft.

14.18 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.