CHAPTER 7

Record, examine, develop

1. Record the facts

The next step in the basic procedure, after selecting the work to be studied, is to **record all the facts** relating to the existing method. The success of the whole procedure depends on the accuracy with which the facts are recorded, because they will provide the basis of both the critical examination and the development of the improved method. It is therefore essential that the record be clear and concise.

Recording serves essentially as a basis for subsequent analysis and examination. It is not an end in itself. Recording may be carried out in two phases: first, a rough sketch or charting of the job being studied to establish whether the recorded information is of use; and, second, a more formal and accurate chart or diagram to include in a report or presentation.

The usual way of recording facts is to write them down. Unfortunately, this method is not suited to recording the complicated processes which are so common in modern industry. This is particularly so when an exact record is required of every minute detail of a process or operation. To describe exactly everything that is done in even a very simple job which takes perhaps only a few minutes to perform would probably result in several pages of closely written script, which would require careful study before anyone reading it could be quite sure that he or she had grasped all the detail.

To overcome this difficulty other techniques or "tools" of recording have been developed, so that detailed information may be recorded precisely and at the same time in standard form, in order that it may be readily understood by all method study persons, in whatever factory or country they may be working.

The most commonly used of these recording techniques are **charts** and **diagrams**. There are several types of standard chart available, each with its own special purposes. They will be described in turn later in this chapter and in subsequent chapters. For the present it will be sufficient to note that the charts available fall into two groups:

- ☐ those which are used to record a **process sequence**, i.e. a series of events or happenings in the order in which they occur, but which do not depict the events to scale; and
- ☐ those which record **events**, also in sequence, but **on a time scale**, so that the interaction of related events may be more easily studied.

The names of the various charts are shown in table 8, which lists them in the two groups given above and also lists the types of diagram commonly used.

Table 8. The most commonly used method study charts and diagrams

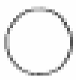
A. CHARTS	Indicating process SEQUENCE Outline process chart Flow process chart — Worker type Flow process chart — Material type Flow process chart — Equipment type Two-handed process chart Procedure flowcharts
B. CHARTS	Using a TIME SCALE Multiple activity chart Simo chart
C. DIAGRAMS	Indicating MOVEMENT Flow diagram String diagram Cyclegraph Chronocyclegraph Travel chart

Diagrams are used to indicate movement and/or interrelationships of movements more clearly than charts can do. They usually do not show all the information recorded on charts, which they supplement rather than replace.

Process chart symbols

The recording of the facts about a job or operation on a process chart is made much easier by the use of a set of five standard symbols,[1] which together serve to represent all the different types of activity or event likely to be encountered in any factory or office. They thus serve as a very convenient, widely understood type of shorthand, saving a lot of writing and helping to show clearly just what is happening in the sequence being recorded.

The two principal activities in a process are **operation** and **inspection**. These are represented by the following symbols:



OPERATION

Indicates the main steps in a process, method or procedure. Usually the part, material or product concerned is modified or changed during the operation

It will be seen that the symbol for an operation is also used when charting a procedure, as for instance a clerical routine. An operation is said to take place when information is given or received, or when planning or calculating takes place.

[1] The symbols used throughout this book are those recommended by the American Society of Mechanical Engineers and adopted in BSI: *Glossary of terms used in management services*, BSI 3138 (London, 1991).

□ *INSPECTION*

> Indicates an inspection for quality and/or check for quantity

The distinction between these two activities is quite clear:

An **operation** always takes the material, component or service a stage further towards completion, whether by changing its shape (as in the case of a machined part) or its chemical composition (during a chemical process) or by adding or subtracting material (as in the case of an assembly). An operation may equally well be a preparation for any activity which brings the completion of the product nearer.

An **inspection** does not take the material any nearer to becoming a completed product. It merely verifies that an operation has been carried out correctly as to quality and/or quantity. Were it not for human shortcomings, most inspections could be done away with.

Often a more detailed picture will be required than can be obtained by the use of these two symbols alone. In order to achieve this, three more symbols are used:

⇨ *TRANSPORT*

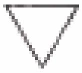
> Indicates the movement of workers, materials or equipment from place to place

A **transport** thus occurs when an object is moved from one place to another, except when such movements are part of an operation or are caused by the operative at the workstation during an operation or an inspection. This symbol is used throughout this book whenever material is handled on or off trucks, benches, storage bins, and so on.

D *TEMPORARY STORAGE OR DELAY*

> Indicates a delay in the sequence of events: for example, work waiting between consecutive operations, or any object laid aside temporarily without record until required

Examples of **temporary storage or delay** are work stacked on the floor of a shop between operations, cases awaiting unpacking, parts waiting to be put into storage bins or a letter waiting to be signed.

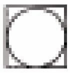


PERMANENT STORAGE

> Indicates a controlled storage in which material is received into or issued from a store under some form of authorization, or an item is retained for reference purposes

A **permanent storage** thus occurs when an object is kept and protected against unauthorized removal. The difference between a "permanent storage" and a "temporary storage or delay" is that a requisition, or other form of formal authorization, is generally required to get an article out of permanent storage but not out of temporary storage.

In this book, for the sake of simplicity, temporary storage or delay will be referred to as "delay", and permanent storage as just "storage".



Combined activities. When it is desired to show activities performed at the same time or by the same operative at the same workstation, the symbols for those activities are combined, e.g. the circle within the square represents a combined operation and inspection.

Figure 21 gives an example of the use of these symbols.

The outline process chart

It is often valuable to obtain a "bird's-eye" view of a whole process or activity before embarking on a detailed study. This can be obtained by using an **outline process chart**.

> An outline process chart is a process chart giving an overall picture by recording in sequence only the main operations and inspections

In an outline process chart, only the principal operations carried out and the inspections made to ensure their effectiveness are recorded, irrespective of who does them and where they are performed. In preparing such a chart, only the symbols for "operation" and "inspection" are necessary.

In addition to the information given by the symbols and their sequence, a brief note of the nature of each operation or inspection is made beside the symbol, and the time allowed for it (where known) is also added.

An example of an outline process chart is given in figure 23. In order that the reader may obtain a firm grasp of the principles involved, the assembly represented on the chart is shown in a sketch (figure 22) and the operations charted are given in some detail below.

Example of an outline process chart: Assembling a switch rotor[2]

The assembly drawing (figure 22) shows the rotor for a slow make-and-break switch.

It consists of a spindle (1); a plastic moulding (2); and a stop pin (3).

In making an outline process chart it is usually convenient to start with a vertical line down the right-hand side of the page to show the operations and inspections undergone by the principal unit or component of the assembly (or compound in chemical processes) — in this case the spindle. The time allowed per piece in hours is shown to the left of each operation. No specific time is allowed for inspections as the inspectors are on time work.

The brief descriptions of the operations and inspections which would normally be shown alongside the symbols have been omitted so as not to clutter the figure.

The operations and inspections carried out on the spindle, which is made from 10 mm diameter steel rod, are as follows:

Operation 1 Face, turn, undercut and part off on a capstan lathe (0.025 hours).

Operation 2 Face opposite end on the same machine (0.010 hours).

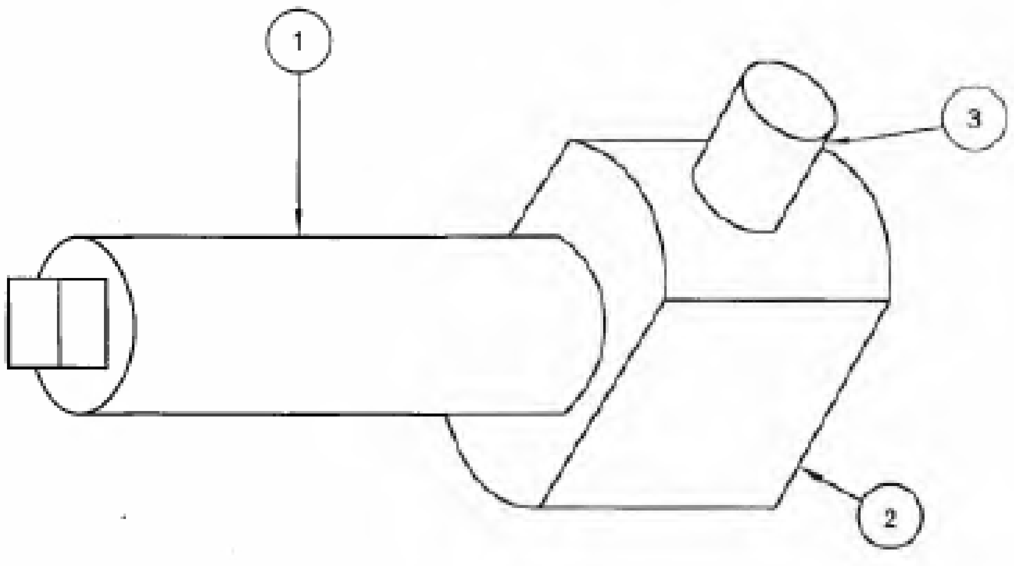
After this operation the work is sent to the inspection department for:

Inspection 1 Inspect for dimensions and finish (no time fixed). From the inspection department the work is sent to the milling section.

Operation 3 Straddle-mill four flats on end on a horizontal miller (0.070 hours).

Operation 4 Remove burrs at the burring bench (0.020 hours).

Figure 22. Switch rotor assembly



[2] This example is adapted from W. Rodgers: *Methods engineering chart and glossary* (Nottingham (United Kingdom), School of Management Studies Ltd.).

The work is returned to the inspection department for:

Inspection 2 Final inspection of machining (no time).

From the inspection department the work goes to the plating shop for:

Operation 5 Degreasing (0.0015 hours).

Operation 6 Cadmium plating (0.008 hours).

From the plating shop the work goes again to the inspection department for:

Inspection 3 Final check (no time).

The plastic moulding is supplied with a hole bored concentric with the longitudinal axis.

Operation 7 Face on both sides, bore the cored hole and ream to size on a capstan lathe (0.080 hours).

Operation 8 Drill cross-hole (for the stop pin) and burr on two-spindle drill press (0.022 hours).

From the drilling operation the work goes to the inspection department for:

Inspection 4 Final check dimensions and finish (no time).

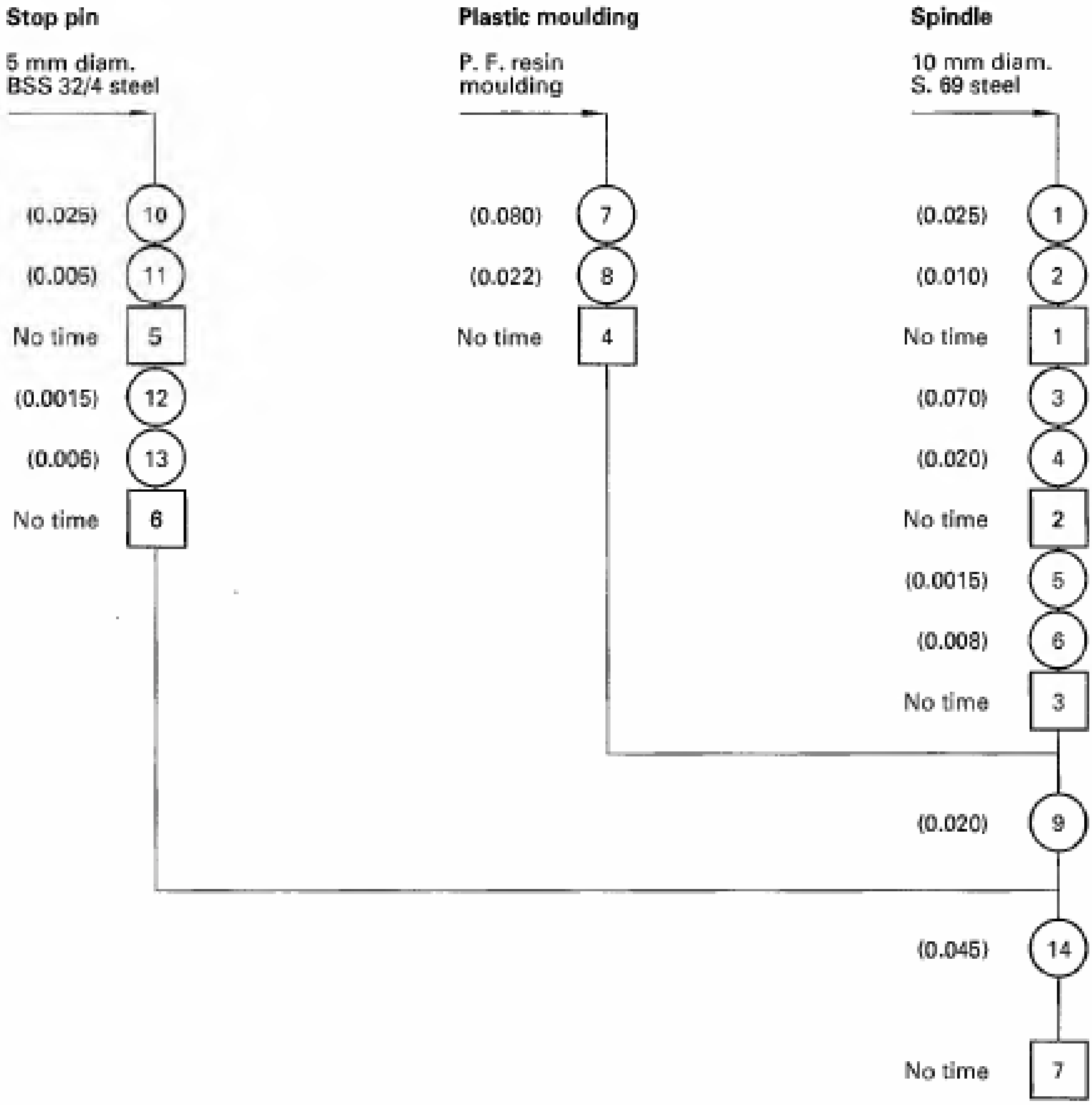
It is then passed to the finished-part stores to await withdrawal for assembly.

It will be seen from the chart that the operations and inspections on the moulding are on a vertical line next to that of the spindle. This is because the moulding is the first component to be assembled to the spindle. The stop-pin line is set farther to the left, and if there were other components they would be set out from right to left in the order in which they were to be assembled to the main item.

Note especially the method of numbering the operations and inspections. It will be seen that both operations and inspections start from 1. The numbering is continuous from one component to another, starting from the right, to the point where the second component joins the first. The sequence of numbers is then transferred to the next component on the left and continues through its assembly to the first component until the next assembly point, when it is transferred to the component about to be assembled. Figure 23 makes this clear. The assembly of any component to the main component or assembly is shown by a horizontal line from the vertical operation line of the minor component to the proper place in the sequence of operations on the main line. (Sub-assemblies can, of course, be made up of any number of components before being assembled to the principal one; in that case the horizontal joins the appropriate vertical line which appears to the right of it.) The assembly of the moulding to the spindle, followed by the operation symbol and number, is clearly shown in the figure.

Operation 9 Assemble the moulding to the small end of the spindle and drill the stop-pin hole right through (0.020 hours).

Figure 23. Outline process chart: Switch rotor assembly



Once this has been done the assembly is ready for the insertion of the stop pin (made from 5 mm diameter steel rod) which has been made as follows:

Operation 10 Turn 2 mm diameter shank, chamfer end and part off on a capstan lathe (0.025 hours).

Operation 11 Remove the "pip" on a linisher (0.005 hours).

The work is then taken to the inspection department.

Inspection 5 Inspect for dimensions and finish (no time).

After inspection the work goes to the plating shop for:

Operation 12 Degreasing (0.0015 hours).

Operation 13 Cadmium plating (0.006 hours).

The work now goes back to the inspection department for:

Inspection 6 Final check (no time).

It then passes to the finished-part stores and is withdrawn for:

Operation 14 Stop pin is fitted to assembly and lightly riveted to retain it in position (0.045 hours).

Inspection 7 The completed assembly is finally inspected (no time).

It is then returned to the finished-parts store.

In practice, the outline process chart would bear against each symbol, beside and to the right of it, an abbreviated description of what is done during the operation or inspection. These entries have been left out of figure 23 so that the main sequence of charting may be seen more clearly.

Figure 24 shows some of the conventions used when drawing outline process charts. In this instance the subsidiary component joins the main part after inspection 3, and is assembled to it during operation 7. The assembly undergoes two more operations, numbers 8 and 9, each of which is performed four times in all, as is shown by the "repeat" entry. Note that the next operation after these repeats bears the number 16, not 10.

As was explained earlier in this chapter, the outline process chart is intended to provide a first "bird's-eye" view of the activities involved, for the purpose of eliminating unnecessary ones or combining those that could be done together. It is usually necessary to go into detail greater than the outline process chart provides. In the following pages the flow process chart will be described and its use as a tool of methods improvement illustrated.

Flow process charts

Once the general picture of a process has been established, it is possible to go into greater detail. The first stage is to construct a **flow process chart**.

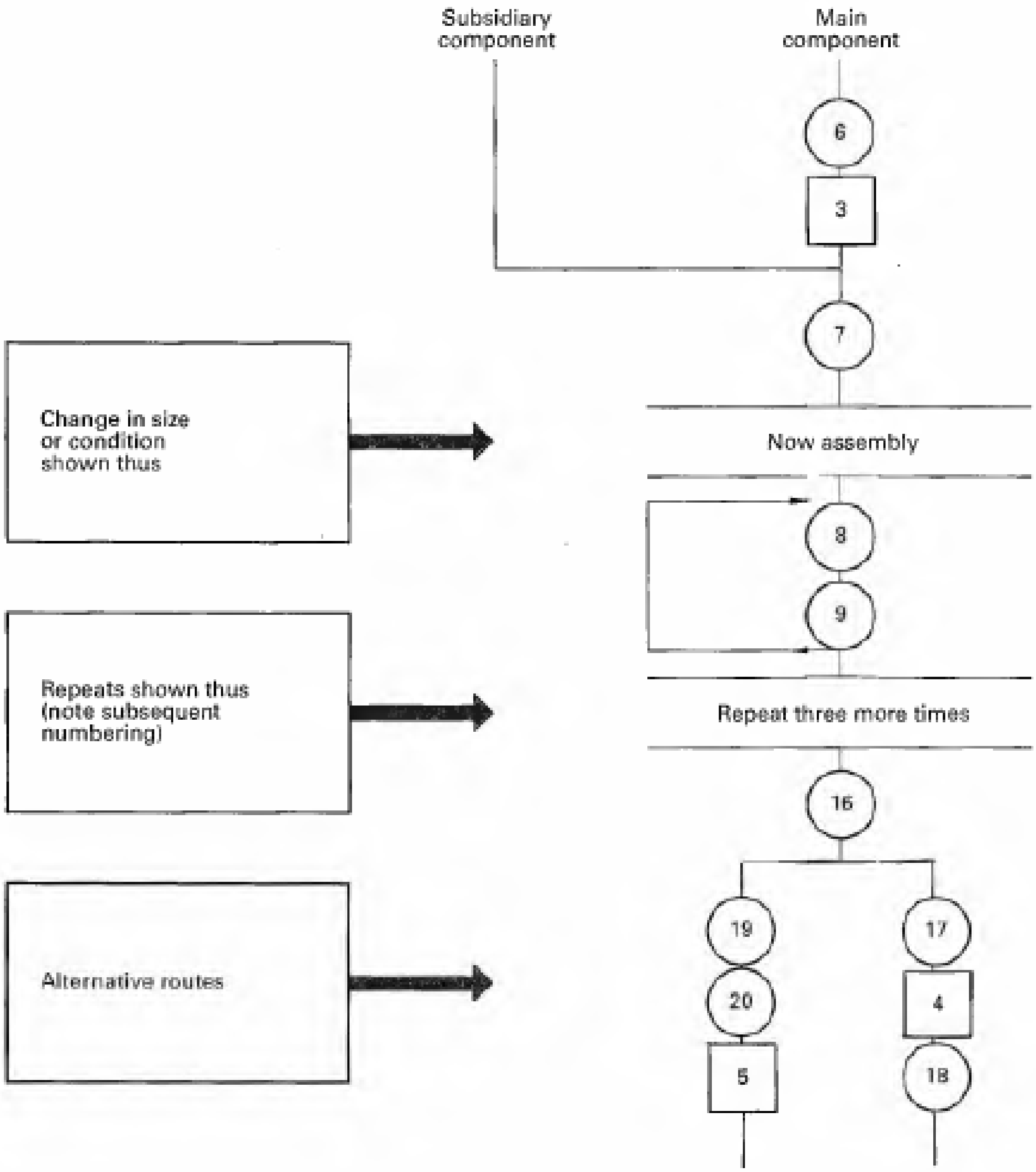
A flow process chart is a process chart setting out the sequence of the flow of a product or a procedure by recording all events under review using the appropriate process chart symbols.

- ☐ Flow process chart — Worker type: A flow process chart which records what the operator does.
- ☐ Flow process chart — Material type: A flow process chart which records how material is handled or treated.
- ☐ Flow process chart — Equipment type: A flow process chart which records how the equipment is used.

A flow process chart is prepared in a manner similar to that in which the outline process chart is made, but using, in addition to the symbols for "operation" and "inspection", those for "transport", "delay" and "storage".

Whichever type of flow process chart is being constructed, the same symbols are always used and the charting procedure is very similar. (It is customary to use the active voice of verbs for entries on worker-type charts, and the passive voice on material-type and equipment-type charts. This

Figure 24. Some charting conventions



convention is more fully explained in Chapter 8, section 3.) In fact, it is usual to have only one printed form of chart for all three types, the heading bearing the words "Worker/material/equipment type", the two words not required being deleted.

Because of its greater detail, the flow process chart does not usually cover as many operations per sheet as may appear on a single outline process chart. It is usual to make a separate chart for each major component of an assembly, so that the amount of handling, delays and storages of each may be independently studied. This means that the flow process chart is usually a single line.

An example of a material-type flow process chart constructed to study what happened when a bus engine was stripped, degreased and cleaned for inspection is given in figure 25. This is an actual case recorded at the workshop of a transport authority in a developing country. After discussing the principles of flow process charting and the means of using them in the next few pages, we shall go on to consider this example in detail. Worker-type charts are discussed in Chapter 8.

When flow process charts are being made regularly, it is convenient to use printed sheets similar to that shown in figure 26. (In charts of this kind the five symbols are usually repeated down the whole length of the appropriate columns. This has not been done in the charts presented in this book, which have been simplified to improve clarity.) This also ensures that the work study person does not omit any essential information. In figure 26 the operation just described on the chart in figure 25 is set down again.

Before we go on to discuss the uses of the flow process chart as a means of examining critically the job concerned with a view to developing an improved method, there are some points which must always be remembered in the preparation of process charts. These are important because process charts are the most useful tool in the field of method improvement; whatever techniques may be used later, the making of a process chart is always the first step.

(1) Charting is used for recording because it gives a complete picture of what is being done and helps the mind to understand the facts and their relationship to one another.

(2) Charts are an important means of illustrating clearly to everyone concerned the way the job is being carried out. Although supervisors and workers may not be trained in the use of a particular recording technique, they can understand a chart or diagram sufficiently to confirm that it represents the "time" situation and can often see the inefficiencies inherent in a chart which, for example, includes a large number of delay or transport symbols.

(3) The details which appear on a chart must be obtained from **direct observation.** Once they have been recorded on the chart, the mind is freed from the task of carrying them, but they remain available for reference and for explaining the situation to others. Charts must not be based on memory but must be prepared **as the work is observed** (except when a chart is prepared to illustrate a proposed new method). Details which have been recorded should be reviewed and confirmed with the

Figure 25. Flow process chart: Engine stripping, cleaning and degreasing

Chart No. *1*	Sheet No. *1* of *1*	Method:	*Original*
Product:	*Bus engines*	Operative(*s*):	
		Location:	*Degreasing shop*
Process:	*Stripping, degreasing and cleaning used engines*	Charted by:	
		Approved by:	Date:

Distance (m)	Symbol	Activity	Type of activity
	▽ 1	*In old-engine stores*	
	⇨ 1	*Picked up engine by crane (electric)*	*Non-productive*
24	⇨ 2	*Transported to next crane*	*"*
	⇨ 3	*Unloaded to floor*	*"*
	⇨ 4	*Picked up by second crane (electric)*	*"*
30	⇨ 5	*Transported to stripping bay*	*"*
	⇨ 6	*Unloaded to floor*	*"*
	○ 1	*Engine stripped*	*Productive*
	○ 2	*Main components cleaned and laid out*	*"*
	□ 1	*Components inspected for wear; inspection report written*	*Non-productive*
3	⇨ 7	*Parts carried to degreasing basket*	*"*
	⇨ 8	*Loaded for degreasing by hand-operated crane*	*"*
1.5	⇨ 9	*Transported to degreaser*	*"*
	⇨ 10	*Unloaded into degreaser*	*"*
	○ 3	*Degreased*	*Productive*
	⇨ 11	*Lifted out of degreaser by crane*	*Non-productive*
6	⇨ 12	*Transported away from degreaser*	*"*
	⇨ 13	*Unloaded to ground*	*"*
	D 1	*To cool*	*"*
12	⇨ 14	*Transported to cleaning benches*	*"*
	○ 4	*All parts completely cleaned*	*Productive*
9	⇨ 15	*All cleaned parts placed in one box*	*Non-productive*
	D 2	*Awaiting transport*	*"*
	⇨ 16	*All parts except cylinder block and heads loaded on trolley*	*"*
76	⇨ 17	*Transported to engine inspection section*	*"*
	⇨ 18	*Parts unloaded and arranged on inspection table*	*"*
	⇨ 19	*Cylinder block and head loaded on trolley*	*"*
76	⇨ 20	*Transported to engine inspection section*	*"*
	⇨ 21	*Unloaded on ground*	*"*
237.5	D 3	*Stored temporarily awaiting inspection*	*"*

(Adapted from an original)

Figure 26. Flow process chart — Material type: Engine stripping, cleaning and degreasing (original method)

Flow process chart		**~~Worker~~ /Material/~~Equipment~~ type**			
Chart No. *1* Sheet No. *1* of *1*	Summary				
Subject charted: *Used bus engines*	Activity		Present	Proposed	Saving
	Operation	○	*4*		
	Transport	⇨	*21*		
Activity: *Stripping, cleaning and degreasing prior to inspection*	Delay	D	*3*		
	Inspection	□	*1*		
	Storage	▽	*1*		
Method: Present/~~Proposed~~	Distance (m)		*237.5*		
Location: *Degreasing shop*	Time (work-min.)		—	—	—
Operative(s): Clock Nos. *1234* *571*	Cost		—		
	Labour		—		
Charted by: Date:	Material		—		
Approved by: Date:	Total		—	—	—

Description	Qty.	Dist-ance (m)	Time (min.)	○	⇨	D	□	▽	Remarks
Stored in old-engine store								•	
Engine picked up					•				*Electric crane*
Transported to next crane		*24*			•				*Electric crane*
Unloaded to floor					•				
Picked up					•				*Electric crane*
Transported to stripping bay		*30*			•				*Electric crane*
Unloaded to floor					•				
Engine stripped				•					
Main components cleaned and laid out				•					
Components inspected for wear;									
inspection report written							•		
Parts carried to degreasing basket		*3*			•				
Loaded for degreasing					•				
Transported to degreaser		*1.5*			•				*Hand crane*
Unloaded into degreaser					•				
Degreased				•					
Lifted out of degreaser					•				*Hand crane*
Transported away from degreaser		*6*			•				*Hand crane*
Unloaded to ground					•				
To cool						•			
Transported to cleaning benches		*12*			•				*By hand*
All parts cleaned completely				•					
All cleaned parts placed in one box		*9*			•				*By hand*
Awaiting transport						•			
All parts except cylinder block and heads									
loaded on trolley					•				
Transported to engine inspection section		*76*			•				*Trolley*
Parts unloaded and arranged on									
inspection table					•				
Cylinder block and head loaded on trolley					•				
Transported to engine inspection section		*76*			•				*Trolley*
Unloaded to ground					•				
Stored temporarily awaiting inspection						•			
Total		*237.5*		*4*	*21*	*3*	*1*	*1*	

(Adapted from an original)

supervisor. This confirmation has two aims. First, it ensures that the facts are correct. Second, it strengthens the bond between the work study person and the supervisor, who appreciates that his or her opinion is valuable to the investigation.

(4) A high standard of neatness and accuracy should be maintained in preparing fair copies of charts constructed from direct observation. The charts will be used in explaining proposals for standardizing work or improving methods. An untidy chart will always make a bad impression and may lead to errors.

(5) To maintain their value for future reference and to provide as complete information as possible, all charts should carry a heading giving the following information (see figure 26):

   (a) the name of the product, material or equipment charted, with drawing numbers or code numbers;
   (b) the job or process being carried out, clearly stating the starting-point and the end point, and whether the method is the present or proposed one;
   (c) the location in which the operation is taking place (department, factory, site, etc.);
   (d) the chart reference number, sheet number and the total number of sheets;
   (e) the observer's name and, if desired, that of the person approving the chart;
   (f) the date of the study;
   (g) a key to the symbols used. This is necessary for the benefit of anyone who may study the chart later and who may have been accustomed to using different symbols. It is convenient to show these as part of a table summarizing the activities in the present and proposed methods (see figure 26);
   (h) a summary of distance, time and, if desired, cost of labour and material, for comparison of old and new methods.

(6) Before leaving the chart, check the following points:

   (a) Have the facts been correctly recorded?
   (b) Have any over-simplifying assumptions been made (e.g. is the investigation so incomplete as to be inaccurate)?
   (c) Have all the factors contributing to the process been recorded?

So far we have been concerned only with the "record" stage. We must now consider the steps necessary to **examine critically** the data recorded.

2. Examine critically: The questioning technique

> The questioning technique is the means by which the critical examination is conducted, each activity being subjected in turn to a systematic and progressive series of questions

The five sets of activities recorded on the flow process chart fall naturally into two main categories, namely:

- those in which something is actually happening to the material or workpiece under consideration, i.e. it is being worked upon, moved or examined; and
- those in which it is not being touched, being either in storage or at a standstill owing to a delay.

Activities in the first category may be subdivided into three groups:

- **MAKE READY activities** required to prepare the material or workpiece and set it in position ready to be worked on. In the example in figure 25 these are represented by the loading and transporting of the engine to the degreasing shop, transporting it to the cleaning benches, etc.
- **DO operations** in which a change is made in the shape, chemical composition or physical condition of the product. In the case of the example these are the dismantling, cleaning and degreasing operations. Some "do" operations may be further classified as "key" operations. For example, deburring a machined part is a "do" operation but not a "key" one since it would not be performed if no machining were carried out.
- **PUT AWAY activities** during which the work is moved aside from the machine or workplace. The "put away" activities of one operation may be the "make ready" activities of the next — as, for example, transport between operations from the degreaser to the cleaning benches. Putting parts into storage, putting letters into an "Out" tray and inspecting finished parts are other examples.

It will be seen that, while "make ready" and "put away" activities may be represented by "transport" and "inspection" symbols, "do" operations can only be represented by "operation" symbols.

The aim is obviously to have as high a proportion of "do" operations as possible, since these are the only ones which carry the product forward in its progress from raw material to completion. ("Do" operations in non-manufacturing industries are those operations which actually carry out the activity for which the organization exists, for example the act of selling in a shop or the act of typing in an office.) These are "productive" activities; all others, however necessary, may be considered as "non-productive", including storages and delays which represent tied-up capital that could have been used to further the business.

An alternative approach is to first examine the necessity of "key" operations. If these can be removed, associated "do" (but non-"key") and non-productive operations will automatically be removed.

The primary questions

The questioning sequence used follows a well-established pattern which examines:

the *PURPOSE*	for which	the activities are undertaken
the *PLACE*	at which	
the *SEQUENCE*	in which	
the *PERSON*	by whom	
the *MEANS*	by which	

with a view to	*ELIMINATING* *COMBINING* *REARRANGING* or *SIMPLIFYING*	those activities.

In the first stage of the questioning technique, the purpose, place, sequence, person and means of every activity recorded are systematically queried, and a reason for each reply is sought.

The primary questions therefore are:

PURPOSE:	**What** **Why**	is actually done?[3] is the activity necessary at all?	*ELIMINATE* unnecessary parts of the job
PLACE:	**Where**	is it being done? **Why** is it done at that particular place?	*COMBINE* wherever possible or *REARRANGE* the sequence of operations for more effective results.
SEQUENCE:	**When**	is it done? **Why** is it done at that particular time?	
PERSON:	**Who**	is doing it? **Why** is it done by that particular person?	
MEANS:	**How**	is it being done? **Why** is it being done in that particular way?	*SIMPLIFY* the operation.

The secondary questions

> The secondary questions cover the second stage of the questioning technique, during which the answers to the primary questions are subjected to further query to determine whether possible alternatives of place, sequence, persons and/or means are practicable and preferable as a means of improvement upon the existing method

Thus, during this second stage of questioning (having asked already, about every activity recorded, what is done and why is it done), the method

[3] Many investigators use the question: What is actually achieved?

study person goes on to inquire: What **else** might be done? And, hence: What **should** be done? In the same way, the answers already obtained on place, sequence, person and means are subjected to further inquiry.

Combining the two primary questions with the two secondary questions under each of the headings "purpose, place", etc., yields the following list, which sets out the questioning technique in full:

PURPOSE:	**What** is done?
	Why is it done?
	What **else** might be done?
	What **should** be done?
PLACE:	**Where** is it done?
	Why is it done **there**?
	Where **else** might it be done?
	Where **should** it be done?
SEQUENCE:	**When** is it done?
	Why is it done **then**?
	When **might** it be done?
	When **should** it be done?
PERSON:	**Who** does it?
	Why does **that** person do it?
	Who **else** might do it?
	Who **should** do it?
MEANS:	**How** is it done?
	Why is it done **that** way?
	How **else** might it be done?
	How **should** it be done?

These questions, in the above sequence, must be asked systematically every time a method study is undertaken. They are the basis of successful method study.

CHAPTER 8

Movement of workers in the working area

1. Movement of workers and material

There are many types of activity in which workers move at irregular intervals between a number of points in the working area, with or without material. This situation occurs very often in industry and commerce, and even in the home. In manufacturing concerns it occurs when:

- bulk material is being fed to or removed from continuous process, and is stored around the process;
- an operative is looking after two or more machines;
- labourers are delivering materials to or removing work from a series of machines or workplaces.

Outside manufacturing operations, examples of its occurrence are:

- in stores and shops where a variety of materials are being removed from or put away into racks or bins;
- in restaurant and canteen kitchens during the preparation of meals;
- in control laboratories where routine tests are carried out at frequent intervals.

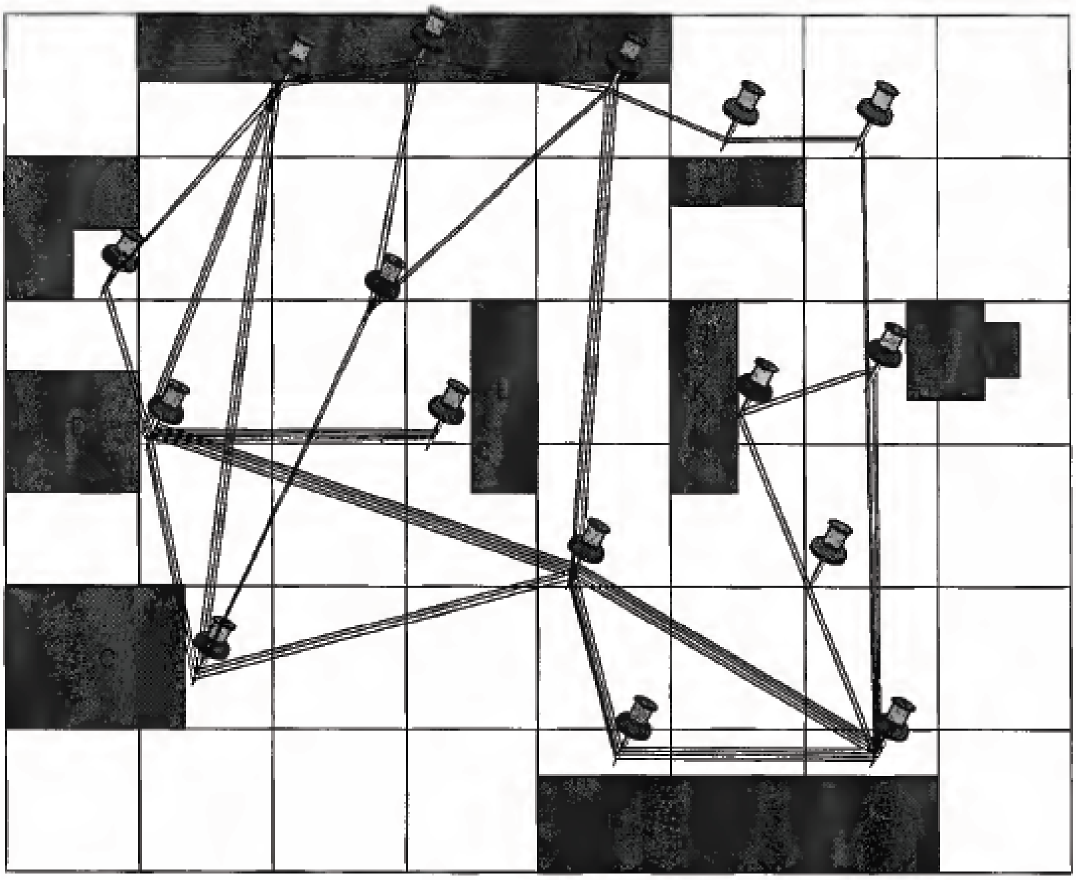
2. The string diagram

One technique for recording and examining this form of activity is the **string diagram**. It is one of the simplest of the techniques of method study and one of the most useful.

> The string diagram is a scale plan or model on which a thread is used to trace and measure the path of workers, material or equipment during a specified sequence of events

The string diagram (figure 33) is thus a special form of flow diagram, in which a string or thread is used to measure distance. Because of this it is necessary that the string diagram be drawn correctly to scale, whereas the ordinary flow diagram will probably be drawn only approximately to scale,

Figure 33. A string diagram



with pertinent distances marked on it so that scaling off is unnecessary. The string diagram is started in exactly the same way as all other method studies: by recording all the relevant facts from direct observation. Like the flow diagram, it will most often be used to supplement a flow process chart, the two together giving the clearest possible picture of what is actually being done. As always, the flow process chart will be examined critically in order to make sure that all unnecessary activities are eliminated before a new method is developed.

A string diagram can be used to plot the movements of materials, and this is sometimes done, especially when a work study person wants to find out easily just how far the materials travel. We could have constructed a string diagram for each of the examples in the last chapter, but this was not necessary. The simple flow diagram showed all that was needed, and was quicker to prepare for the circumstances illustrated. The string diagram is most often used, however, for plotting the movements of workers, and it is this application which is considered in the examples given in the present chapter.

The work study person proceeds to follow the worker being investigated as he or she moves from point to point in doing the job. (If the working area is a fairly small one which can be seen as a whole from one point, he or she can watch the worker without moving.) The study person notes methodically each point to which the worker moves and, if the journeys are fairly long, the times of arrival and departure. It will save a good deal of writing if the observer codes the various machines, stores and other points of call by numbers, letters or other means.

Figure 34. A simple movement study sheet

Movement study sheet

Chart No. *1* Sheet No. *1 of 2* — Operative(s):

Operation: *Transport biscuit tiles from inspection to storage bins and unload into bins* — Charted by:

Date:

Location: *Biscuit warehouse* — Cross-reference: *String diagrams 1 and 2*

1 Time dep.	2 Time arr.	3 Time elapsed	4 Move to	5 Notes
			Inspection bench (I) *to Bin 4* */ 13* */ 5* */ 32* */ 18*	

The form of study sheet required is very simple. A sample of the headings required is given in figure 34. Continuation sheets need only give columns 1, 2, 3, 4 and 5.

The recording of movements will continue for as long as the work study person thinks is necessary to obtain a representative picture of the worker's movements, which may be a few hours, a day, or even longer. The study person must be sure that he or she has noted **all** the journeys made by the worker and has seen them made enough times to be sure of their relative frequency. Insufficient study may produce a misleading picture, since the work study person may only have watched the worker during a part of the complete cycle of activities while using only a few of his or her various paths of movement. Later in the cycle he or she may not use these at all but use others a great deal. Once the study person is satisfied that he or she has a true picture — which should be checked with the worker concerned to make sure that there is nothing else which is usually done that has not been observed — the string diagram may be constructed.

A scale plan of the working area similar to that required for a flow diagram must be made (the same plan may be used so long as it has been accurately drawn). Machines, benches, stores and all points at which calls are made should be drawn in to scale, together with such doorways, pillars and partitions as are likely to affect paths of movements. The completed plan should be attached to a softwood or composition board, and pins driven into it firmly at every stopping point, the heads being allowed to stand well clear of the surface (by about 1 cm). Pins should also be driven in at all the turning-points on the route. A measured length of thread is then taken and tied round the pin at the starting-point of the movements (the inspection bench (I) in figure 33). It is then led around the pins at the other points of call in the order noted on the study sheet until all the movements have been dealt with.

The result is an overall picture of the paths of movement of the operative, those which are most frequently traversed being covered with the greatest number of strings, the effect being as in figure 33.

It will be seen from the sketch that certain paths — in particular those between A and D, A and H, and D and L — are traversed more frequently than the others. Since most of these points are at a fair distance from one another, the diagram suggests that critical examination is called for, with a view to moving the work points which they represent closer together.

It will be remembered that the thread used was measured before the study person started to make the diagram. By measuring the length remaining and subtracting this from the total length, the length used can be found. This will represent, to scale, the distance covered by the worker. If two or more workers are studied over the same working area, different coloured threads may be used to distinguish between them.

The **examination** of the diagram and the **development** of the new layout can now proceed on the same lines as with a flow diagram, with templates being used and the pins and templates being moved around until an arrangement is found by which the same operations can be performed with a minimum movement between them. This can be ascertained by leading the thread around the pins in their new positions, starting from the same point and following the same sequence. When the thread has been led around all the points covered by the study, the length left over can again be measured. The difference in length between this and the thread left over from the original study will represent the reduction in distance travelled as a result of the improved layout. The process may have to be repeated several times until the best possible layout (i.e. the layout with which the minimum length of thread is used) is achieved.

The string diagram is a useful aid in explaining proposed changes to management, supervisors and workers. If two diagrams are made, one showing the original layout and one the improved layout, the contrast is often so vivid — particularly if brightly coloured thread is used — that the change will not be difficult to "sell". Workers especially are interested in seeing the results of such studies and discovering how far they have to walk. The idea of reducing one's personal effort appeals to almost everyone!

4. The multiple activity chart

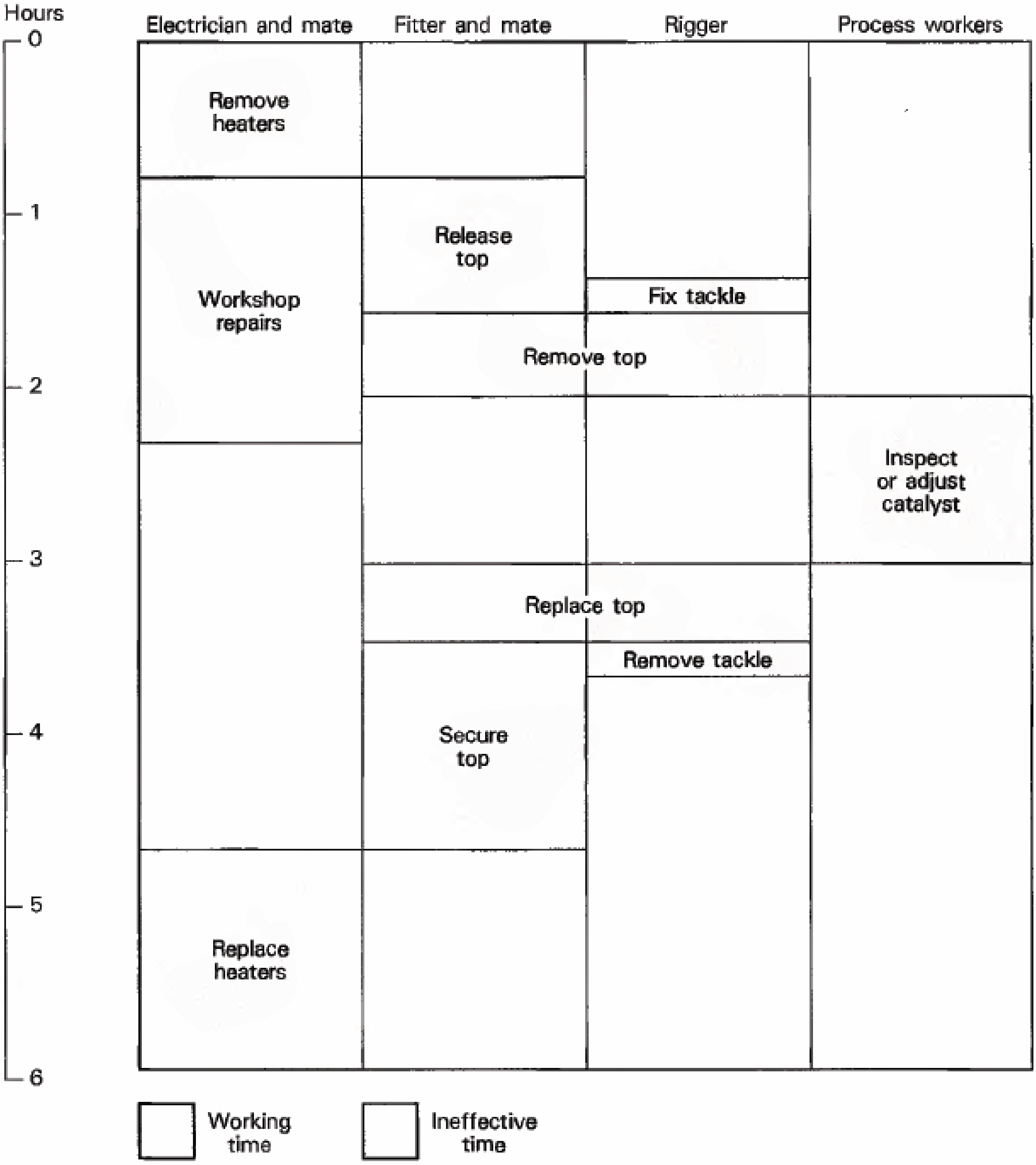
We come now to the first of the charts listed in table 8 which use a time scale — the **multiple activity chart.** This is used when it is necessary to record on one chart the activities of one subject in relation to another.

> A multiple activity chart is a chart on which the activities of more than one subject (worker, machine or item of equipment) are each recorded on a common time scale to show their interrelationship

By using separate vertical columns, or bars, to represent the activities of different operatives or machines against a common time scale, the chart shows very clearly periods of idleness on the part of any of the subjects during the process. A study of the chart often makes it possible to rearrange these activities so that such ineffective time is reduced.

The multiple activity chart is extremely useful in organizing teams of operatives on mass-production work, and also on maintenance work when expensive plant cannot be allowed to remain idle longer than is absolutely necessary. It can also be used to determine the number of machines which an operative or operatives should be able to look after.

Figure 39. Multiple activity chart: Inspection of catalyst in a converter (original method)



In making a chart, the activities of the different operatives or of the different operatives and machines are recorded in terms of working time and idle time. These times may be recorded by ordinary wristwatch, by stop-watch or by electronic timing, according to the duration of the various periods of work and idleness (i.e. whether they are a matter of minutes or seconds). Extreme accuracy is not required, but timing must be accurate enough for the chart to be effective. The times are then plotted in their respective columns in the manner shown in figure 39.

The use of the multiple activity chart can best be shown by an example.

Example of a multiple activity chart applied to team work: Inspection of catalyst in a converter[1]

☐ *RECORD*

This is an application in the field of plant maintenance and is useful in showing that method study is not confined to repetitive or production operations.

During the "running-in" period of a new catalytic converter in an organic chemical plant, it was necessary to make frequent checks on the condition of the catalyst. In order that the converter should not be out of service for any longer than was strictly necessary during these inspections, the job was studied.

In the original method the removal of the top of the vessel was not started until the heaters had been removed, and the replacement of the heaters was not started until the top had been completely fixed. The original operation, with the relationships between the working times of the various workers, is shown in figure 39.

☐ *EXAMINE critically*

It will be seen from this chart that, before the top of the vessel was removed by the fitter and his or her mate, the heaters had to be removed by the electrician and his or her mate. This meant that the fitters had to wait until the electricians had completed their work. Similarly, at the end of the operation the heaters were not replaced until the top had been replaced, and the electricians had to wait in their turn. A critical examination of the operation and questioning of the existing procedure revealed that in fact it was not necessary to wait for the heaters to be removed before removing the top.

☐ *DEVELOP the new method*

Once this had been determined, it was possible to arrange for the top to be unfastened while the heaters were being removed and for the heaters to be replaced while the top was being secured in place. The result appears on the chart in figure 40.

It will be seen that the idle time of the electrician and fitter and their respective mates has been substantially reduced, although that of the rigger remains the same. Obviously the rigger and the process workers will be otherwise occupied before and after performing their sections of the job and are not, in fact, idle while the heaters and cover are being removed or replaced. The saving effected by this simple change was 32 per cent of the total time of the operation.

The simple form of multiple activity chart shown here can be constructed on any piece of paper having lines or squares which can be used to form a time scale. It is more usual, however, to use printed or duplicated forms, similar in general layout to the standard flow process charts, and to draw vertical bars to represent the activities charted. Figures 41, 42 and 43 show multiple activity charts drawn on printed forms.

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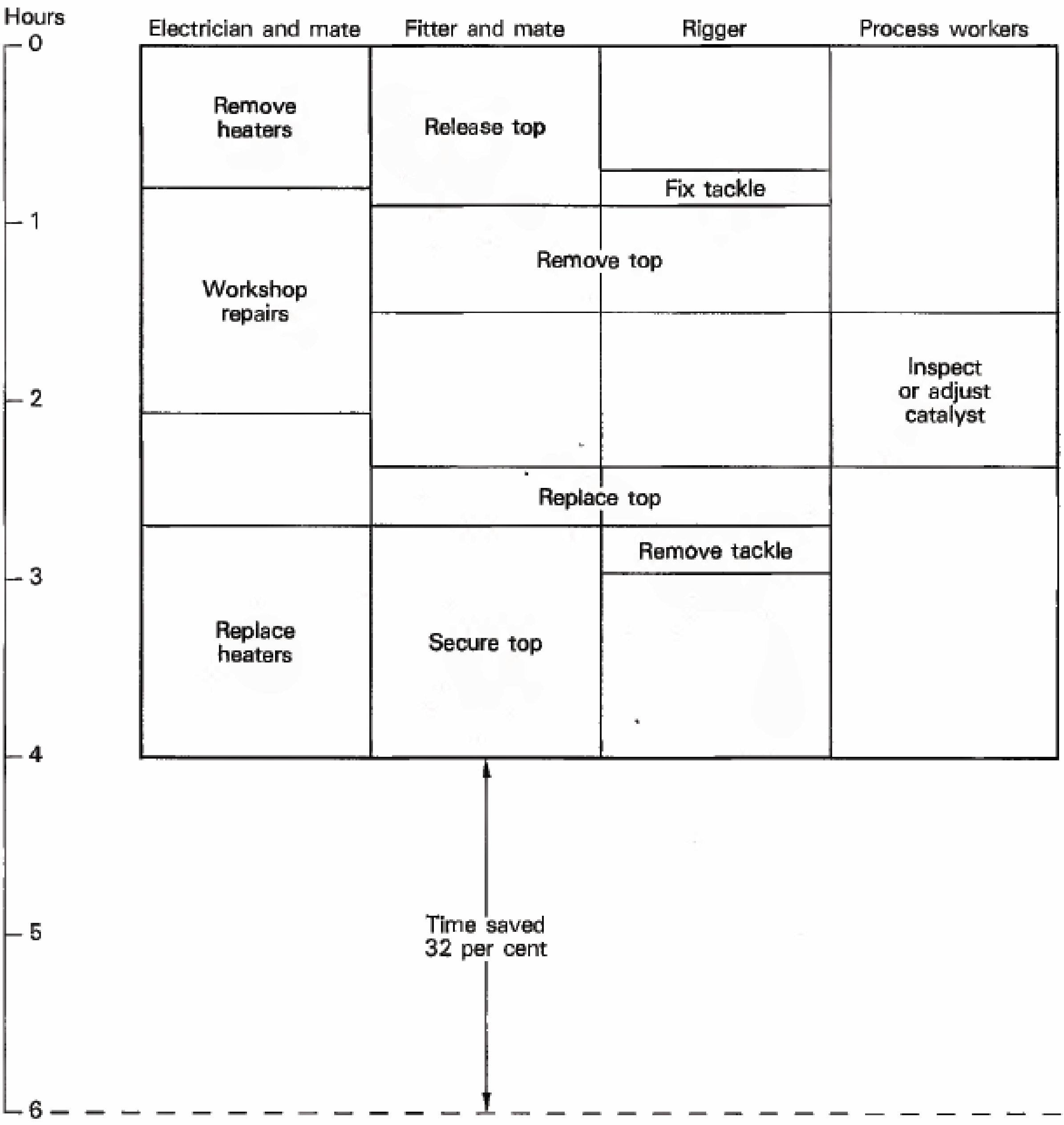
[1] Adapted from an example in *Method study*, a handbook issued by Imperial Chemical Industries Ltd., Work Study Department.

Figure 40. Multiple activity chart: Inspection of catalyst in a converter (improved method)



The multiple activity chart can also be used to present a picture of the operations performed simultaneously by a worker and one or more machines. The chart may be drawn in the manner shown in figure 41, with the vertical activity bars close to each other down the middle of the sheet. In this way the beginning and end, and hence the duration, of every period of activity of either worker or machine are clearly seen in relation to one another. By a study of these activities it is possible to determine whether better use can be made of the operative's time or of the machine time. In particular, it offers a means of determining whether a worker minding a machine, whose time is only partly occupied, can manage to service another machine, or whether the increase in ineffective time of the two machines will offset any gain to be obtained from employing the worker's time more fully. This is an important question in those countries where human resources are more readily available than machines and other capital equipment.

This example is a dramatic illustration of the manner in which the productivity of land, plant and labour can be increased by method study properly and systematically applied, at a cost of only 20 metres of light railway track.

5. The travel chart

The string diagram is a very neat and effective way of recording for critical examination the movement of workers or materials about the work area, especially when readily understood "before" and "after" models are needed to help in presenting the merits of a proposed change. String diagrams do take rather a long time to construct, however, and when a great many movements along complex paths are involved the diagram may end up looking like a forbidding maze of criss-crossing lines. When the movement patterns are complex, the **travel chart** is a quicker and more manageable recording technique.

> A travel chart is a tabular record for presenting quantitative data about the movements of workers, materials or equipment between any number of places over any given period of time

Figure 46 shows a typical travel chart. It records the movements of a messenger delivering papers or information to the various desks and workstations in an office. The layout of the office, showing the relative positions of the workstations, is sketched beneath the travel chart.

The travel chart is always a square, having within it smaller squares. Each small square represents a workstation — that is, in the present example, a place visited by the messenger. There are ten stations, and so the travel chart is drawn with ten small squares across, numbered 1 to 10 from left to right, and ten small squares down, again numbered 1 to 10 going down. Thus for ten workstations the travel chart contains a total of $10 \times 10 = 100$ small squares, and has a diagonal line drawn across it from top left to bottom right.

The squares from left to right along the top of the chart represent the places **from where** movement or travel takes place: those down the left-hand edge represent the stations **to which** the movement is made. For example, consider a movement from station 2 to station 9. To record this, the study person enters the travel chart at the square numbered 2 along the top of the chart, runs a pencil down vertically through all the squares underneath this one until he or she reaches the square which is horizontally opposite the station marked 9 on the left-hand edge. This is the terminal square, and the study person will make a mark in that square to indicate one journey from station 2 to station 9. All journeys are recorded in the same way, always starting at the top in the square of departure, always travelling vertically downwards, and always ending in the square opposite the station of arrival, as read from the left-hand

Figure 46. Travel chart: Movements of messenger in office

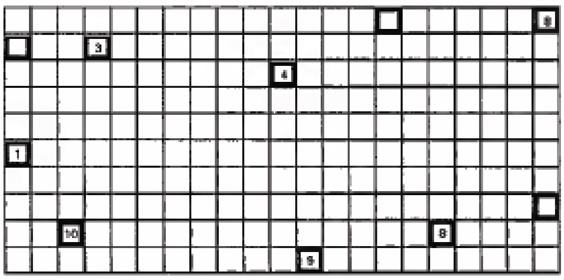
Movement FROM ▽

Station (Movement TO △)	1	2	3	4	5	6	7	8	9	10
1						✓ 1				✓ 1
2					✓✓✓✓✓ 5	✓✓ 2	✓ 1		✓ 1	✓ 1
3								✓ 1	✓ 1	
4			✓ 1			✓ 1			✓ 1	
5	✓ 1	✓ 1		✓ 1			✓ 1		✓ 1	✓ 1
6		✓ 1		✓ 1				✓ 1	✓ 1	✓ 1
7	✓ 1	✓ 1	✓ 1						✓ 1	
8					✓ 1				✓ 1	✓ 1
9		✓✓✓✓✓✓ 6					✓ 1			
10		✓ 1		✓ 1		✓ 1	✓ 1	✓ 1		

Summary of movements INTO station number	Station
2	1
10	2
2	3
3	4
6	5
5	6
4	7
3	8
7	9
5	10

2	10	2	3	6	5	4	3	7	5
Summary of movements FROM station number									
1	2	3	4	5	6	7	8	9	10

Layout sketch of office showing location of stations



edge. Of course, the study person does not actually trace in the path over which the pencil moves but just places a small tick or other mark in the terminal square to record the journey.

To make the recording method completely clear, let us suppose that the messenger travelled the following route: 2 to 9 to 5 to 3 and back to 2. The journey from 2 to 9 will be marked by a tick as described above. To enter the journey from 9 to 5, the study person will return to the top of the chart, select square 9, move down the column below this until he or she reaches the square opposite 5 on the left-hand edge, and record the movement by a tick there. To the top again to select square 5, down from there to that opposite 3; another tick for that journey. Finally, up to the top once more to select square 3, and down to that opposite number 2 for the recording of the final leg of the messenger's walk.

Example of a travel chart: Movement of messenger in an office

☐ *RECORD*

The first stage of the recording process, that is when the method study person observes the movement of the messenger actually in the office, can be carried out very simply on a study sheet similar to that shown in figure 47. Once the stations visited have been numbered and keyed to a sketch of the workplace, the entries recording the journeys made require very little writing.

The travel chart is then compiled in the method study office. After all the movements have been entered on the chart with ticks, the ticks in each small square are added up, the total being entered in the square itself. The movements are then summarized, in two ways. Down the right-hand side of the chart, the number of movements **into** each station is entered against the square representing the station, as read from the left-hand edge. Underneath the chart, the number of movements **from** each station is recorded, this time under the relevant squares as read off the top of the chart.

In the chart in figure 46 there were two movements **into** station 1, as can be seen by running an eye across the line of squares against station 1 on the left-hand edge. Similarly, in the next horizontal line of squares, that opposite station 2, there are altogether ten movements shown, **into** station 2. For the movements **from** stations, the totalling is carried out vertically: it will be seen that there were ten movements from station 2, as shown in the column of squares under station 2 at the top of the chart. With very little practice, the chart and its summaries can be compiled extremely quickly — much quicker than it takes to describe what is done.

In figure 46 the summary of movements **into** each station shows the same number of movements as those recorded at the bottom as being made **from** that station, indicating that the messenger finished at the same station as he or she started out from when the study commenced. If he or she had finished somewhere else (or if the study had been broken off when he or she was somewhere else), there would have been one station where there was one more movement in than the number of movements out, and this would be where the study finished.

☐ *EXAMINE critically*

An examination of the chart shows that ten journeys have been made into station 2, seven into station 9 and six into station 5. These are the busiest stations. A scrutiny of the body of the chart helps to confirm this: there were six journeys from station 2 to station 9, and five from station 5 to station 2. The busiest route is 5-2-9. This suggests that it would be better to locate these stations next to each other. It might then be possible for the clerk at station 5 to place finished work directly into the in-tray at station 2, and the clerk there to pass his or her work on to station 9, thus relieving the messenger of a good deal of travelling.

CHAPTER 9

Methods and movements at the workplace

1. General considerations

In this book we have gradually moved from the wide field of the productivity of industry as a whole to considering in a general way how the productivity of workers and machines can be improved through the use of work study. Still moving from the broader to the more detailed approach, we have also examined procedures of a general nature for improving the effectiveness with which complete sequences of operations are performed and with which material flows through the working area. Turning from materials to workers, we have discussed methods of studying the movements of persons around the working area and the relationships between men or women and machines or workers working together in groups. We have done so following the principle that the broad method of operation must be put right before we attempt improvements in detail.

The time has now come to look at one worker working at a workplace, bench or table and to apply to him or her the principles which have been laid down and the procedures shown in the examples given.

In considering the movements of workers and materials on the larger scale, we have been concerned with the more efficient use of existing plant and machinery (and, where possible, materials) through the elimination of unnecessary idle time, the more effective operation of processes and the more efficient use of the services of labour through the elimination of unnecessary and time-consuming movement within the working area of factory, department or yard.

As our example (Chapter 8) of the trolley operative's need for relaxation shows, the factor of fatigue affects the solution of problems even when we are dealing with areas larger than the individual workplace. But when we come to study individuals at the workplace, the way in which they apply their effort and the amount of fatigue resulting from their manner of working become primary factors affecting their productivity.

Before embarking on a detailed study of an operative doing a job at a single workplace, it is important to make certain that the job is in fact necessary and is being done as it should be done. The questioning technique must be applied as regards:

- ☐ *PURPOSE*

  To ensure that the job is necessary.

- *PLACE*

  To ensure that it is being done where it should be done.
- *SEQUENCE*

  To ensure that it is in its right place in the sequence of operations.
- *PERSON*

  To ensure that it is being done by the right person.

Once these have been verified and it is certain that the job cannot be eliminated or combined with another operation, it is possible to go on to determine the

- *MEANS*

  by which the job is being done

and to simplify them as much as is economically justified.

Later in this chapter we shall consider the recording techniques adopted to set out the detailed movements of an individual at his or her workplace in ways which facilitate critical examination and the development of improved methods, in particular the **two-handed process chart,** as well as the **PTS chart** which will be referred to in Part Four of this book. Before doing this, however, it is appropriate to discuss the principles of motion economy and a number of other matters which influence the design of the workplace itself, so as to make it as convenient as possible for the worker to perform his or her job.

2. The principles of motion economy

There are a number of "principles" concerning the economy of movements which have been developed as a result of experience and which form a good basis for the development of improved methods at the workplace. They may be grouped under three headings:

A. Use of the human body

B. Arrangement of the workplace

C. Design of tools and equipment

They are useful in shop and office alike and, although they cannot always be applied, they do form a very good basis for improving the efficiency and reducing the fatigue of manual work. The ideas expounded by Professor Barnes[1] are described here in a somewhat simplified fashion.

A. Use of the human body

When possible:

(1) The two hands should begin and complete their movements at the same time.

(2) The two hands should not be idle at the same time except during periods of rest.

(3) Motions of the arms should be symmetrical and in opposite directions and should be made simultaneously.

[1] See Ralph M. Barnes: *Motion and time study: Design and measurement of work* (New York and London, John Wiley, 7th ed., 1980), Chs. 15-17.

(4) Hand and body motions should be made at the lowest classification at which it is possible to do the work satisfactorily (see section 3 below).

(5) Momentum should be employed to help the worker, but should be reduced to a minimum whenever it has to be overcome by muscular effort.

(6) Continuous curved movements are to be preferred to straight-line motions involving sudden and sharp changes in direction.

(7) "Ballistic" (i.e. free-swinging) movements are faster, easier and more accurate than restricted or controlled movements.

(8) Rhythm is essential to the smooth and automatic performance of a repetitive operation. The work should be arranged to permit easy and natural rhythm whenever possible.

(9) Work should be arranged so that eye movements are confined to a comfortable area, without the need for frequent changes of focus.

3. Classification of movements

The fourth "rule" of motion economy in the use of the human body calls for movements to be of the lowest classification possible. This classification is built up on the pivots around which the body members must move, as shown in table 9.

Table 9. Classification of movements

Class	Pivot	Body member(s) moved
1	Knuckle	Finger
2	Wrist	Hand and fingers
3	Elbow	Forearm, hand and fingers
4	Shoulder	Upper arm, forearm, hand and fingers
5	Trunk	Torso, upper arm, forearm, hand and fingers

It is obvious that each movement above Class 1 will involve movements of all classes below it. Thus the saving in effort resulting from using the lowest class possible is obvious. If, in laying out the workplace, everything needed is placed within easy reach, this will minimize the class of movement which the work itself requires from the operative.